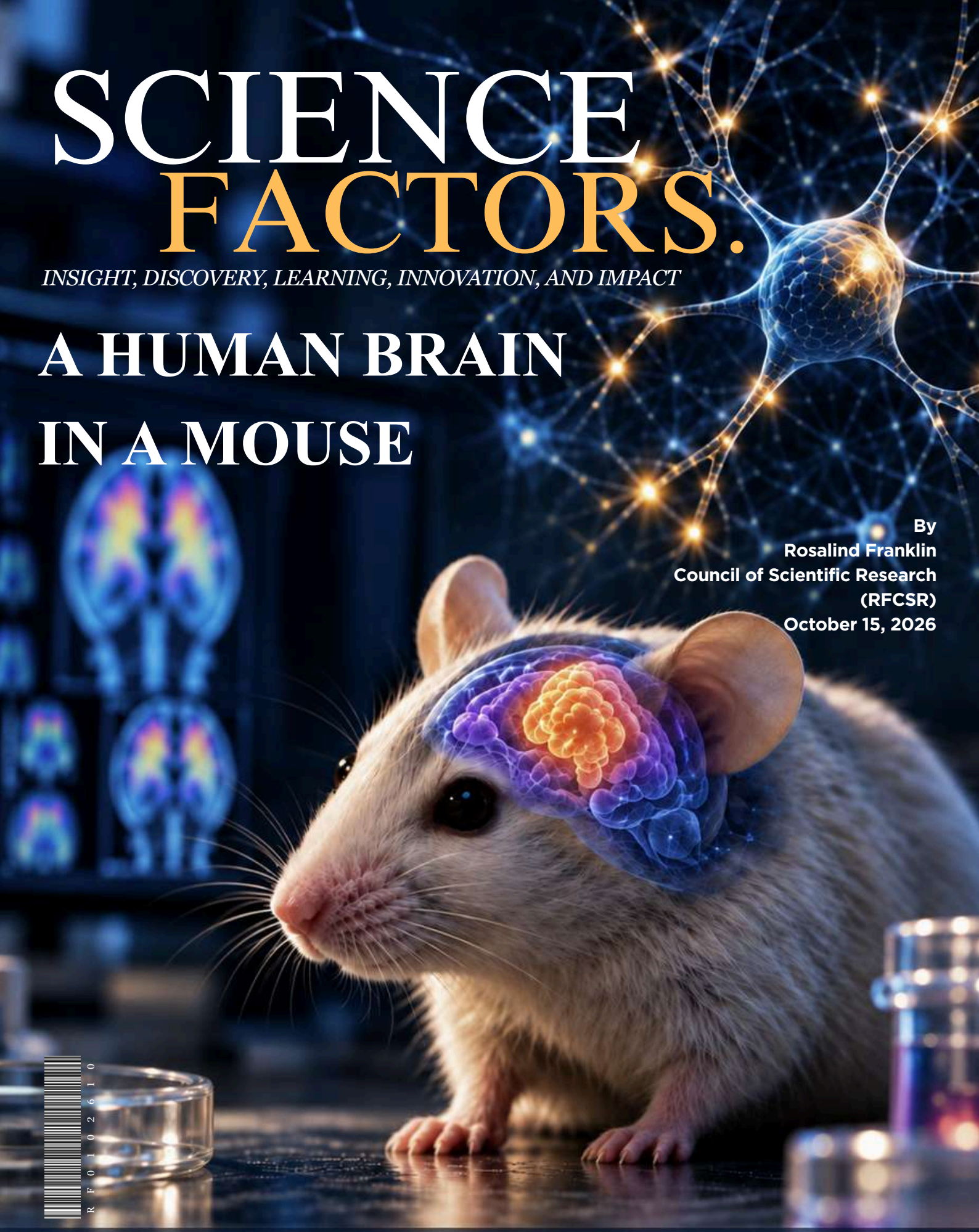
SCIENCE FACTORS.

INSIGHT, DISCOVERY, LEARNING, INNOVATION, AND IMPACT

A HUMAN BRAIN IN A MOUSE

By
Rosalind Franklin
Council of Scientific Research (RFCSR)
October 15, 2026



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Life in the Shadows: Microbial Survival on the Moon | **p15**

Robot in the Blood: A New Way to Deliver Drugs and Detect Cancer | **p17**



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LETTER *from the* EDITOR

Dr. Animesha Rath
The Editor-in-Chief

Dear Readers,

A discovery becomes especially compelling when it changes how we see something familiar. A shadow becomes a possible refuge for microbes. Humidity becomes a resource for wearable electronics. Soil becomes a living archive of plants. In this *October 2026* issue of Science Factors, we explore how looking more closely can reveal possibilities hidden in plain sight.

Our featured stories take us into three remarkable research settings. Human cortical tissue developing in specially prepared mice offers a new window into brain development and neural connections, while raising important questions about how such models should be interpreted and used. Research on the lunar south pole examines whether sheltered terrain could allow microbes carried from Earth to survive. Meanwhile, a tiny magnetic robot demonstrates how controlling fluid movement inside blood vessels could support drug delivery, clot treatment and the capture of rare tumour cells.

Across these stories, excitement is accompanied by a necessary distinction: what an experiment demonstrates today and what it might make possible tomorrow.

That distinction also runs through our expert contributions. Discussions of dietary support in autism shift attention from food restriction to nutritional adequacy, sensory acceptance and family feasibility. Antimicrobial nanomedicine invites another practical question: what does a more complex formulation contribute that a simpler treatment cannot? Work on synthetic biomolecular condensates explores how minimal molecular building blocks can create organised, responsive compartments with useful chemical functions. Together, these perspectives connect scientific imagination with the evidence needed for application.

Nature provides another thread through the issue. Buried seed banks reveal why seed abundance alone cannot describe ecological diversity. Mangrove research follows carbon beyond roots and sediments into tidal waters. A spider-web-inspired electrode shows how materials can work with environmental moisture, while an artificial nose demonstrates the value of adapting to background signals.

Science advances through observation, collaboration and the willingness to question an appealing explanation. Our aim is to share that process alongside its discoveries, making room for both wonder and careful judgement.

I thank our contributors, reviewers and editorial team for bringing these pages together, and our readers for continuing to ask thoughtful questions. May this issue inspire you to look again at the familiar and notice something unexpected.

Happy reading!



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Fuel discovery, inspire the future.

FEATURED RESEARCH

Behind every discovery lies a story of curiosity, perseverance, and wonder. Science unfolds through relentless research and bold explorations into the unknown. These are the journeys that shape our understanding of the world—and beyond.

| By Dr. Sourav Kumar

HUMAN BRAIN TISSUE IN MICE: A NEW WINDOW INTO BRAIN DEVELOPMENT

FEATURED

One quiet morning at Stanford University in California, Lena Morales stopped beside a small cage and stared at a mouse that seemed ordinary until she remembered what was inside its skull. "How can a human brain grow inside a mouse?" she whispered. Her colleague Marcus Reed smiled. That was exactly the strange question their laboratory had been chasing. The researchers had created a special mouse whose developing cerebral cortex the outer part of the brain involved in many complex functions was largely depleted. Then, while the mice were very young, they placed human stem cell derived cortical organoids into the empty space. An organoid is a tiny three dimensional group of cells grown from stem cells that can develop features of a human brain region. Earlier experiments had shown that such organoids could survive after transplantation, but there was a problem: a normal mouse brain had limited space, and its own rapidly developing cells competed with the human cells. Lena wondered what would happen if the human tissue had room to grow.

Weeks turned into months, and the mystery became a careful investigation. Marcus and Lena watched the transplanted mice with MRI scans, microscopes, genetic tests and recordings of brain activity. They wanted to know whether the human tissue would merely survive or actually become organized and connected to the mouse nervous system. The answer slowly appeared. The human cortical grafts grew strongly, and by three months they made up most of the combined cortical tissue in the transplanted mice. The researchers found many kinds of human brain cells, including developing neurons, support cells called astrocytes, and different layers or types of cortical neurons. They also found a particularly interesting group called layer 5 extratelencephalic, or L5 ET, neurons. These cells can send signals over long distances, and some had features associated with specialized human neurons that are not normally found in rodents. The researchers even detected sparse human derived neuronal projections reaching the mouse's cervical spinal cord. Lena leaned toward the microscope. "So they are not just growing," she said. "They are connecting."

But another question was waiting: **Were those connections actually doing anything?** To find out, the team used a technique that made activity in the human neurons visible through changes in calcium inside the cells. On the screen, sudden waves of activity appeared. A small region of the human graft became active, and within



| By Dr. Sourav Kumar

about a hundred milliseconds the activity spread across the graft. The bursts returned every few minutes, with smaller events occurring inside them. Electrical recordings with tiny probes told a similar story, showing organized bursts across the graft rather than activity confined to one small spot. Even more striking, the brain activity was closely related to facial movement in the mice. The human derived tissue, it seemed, had become an electrically active network integrated into the animal's nervous system. Yet Lena knew that a flashing signal on a screen was not the same thing as proving a human mind had appeared. The experiment was about cells, circuits and behaviour—not about creating a human brain inside a mouse.

The researchers therefore turned to behaviour. Using a depth camera and a computer method called MoSeq, they divided the animals' movements into tiny repeated actions, almost like syllables in a language. Control mice, mice without the normal cortex and mice with human cortical grafts showed different overall patterns of spontaneous behaviour. Yet the differences were not simple. The transplanted mice retained broadly normal locomotion. In a working memory maze, control and transplanted mice performed above chance, while mice without the cortex did not. However, the transplanted animals showed changes in gait and other behaviours, while some memory and conditioning tasks revealed differences from normal controls. Adding human cortical tissue therefore did not restore every function to normal. Instead, the graft joined a complex biological system whose effects could be measured through cells, electrical activity and behaviour.

That evening, as the Stanford laboratory grew quiet, Lena looked again at images of the human derived network spreading through the mouse brain. The experiment demonstrated something remarkable but precise: human cortical organoids could grow extensively in a specially prepared mouse, develop diverse human cortical cell types, connect with the host nervous system, produce organized electrical activity and influence measurable behaviour. The researchers suggested that this "xenocortical" model could eventually help scientists study human brain development, investigate diseases and test treatments in living systems. But the word eventually mattered. The study did not show that the graft recreated a complete human cortex or that the mice gained human thoughts or consciousness. It showed that living human neural tissue could develop and function within a carefully designed animal model in ways ordinary laboratory dishes cannot reveal. Lena switched off the microscope and paused at the door. If scientists could watch human neurons grow, connect and communicate inside a living system, what other secrets of the developing brain might they discover next?

The next chapter will require patience as well as curiosity. Future studies could ask whether organoids grown from patients' cells develop differently in this environment, and whether those differences reveal clues about neurological conditions. Researchers would also need to establish how reliably the model reproduces particular features of human development before using it to evaluate possible treatments.

Alongside these scientific questions, careful ethical oversight and attention to animal welfare must guide the work. For now, the model offers a starting point: an opportunity to observe human neural development in a living system while recognizing the limits of what it represents.



REFERENCE

Kaganovsky, K., Kelley, K.W., Gschwind, T. et al. Developmental xenocortication using human-derived organoids in mice. Nature (2026). https://doi.org/10.1038/s41586-026-11032-2

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| By Dr. Avijit Das

LIFE IN THE SHADOWS: MICROBIAL SURVIVAL ON THE MOON

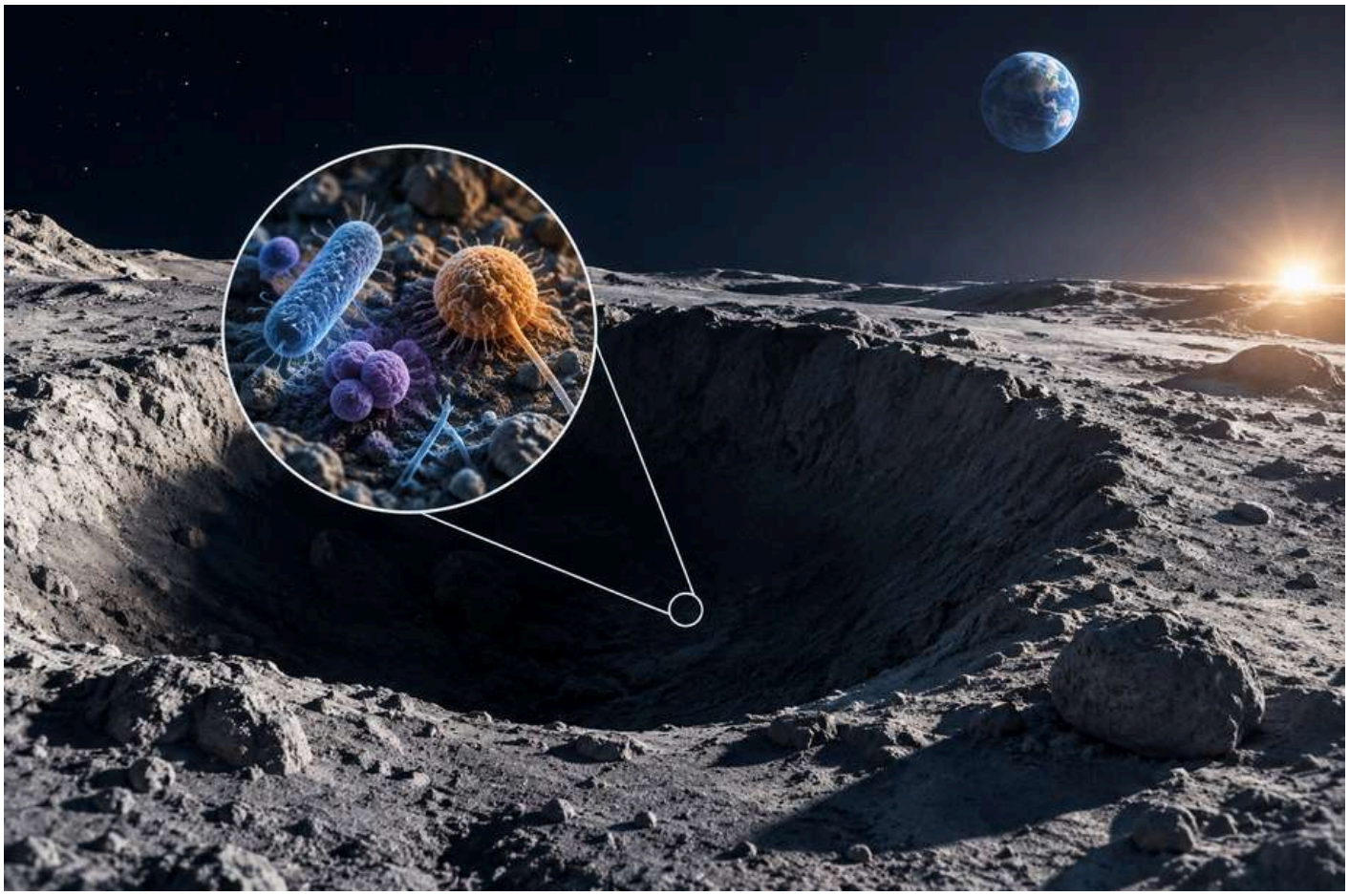
FEATURED

It began with a strange question at NASA's Goddard Space Flight Center in Greenbelt, Maryland: could a place that looked completely lifeless from Earth still offer tiny hiding places where microbes might survive?

On a quiet morning, fictional planetary scientist Priya Nair stared at a glowing map of the lunar south pole while her colleague Marcus Reed studied the numbers beside it. Everyone knew the Moon was a brutal place for life. There was almost no atmosphere, intense radiation, and extreme temperatures. But the south pole was different. The Sun stayed low above the horizon, and mountains, craters, and deep shadows could block much of its light. Priya leaned closer to the screen. "What if the shape of the ground changes the story?" she asked. The question led the team toward a part of the Moon that had often been treated as simply hostile, without fully considering its complicated topography.

The problem was that scientists needed to know where survival might actually be possible. Priya and Marcus were not sending microbes to the Moon. Instead, they combined existing experiments about microbial survival with measurements of the lunar surface. They focused on five microbial groups: Bacillus, Deinococcus, Staphylococcus, Aspergillus, and Fusarium. Some were common microbes associated with humans or spacecraft, while others were known for surviving harsh conditions. The scientists especially examined two dangers: ultraviolet radiation and high temperature. They used temperature measurements from NASA's Lunar Reconnaissance Orbiter and detailed information about the Moon's shape and illumination. At first, the work sounded almost like a giant puzzle. Every crater wall, ridge, and shadow could change how much sunlight reached a small patch of ground. The team wanted to find places where the conditions stayed below the limits that would make survival unlikely for at least one Earth day.

Then the maps began to reveal something surprising. As Marcus changed the models to include the Moon's uneven



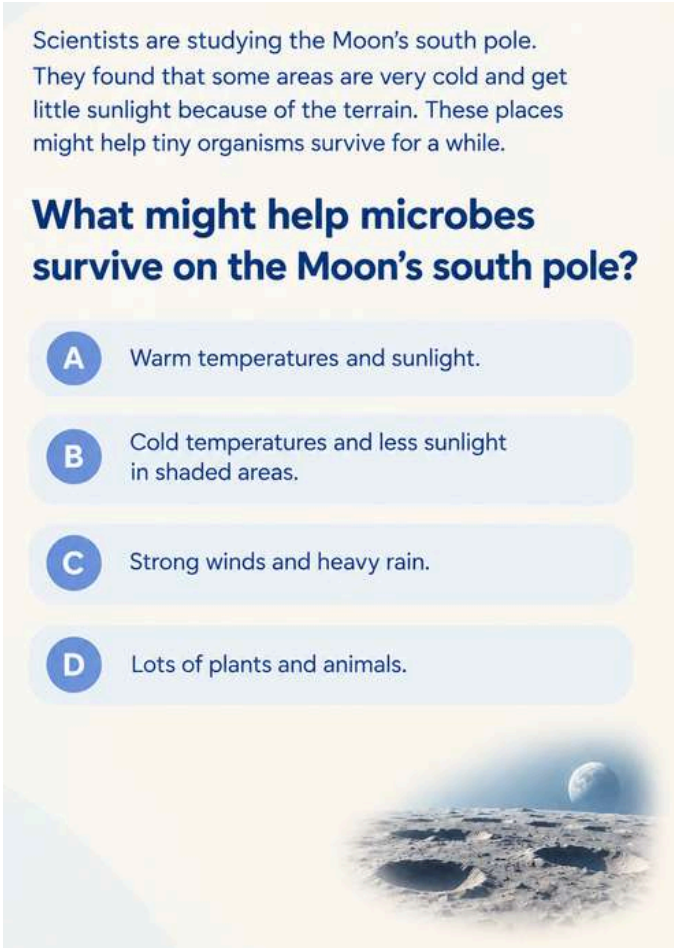
By Dr. Avijit Das

surface, dark regions appeared among the brighter ones. Some areas near the south pole received far less ultraviolet light than surrounding terrain. The researchers found that several regions could potentially allow some of the microbes they studied to survive, at least in a dormant or "cryptobiotic" state a condition in which an organism remains alive but is not actively growing. Aspergillus showed the broadest potential survivability in their analysis. At selected Artemis III candidate regions, high resolution models found significant areas where microbes might survive for a day, while some areas offered possible survival for longer periods. Permanently shadowed regions were especially interesting because they receive no direct sunlight, although scattered ultraviolet light from nearby surfaces still matters. The discovery was not that the Moon was secretly alive, but that its landscape could create small environmental shelters where life carried from Earth might endure.

For Priya, the strangest part came after the maps looked convincing. She imagined a future astronaut stepping carefully across the lunar south pole, unaware that a tiny boot print might create its own patch of shade. The paper notes that even boot prints, rover tracks, or small scooped depressions could potentially create small scale shadowed features at polar latitudes. At the same time, astronauts themselves could carry microbes from Earth. Airlocks, spacesuits, and human activity could become routes by which microscopic life reaches the lunar surface. That made the discovery important for more than curiosity. The study suggested that contamination could interfere with searches for other materials and that stronger measures to limit unwanted biological transfer may be useful. But Marcus reminded Priya of one crucial distinction: survival was not the same as growth. The study did not show that microbes would reproduce on the Moon. The researchers specifically noted that present day lunar conditions probably lack stable liquid water and other requirements needed for active growth.

That evening, as the laboratory lights dimmed, Priya looked once more at the tiny dark patches scattered across the lunar map. They were not forests, oceans, or signs of living colonies. They were possible niches identified through models built from remote sensing and previous survival experiments, and the researchers stressed that more experiments and finer resolution studies are still needed. Better maps, additional environmental factors, laboratory tests, and closer studies of individual lunar sites could change the picture. Yet the idea remained powerful: on a world that seemed completely exposed and lifeless, the landscape itself might provide small shelters for microscopic passengers from Earth. And perhaps that lesson reaches farther than the Moon, because similar survivable niches may exist on other airless worlds—and somewhere in those shadows, scientists may one day discover a question even stranger than whether life can survive there.

For future lunar missions, these findings raise a practical question: how can exploration proceed without confusing traces of Earth with evidence from the Moon? Careful records of spacecraft cleanliness, astronaut activities, and sampling locations could help researchers interpret future discoveries. Testing microbial survival under realistic lunar conditions would also help refine the maps. Each step could bring scientists closer to understanding what these sheltered patches truly mean for responsible exploration.



REFERENCE

Prabal Saxena et al. ,Potential survivable niches for microbial life on the lunar south pole. Sci. Adv.12,eaec0811(2026).DOI:10.1126/sciadv.aec0811

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| By Dr. Priyangana Deb

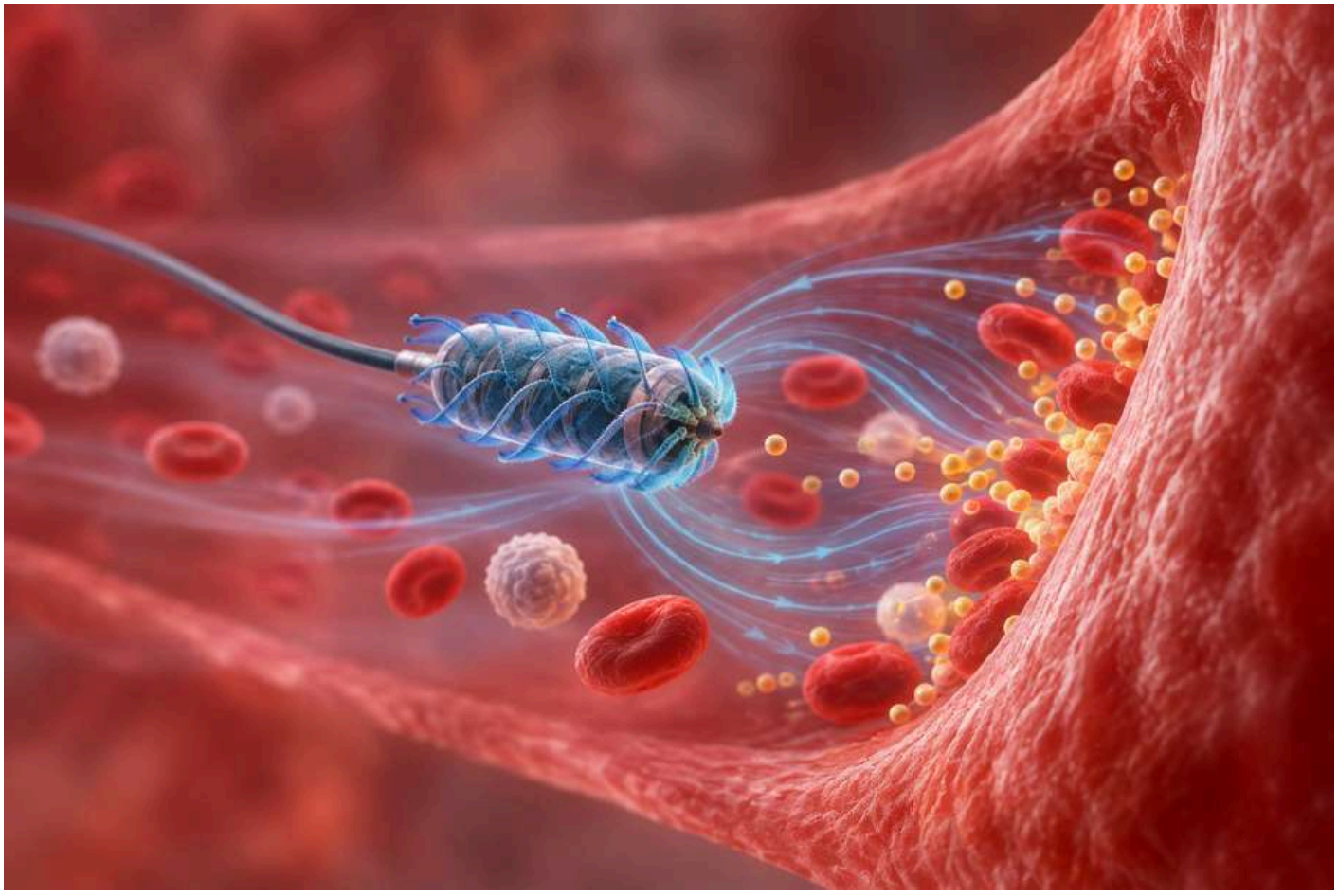
ROBOT IN THE BLOOD: A NEW WAY TO DELIVER DRUGS AND DETECT CANCER

FEATURED

It began with a strange question in Shenzhen, China: what if a tiny robot could change the way things moved inside a blood vessel? In a laboratory at The Chinese University of Hong Kong, Shenzhen, researcher Lin Yue watched fluorescent particles moving quietly through a model vessel. Their paths were almost perfectly straight. This was because blood flow can be laminar, meaning its layers move in an orderly way. Although efficient for circulation, this pattern makes it difficult to push medicines or cells sideways from the fast-moving centre toward the vessel wall. Lin wondered whether a soft robot could disturb that flow without simply blocking it. Her colleague Chen Hao showed her their unusual invention: CiliaVine, a small, vine-shaped soft robot bearing flexible magnetic cilia and wrapped around the tip of a medical guidewire. The cilia were made from a soft polymer containing magnetic particles, allowing them to open, close and beat under an external magnetic field in real time.

The researchers programmed three modes by changing the magnetic signal. In pumping mode, each cilium made a rapid stroke in one direction and returned slowly, pushing fluid outward. Reversing that sequence produced suction, drawing fluid inward. A balanced back-and-forth motion generated tiny vortices that mixed the surrounding fluid. Then Lin saw something that made her lean closer to the screen. When fluorescent particles began near the centre of the model vessel, pumping moved them toward the wall. When particles collected near the wall, suction drew them into the faster central stream, where they were carried away. More than 98% of the accumulated particles were cleared within 30 seconds. In mixing mode, microvortices increased contact between particles and the robot's surface. A moving robot captured over four times as many particles per unit area as a stationary one.

Chen then asked whether this flow control could address real medical problems. The researchers first tested targeted delivery in a hydrogel vessel. Pumping drove a fluorescent model drug toward the wall and into the surro-



| By Dr. Priyangana Deb

unding material. At the vessel surface, its concentration was 146% higher than with passive diffusion alone; even one millimetre into the material, it remained 75% higher. Active cross-stream transport might therefore help medicines reach tissue beside a vessel rather than simply being swept downstream. Next came blood clots. In a vessel phantom containing a clot attached to the wall, CiliaVine helped tissue plasminogen activator, or tPA, reach the clot while clearing loosened residue. With the cilia operating, the clot dissolved in about 40 minutes, compared with an average of 70 minutes without flow regulation. The robot did not replace the drug. Instead, it helped the drug and debris cross the slow boundary layer near the vessel wall.

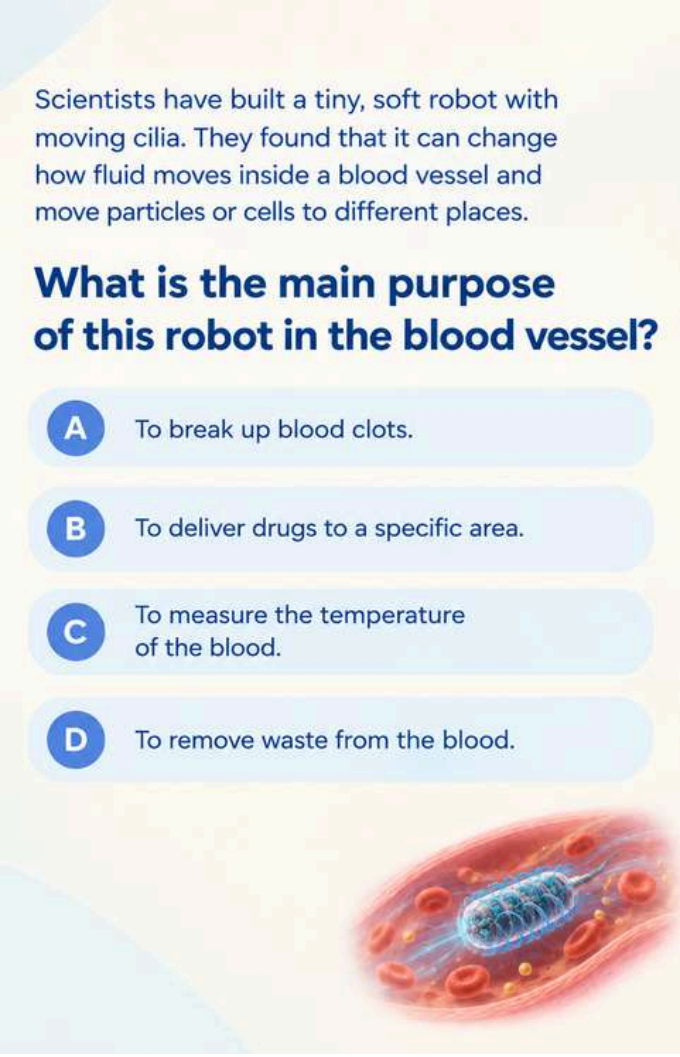
The team also investigated circulating tumour cells, rare cancer cells shed into the bloodstream. They coated the cilia with antibodies that recognize markers on different tumour-cell types. Mixing created low-pressure regions that pulled cells toward the cilia, where antibody binding held them in place. In model tests, active motion captured far more cells than a stationary robot and captured cells at concentrations as low as 10 tumour cells per millilitre. Tests on blood from 23 liver-cancer patients recovered circulating tumour cells from every sample, with counts ranging from one to 33. Higher average counts appeared in intermediate and advanced disease than in early disease, although larger clinical studies would be needed before using the method diagnostically. The researchers then tested the device in 15 rabbits bearing liver tumours. Guided by x-ray imaging, they inserted CiliaVine through the femoral vein into the inferior vena cava and operated it magnetically for 20 minutes. The device captured substantially more suspected tumour cells in tumour-bearing animals than in healthy controls. Examination of nearby vessel tissue found no obvious inflammation or damage, while additional tests indicated little red-blood-cell destruction. These findings were encouraging, but they remained animal experiments rather than proof of safety and effectiveness in people.

That evening, Lin looked again at the tiny robot resting beside the model vessel. It was not a magical machine, nor was it ready for routine patient care. The experiments showed that programmed magnetic movement could regulate local flow and manipulate particles and cells, with possible uses in targeted drug delivery, thrombolysis and tumour-cell enrichment. Questions about long-term safety, precise control, retrieval, manufacturing and performance in varied human vessels still require careful study. Future versions might combine the robot with optical, electrochemical or molecular sensors, allowing doctors to capture rare cells and read biological signals inside particular blood vessels.

Lin smiled at the thought. Perhaps the most important discovery was not merely that a robot could enter the bloodstream, but that something so small could alter the flow around it. And that raised a larger question: what else might scientists one day teach a tiny robot to do inside the human body?

The next challenge is to turn this promising laboratory tool into a reliable medical device.

Success will depend on showing that controlled flow can deliver meaningful benefits while protecting blood vessels and allowing the robot to be safely removed afterward.



REFERENCE

Yibin Wang et al. ,A ciliated intravascular soft millirobot for multimodal in-flow collective manipulation.Sci. Adv.12,eaeg3333(2026).DOI:10.1126/sciadv.aeg3333

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| EXPERT OPINION | DOI: https://doi.org/10.67831/Sci.Factors.2026.1615

Rethinking Treatment for Oligometastatic Breast Cancer: The Role of Precision Radiation



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| Scientific Profile | | Organization Link | | Research Lab Page | | Factors Press |

Areas of Expertise: Radiation Oncology | Breast Oncology | Neuro-oncology

Metastatic breast cancer has traditionally been regarded as an incurable disease requiring long-term systemic treatment, with local therapies generally used for symptom relief or prevention of local complications. This approach has been questioned with the emergence of the concept of oligometastatic disease (OMD), which generally refers to a limited number of metastatic lesions, most commonly one to five, and may represent an intermediate state between localized disease and widespread metastatic dissemination. In some patients, the limited metastatic burden may reflect more favourable tumour biology and could potentially be amenable to aggressive local treatment. If a limited number of deposits can be identified and eradicated, some patients might achieve durable disease control, or even cure. Stereotactic Ablative Body Radiotherapy (SABR), has emerged as the tool best suited to test this hypothesis. Unlike conventional palliative radiotherapy, SABR delivers very high, tumoricidal doses in 1–5 precisely targeted fractions while sparing surrounding normal tissue. In oligometastatic breast cancer (OMBC), the rationale for SABR is primarily local tumour ablation. There is also increasing interest in its potential immunological effects, particularly when combined with immune checkpoint inhibitors (ICIs). This review examines where the evidence for SABR in OMBC currently stands, why the immunotherapy combination is generating fresh optimism despite recent disappointments, and what questions remain open.

Defining Oligometastatic Breast Cancer

Oligometastatic breast cancer is clinically heterogeneous. Classifications distinguish de novo oligometastatic disease (metastases present at initial diagnosis), oligorecurrent disease (a limited relapse after a disease-free interval), and oligoprogressive disease (a small number of lesions progressing while the rest of disease remains controlled on systemic therapy). This distinction matters clinically: emerging data suggest that oligoprogressive and oligorecurrent disease, arising in the context of relatively indolent biology, may respond differently to metastasis-directed therapy than a patient who presents with widespread disease burden from the outset. Biomarker research including candidate markers such as PIK3CA mutation status and YAP/TAZ expression is beginning to explore whether OMD represents a genuinely distinct molecular subtype rather than a matter of tumor burden alone.

The Randomized Evidence: A Story of Contrasts

The strongest signal for metastasis-directed SABR across cancer types comes from SABR-COMET, a phase II trial that randomized patients with a controlled primary tumor and 1–5 metastases (mixed histologies) to standard-of-care systemic therapy with or without SABR to all sites of disease. The long-term results were striking: 8-year overall survival was 27% in the SABR arm versus 14% with standard of care alone, alongside improved progression-free survival. However, breast cancer patients made up only 18% of the trial population, and toxicity, including treatment-related deaths, was seen in the SABR arm underscoring that the benefit came with real risk that needs careful patient selection.

Because SABR-COMET was not breast-cancer-specific, the

cooperative group trial NRG-BR002 was designed to answer the question directly. This phase IIR/III study randomized patients with newly diagnosed OMBC (≤4 extracranial metastases, controlled primary, no progression on ≤12 months of first-line systemic therapy) to standard systemic therapy alone versus systemic therapy plus metastasis-directed therapy (SBRT or surgical resection) to all lesions. Presented at ASCO 2022, the results were negative: total ablation added no detectable progression-free or overall survival benefit over systemic therapy alone, and the trial closed early for futility on the OS question. Treatment was safe, with toxicity comparable between arms, but the efficacy signal simply was not there. A related trial, EA2108, similarly found no survival benefit from adding early local therapy in stage IV breast cancer.

The contradictory results of SABR-COMET and NRG-BR002 have led to a temporary halt to rethink the future direction of management in such patients. It has prompted a shift away from treating "oligometastatic breast cancer" as a monolithic target and toward asking which specific clinical scenarios oligoprogression on a given systemic regimen, bone-only disease, hormone receptor–positive disease, or HER2-positive disease with novel systemic partners might still benefit from ablation. Single-arm data, such as the AVATAR trial presented at ASTRO 2023, suggest SABR directed at oligoprogressive lesions in ER-positive advanced breast cancer can meaningfully delay the need to switch systemic therapy, a clinically relevant endpoint even without a proven survival benefit. Real-world registry data, including a large NHS England prospective cohort of SBRT for 1–3 metachronous oligometastases, are being used to further refine which patients are truly benefiting.

Where Immunotherapy Enters the Picture

Combining SABR with immune checkpoint inhibition aims to explore whether high-dose, ablative radiation is not purely destructive but also immunogenic. Ablative radiation causes immunogenic cell death, releasing tumor antigens that are taken up by dendritic cells and presented to T cells, upregulating MHC class I expression, and in some patients inducing systemic immune activation with increased PD-1 expression on circulating CD4+ and CD8+ T cells. This is the biological basis of the abscopal effect: regression of untreated, distant tumor deposits following irradiation of a single site, historically a rare and unpredictable phenomenon but one that checkpoint blockade may make more reliable by removing the inhibitory brakes that would otherwise blunt the radiation-primed immune response.

Preclinical work in the 4T1 murine triple-negative breast cancer (TNBC) model supports this logic: combining focal radiotherapy with anti-PD-1 antibody produced measurable regression of a second, unirradiated tumor and altered infiltration of myeloid-derived suppressor cells, consistent with a genuine abscopal, immune-mediated effect rather than radiation scatter. TNBC has become the focus of most clinical combination efforts because it is comparatively immunogenic, often with higher tumor mutational burden and PD-L1 expression than luminal disease, and already has an approved role for immunotherapy in the metastatic and early-stage settings.

Clinically, a single-arm phase II study evaluated pembrolizumab combined with radiotherapy in metastatic TNBC, motivated by the modest 13–19% response rates seen with checkpoint inhibitor monotherapy in PD-L1-positive disease, and by case reports (including the well-known Postow abscopal case with ipilimumab) suggesting radiation could unlock systemic responses in patients otherwise progressing on immunotherapy alone. Other early-phase and window-of-opportunity studies, such as trials pairing pembrolizumab with SABR in oligometastatic disease, or intraoperative radiotherapy combined with pembrolizumab in early TNBC, are probing whether the sequencing, dose, and fractionation of radiation can be optimized specifically to prime rather than exhaust the immune response. Dose and fractionation appear genuinely important: excessively high single-fraction doses can damage the very lymphocytes needed to mount a systemic response, so hypofractionated regimens are being explored as a middle ground.

Where This Leaves Practice and Future Directions

At present, SABR should not be offered as standard first-line management for newly diagnosed oligometastatic breast cancer outside of a clinical trial; NRG-BR002 was a well-conducted, adequately powered negative study, and enthusiasm generated by tumor-agnostic data like SABR-COMET does not automatically transfer to breast cancer biology.

Where SABR does appear to have a defensible role today is in the oligoprogressive setting treating a small number of resistant lesions to prolong the effectiveness of an otherwise-working systemic regimen and pragmatically, for palliation and local control.

| EXPERT OPINION |

Immunotherapy combination represents the most promising avenue for moving beyond, but remains investigational. Ongoing and future work needs to define optimal SABR dose-fractionation for immune priming, identify which breast cancer subtypes (most plausibly TNBC, and potentially HER2-positive disease given newer HER2-targeted immune-active agents) are most likely to respond, and validate predictive biomarkers so that ablative, immune-augmenting strategies can be directed at patients truly capable of a durable, systemic anti-tumor response rather than applied indiscriminately. Larger randomized trials specifically pairing SABR with checkpoint inhibition in biomarker-selected OMBC populations are the logical next step to determine whether precision radiation can finally convert a subset of metastatic breast cancer into a chronic, or even curable, condition.

REFERENCES

- Palma DA, Olson R, Harrow S, Gaede S, Louie AV, Haasbeek C, et al. Stereotactic ablative radiotherapy for the comprehensive treatment of oligometastatic cancers: Long-term results of the SABR-COMET phase II randomized trial. Journal of Clinical Oncology. 2020;38(25):2830–2838. DOI
- Chmura SJ, Winter KA, Woodward WA, Borges VF, Salama JK, Al-Hallaq HA, et al. NRG-BR002: A phase IIR/III trial of standard of care systemic therapy with or without stereotactic body radiotherapy (SBRT) and/or surgical resection (SR) for newly oligometastatic breast cancer. Journal of Clinical Oncology. 2022;40(16 Suppl):1007. DOI
- Dagar A, Ghosh A, Singhal A, Kumar A, Sharma J, Sharma A, et al. A study of curative-approach treatment along with metastasis-directed stereotactic body radiation therapy in bone-only oligometastatic breast cancer. International Journal of Radiation Oncology, Biology, Physics. 2026;124(5):1270–1280. DOI

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> *The future of SABR may lie in combining precise tumour ablation with immunotherapy to generate a broader systemic anti-tumour response.*



| EXPERT OPINION | DOI: https://doi.org/10.67831/Sci.Factors.2026.1618

Translating Raman Spectroscopy into Reagent-Free Process Analytical Technologies for Microbial Biomanufacturing



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Areas of Expertise: Biomedical Spectroscopy | Label free imaging | Disease diagnosis | Antimicrobial Resistance | Biophysics |



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There has been an exponential increase in the biomanufacturing processes utilizing microbes or yeast as they are known to be cost-effective, have versatile capability and provide high yields. The ongoing advancements in the biomanufacturing industry are growing along with the challenges of detecting products and processes in real time. An industrial microbial culture is comprised of growth media, cells, and variety of metabolites. An accurate identification of commercially relevant metabolites in a growing complex culture is one of the critical process parameters. The traditional approaches, such as chemical-based assays, high-performance liquid chromatography (HPLC) and mass spectrometry provide valuable information and are highly sensitive but these are known to be time-consuming, involve invasive and extensive sample preparation steps. To achieve consistent quality, yield, and reproducibility, a precise, quantitative, real-time monitoring approach is essential. Among the growing interest of the scientific community in identifying alternate solutions, methods based on the principles of Raman spectroscopy have emerged as a cornerstone process monitoring tool in the biomanufacturing industry.

Raman Spectroscopy is based on the principles of inelastic scattering and can serve as a robust analytical tool to provide analyte-specific information with minimal sample preparation. The potential to acquire Raman signals from complex biological matrices in a non-invasive, reagent-free manner enables its application for quasi real time monitoring. Notably, Raman signals are minimally affected by water, thereby enabling effective monitoring of metabolites, biomass, and other variables in aqueous environments. Leveraging Raman spectroscopy as a real-time monitoring tool for continuous process control will be a significant transition in the biomanufacturing industry. The amalgamation of spectroscopic measurements with chemometric tools can help to transform the high dimensional data into quantitative (e.g. metabolite concentration) as well as qualitative (e.g. sampling time-point) values. As the biomanufacturing moves towards Biopharma 4.0, Raman based methods combined with advanced chemometric or data analysis tools will help in translating from a passive measurement method to an autonomous process control method.

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Our laboratory at the Biosciences and Bioengineering (BSBE) Department, Indian Institute of Technology (IIT) Dharwad works at the intersection of various scientific disciplines ranging from physics, biology and machine learning. The primary focus of our research group is to develop optical sensors for dynamic monitoring and mapping of commercially relevant metabolites at the laboratory and batch scale fermenters. Using Raman spectroscopy as a tool for investigations we focus on identifying lacunae in existing endpoint metabolomics measurements and offer real-time, sustainable frameworks that can be applied for biomanufacturing of biofuels, biochemicals, and other relevant microbial biopolymers.

In our recent work published in Talanta (Phaneeswar et al., 307, 129934 (2026)), we reported Raman spectroscopic identification of protonated and deprotonated lactic acid in the microbial culture supernatant with enhanced limit of detection. Lactic acid is an industrially relevant metabolite derived from microbes; it serves diverse industries, including pharmaceuticals, cosmetics, and food, and is also a monomer used to produce the biobased polymer polylactic acid.

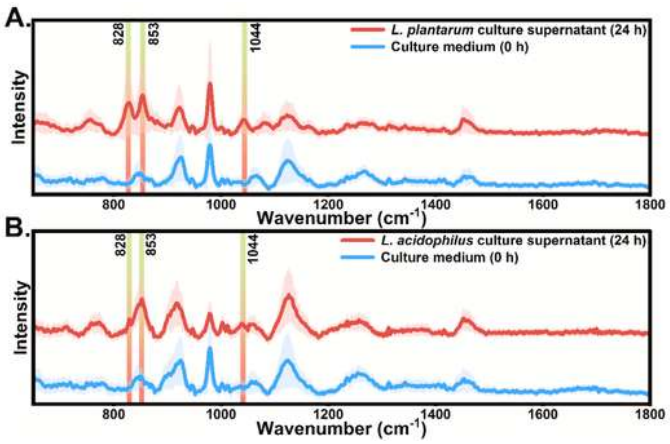


Figure 1: A. Average Raman spectra (stacked for better visualization) of Lactobacillus plantarum culture supernatant collected at 24 h (liquid culture medium supernatant with respect to culture medium at 0 h (2x, n =20) B. Average Raman spectra (stacked for better visualization) of Lactobacillus acidophilus culture supernatant collected at 24 h (liquid culture medium supernatant) with respect to culture medium at 0 h (2x, n =20) (Standard deviation is shown as the shaded area. The red to green highlight represents the lactic acid representative peak at 0 h(red) and 24 h (green)).

This study began with a simple yet intriguing question: "Can we determine the characteristic signal of lactic acid in the complex culture media in a label-free manner and with minimal sample preparation?" We used Lactobacillus plantarum and Lactobacillus acidophilus, well-known lactic acid bacteria (LAB) and recorded Raman spectrum at 0 and 24 h from the liquid culture supernatant without any enzymatic derivatization. As can be seen in Figure 1A, at 0 h negligible signals were observed at 828 cm− 1, 853 cm− 1 and 1044 cm− 1 in the average Raman spectra from the supernatant. In contrast the supernatant of 24 h have prominent bands at these positions suggesting presence of lactic acid. Interestingly, the 24h spectrum from L acidophilus had a small peak at 828 cm-1, which led us to dive further in understanding the protonation state of lactic acid in both cultures, Figure 1B. It was found that the loss of H+ ion from the lactic acid molecule leads to the shift of the Raman signal from 828 cm-1 to 853 cm-1 (conversion of lactic acid to lactate). The driving factor for this proton shift was the pH value at 24 h for both cultures. This was found to be around 3.24 ± 0.1 for L. plantarum and 4.35 ± 0.5 for L. acidophilus. Due to this difference the prominent form of lactic acid was in lactate form in L. acidophilus. This observation was further validated with adding pure lactic acid in buffer solutions at varying pH. Spectra collected from these solutions revealed versatility of this method in identifying both protonated and deprotonated form of lactic acid, Figure 2. This observation is extremely important as most commercial kits available on the market detect only lactate and lack the ability to monitor a growing culture medium. Altogether, this highlights the potential of Raman spectroscopy for real-time, reagent-free monitoring and future integration with in-line bioprocess monitoring systems. Another interesting finding was that that Raman spectroscopy based detection achieved a sub-millimolar concentration limit of detection (~0.6 mM = ~0.05 g/L) for L. plantarum culture and >2 mM for L. acidophilus.

Overall, direct detection of lactic acid in intact culture media, multiplexing capability to resolve protonation states, minimal sample preparation, and signal processing are key attributes of our work. These findings can serve as a solid base for prospective translation of this approach for industrial LAB fermentations where the lactic acid concentrations are very high. Some challenges such as improving the signal-to-noise ratio, tackling the additional complications of the bioreactors such as gas bubbles, higher cell density and deposition of media components

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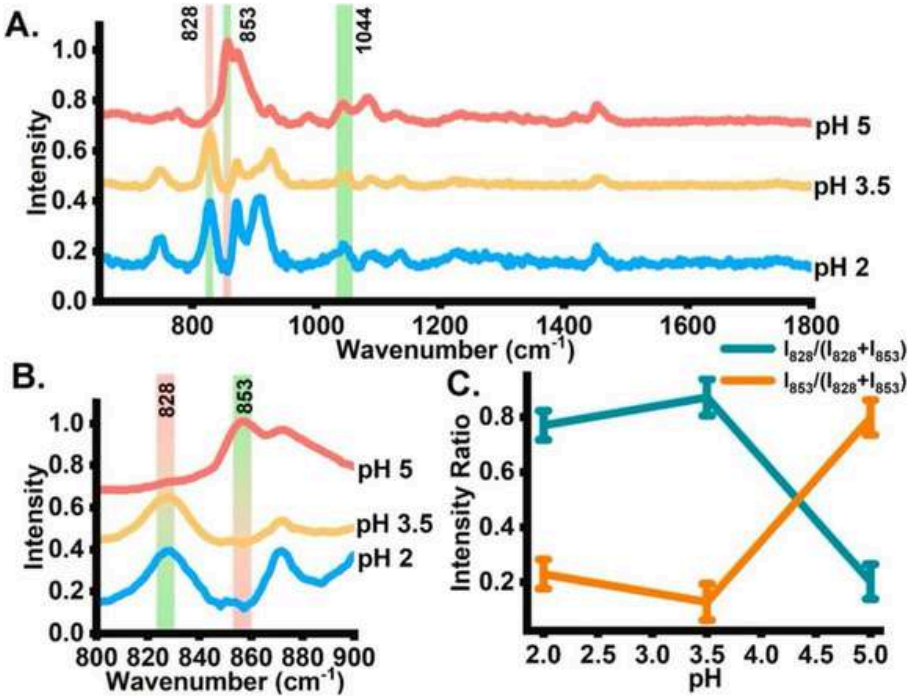


Figure 2: pH-dependent Raman spectral changes of lactic acid/lactate. A. Raman spectra (stacked for better visualization) recorded at pH 2.0, 3.50, and 5.0 showing pronounced variations in the peaks at 828 cm−1 and 853 cm−1 as highlighted. These changes reflect protonation-state-dependent vibrational modes of lactic acid/lactate. B. Enlarged view of the spectral region between 800 and 900 cm−1. C. Corresponding intensity ratios of the 828 cm−1 and 853 cm−1 peaks (I828/(I828+I853)) and (I853/(I828+I853)).

will require additional efforts.

Raman spectroscopy-guided bioprocess sensing spans optics, microbiology, and chemometrics. For early-career researchers, this rapidly evolving field offers substantial opportunities. Despite recent advances, further opportunities lie in multimodal process monitoring where Raman spectroscopy is coupled with complementary sensors such as temperature, pH, fluorescence and mass spectrometry. Here, Raman provides analyte-specific information, while other measurements capture distinct physiological and biochemical aspects of the process. We encourage younger scientists to explore this multimodal process-monitoring dimension by coupling quantitative chemometrics with machine learning. Future investigations in this domain would transform Raman spectroscopy from a tool for identifying biochemical changes to an automated process-monitoring framework.

REFERENCES

- Phaneeswar MS, Karlo J, Bhise KA, Sahu S, Singh SP, et al. Non-enzymatic Raman sensing and imaging of lactic acid directly from intact microbial cultures with protonation-state resolution. Talanta. 2026;307:129934. DOI
- Klaverdijk M, Nemati M, Ottens M, Klijn ME. Impact of bioreactor process parameters and yeast biomass on Raman spectra. Biotechnology Progress. 2025;41(6):e70050. DOI
- Graf A, Lemke J, Schulze M, Soeldner R, Rebner K, Hoehse M, Matuszczyk J. A novel approach for non-invasive continuous in-line control of perfusion cell cultivations by Raman spectroscopy. Frontiers in Bioengineering and Biotechnology. DOI 2022;10:719614. DOI
- Karlo J, Dewangan NK, Phatak AA, Singh SP. Sensing and hyperspectral imaging of the newly synthesized carotenoids in single-cell micro-factories. Sensors and Actuators B: Chemical. 2026;451:139367. DOI

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Dr. Surya Pratap Singh is an Assistant Professor, and Mahamkali Sri Phaneeswar is a BSMS student in the Department of Biosciences and Bioengineering at the Indian Institute of Technology (IIT) Dharwad, India. Their research focuses on developing advanced light-based techniques to detect and study biological molecules without using chemical reagents. Working with the Integrated Biophotonics research group, they explore Raman spectroscopy for studying microbial metabolites, including organic acids, lipids, and carotenoids. Their recent work demonstrates the potential of Raman spectroscopy for detecting lactic acid directly in microbial cultures, supporting faster, safer, and real-time monitoring in industrial biotechnology. This work is one of the contributing studies to the current perspective on Raman spectroscopy's role as a reagent-free monitoring, a step toward real-time monitoring in the biomanufacturing industry.

| EXPERT OPINION | DOI: https://doi.org/10.67831/Sci.Factors.2026.1612

After the Elimination: What Should Go Back on the Plate?



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Areas of Expertise: Nanobiotechnology | Phototheranostics | Drug Delivery | Metal Organic Frameworks

Dietary discussions in autism spectrum disorder (ASD) often begin with removal: gluten, casein, processed foods or other foods considered difficult to tolerate. Yet for a child who already has food selectivity, sensory sensitivities or a narrow repertoire, the more practical question may be what comes next. What can replace the foods that have been removed, and can those replacements be accepted, nutritionally meaningful and sustainable for the family?

This distinction matters particularly for gluten-free and casein-free (GFCF) diets. Interest in GFCF diets remains substantial, but controlled evidence has not established them as a treatment for the core features of autism. A systematic review and meta-analysis of six randomized controlled trials involving 143 children found no statistically significant effect on clinician-reported core symptoms, parent-reported functional level or behavioral difficulties; the certainty of evidence was low to very low. The authors also noted potential gastrointestinal adverse effects and emphasized the need for better-quality trials.

A clinically responsible discussion should therefore move beyond the binary question of whether a restrictive diet "works" and examine how dietary care can remain nutritionally and practically sound when restriction is chosen.

From food elimination to food reconstruction

Our view is that dietary intervention in autism should increasingly be considered as food-environment design. Removing a food is only the first step. The intervention becomes meaningful when the resulting food repertoire is reconstructed. Four dimensions should be considered together. First is nutritional adequacy: replacement foods must contribute appropriately to energy, protein, micronutrients and dietary diversity rather than simply satisfy a restriction. Second is sensory fit: texture, taste, aroma, appearance and consistency can determine whether a food reaches the child's plate. Third is cultural fit: familiar ingredients and household preparations may reduce the distance between a prescribed diet and everyday eating. Fourth is family feasibility: ingredient availability, cost, preparation time, cooking skills and school or social contexts can determine whether a diet can be sustained. This reframes adherence. It is not simply whether a caregiver follows instructions; it is whether a dietary strategy can become part of the child's ordinary food envir-

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Figure 1: A food-environment framework for dietary support in autism, emphasizing progression from restriction and replacement to reconstruction and sustainability, across four dimensions: nutritional adequacy, sensory fit, cultural fit, and family feasibility.

onment.

Why millets are interesting but not magical

Millets are relevant to this reconstruction model because they are traditional grains that can be incorporated into diverse foods and can fit gluten-free dietary patterns. The FAO describes millets as diverse dryland cereals that can provide dietary fiber, minerals, vitamins and protein, with composition varying by species, variety and growing conditions. Our earlier work on nutri-cereals in autism examined their nutritional significance, food formulation, processing considerations, sensory and cultural acceptability, and the need to protect overall nutritional adequacy. The important point is not that millets possess a special therapeutic property for autism. Rather, they can function as a food platform. Foxtail, little and pearl millet can be formulated into familiar or adaptable preparations, allowing dietary restriction to be addressed without making the food environment entirely unfamiliar.

This distinction is essential. Nutritional plausibility is not clinical efficacy. Biological hypotheses involving dietary fibre, resistant starch, polyphenols, microbial metabolites and the gut–brain axis are scientifically interesting, but they should remain hypotheses until tested in appropriately designed clinical studies. A food can be nutritious, acceptable and biologically plausible without being a treatment for autism.

What our pilot taught us beyond its numbers

Our recent 12-week pilot study provides a practical example of why this broader framework matters. Children aged 4–6 years with confirmed ASD received a millet-based GFCF dietary intervention using foxtail, little and pearl millet developed into three recipe formats. The study assessed dietary intake, sensory acceptability, caregiver-reported adherence and feasibility. The recipes were well accepted, reported adherence was 80%, and changes were observed in dietary intake. Caregivers also reported changes in gastrointestinal comfort, sleep and hyperactivity. Ingredient availability and preparation time emerged as practical barriers. These findings are useful primarily as feasibility signals. They show that a millet-based GFCF food strategy can be implemented and studied in a real-world setting. They do not establish that millets treat autism, that the intervention changes core autistic characteristics, or that caregiver-reported changes were caused by the diet. The single-arm design, short duration and reliance on caregiver-reported outcomes limit causal interpretation.

The more important lesson is methodological. Acceptability should be measured alongside nutritional intake. Adherence should be interpreted alongside household workload. Dietary outcomes should be distinguished from clinical outcomes. Caregiver observations should generate hypotheses that can subsequently be tested using objective and validated measures.

A new research question: for whom, under what conditions, and compared with what?

The next generation of dietary research in autism should move beyond the question of whether a named diet is effective in general. More informative questions are: Which children are most likely to accept a particular food strategy

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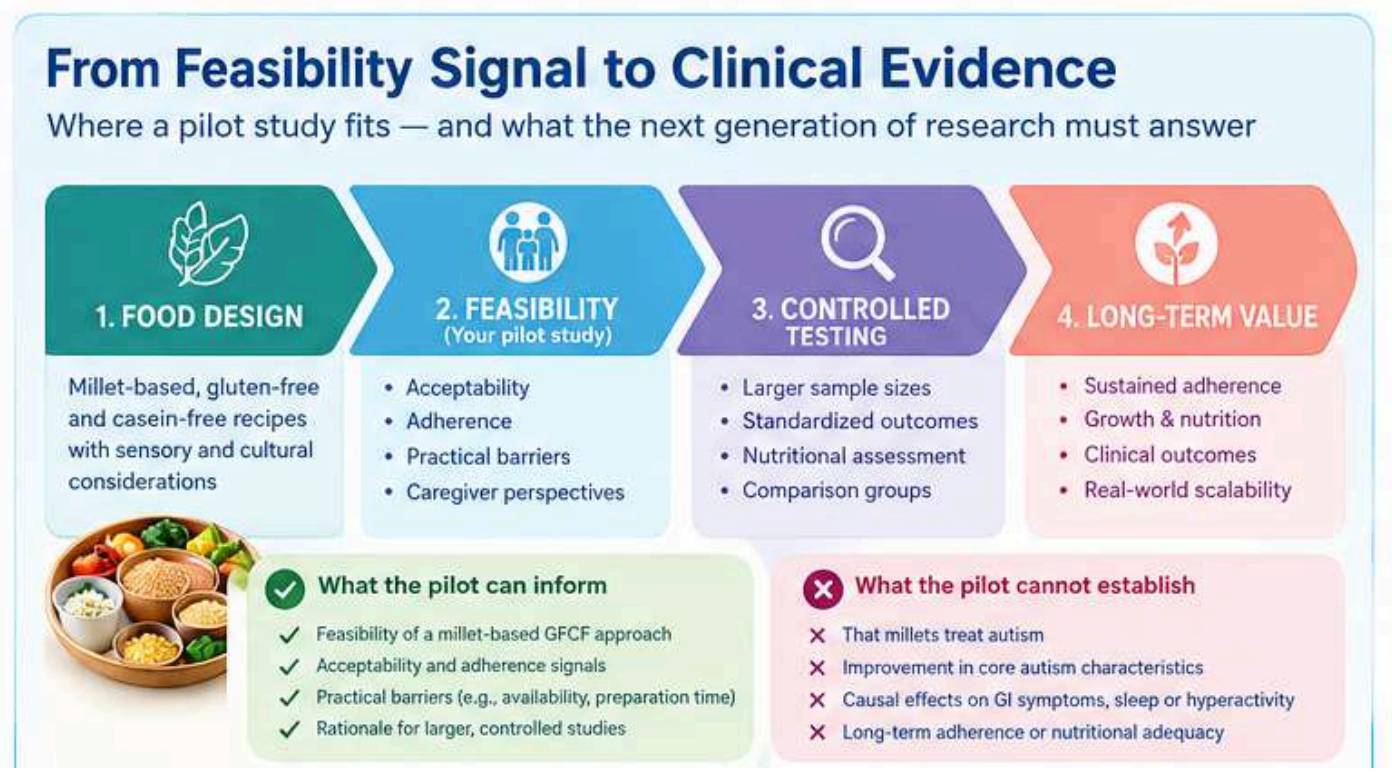


Figure 1: The progression from millet-based food design and feasibility assessment to controlled testing and evaluation of long-term value, highlighting what a pilot study can inform and what it cannot establish.

? Does baseline food selectivity influence implementation? Do sensory characteristics predict adherence? How do cost, ingredient availability and preparation time affect sustained use? What happens to growth, micronutrient status and dietary diversity over longer periods? Controlled trials should separate nutritional outcomes from autism-specific outcomes. Measures of gastrointestinal symptoms, sleep, adaptive behaviour and quality of life can be studied alongside standardized developmental or behavioural measures, while dietary intake and nutritional biomarkers provide evidence about adequacy. Longer follow-up is essential because a strategy that works for twelve weeks may not remain feasible for a year. This approach also argues for multidisciplinary research. Pediatricians, dietitians, food scientists, occupational therapists, psychologists and caregivers contribute different pieces of the same problem. Food formulation and sensory science may be as relevant to adherence as the nutrient composition of the ingredient itself.

Where the field could go next

We propose a simple progression: restriction → replacement → reconstruction → sustainability → controlled evaluation.

Millets may occupy an interesting place within this pathway, particularly in settings where traditional grains are familiar and accessible. But the broader principle is more important than the ingredient. Dietary care in autism should not be reduced to finding a "special diet." The more constructive goal is to create food environments that are nutritionally adequate, sensory-compatible, culturally meaningful and realistic for families. Our pilot provides one example of how this can be explored; our earlier work provides a nutritional and food-science foundation; and the remaining evidence gap points toward the need for controlled, longer-term studies. The future of dietary support may therefore depend less on what science asks families to remove and more on what it helps them put back on the table.

REFERENCES

- Dahake U. et al., Nutrition and Health, 2026. DOI
- Dahake U. and Deotale S. M., Millets: A Sustainable and Nutritious Crop, Springer Nature, 2026, pp. 65–86. DOI
- Keller A. et al., Nutrients, 2021, 13(2): 470. DOI
- Food and Agriculture Organization of the United Nations (FAO), International Year of Millets 2023: What Are Millets?, 2023.

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> *"A dietary intervention begins with restriction only if it ends with a food repertoire that the child and family can actually sustain."*

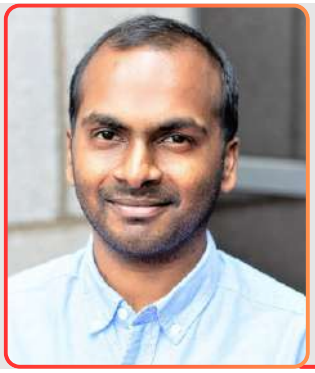
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Dr. Urmila Dahake is an Additional Professor in the Department of Pediatrics at AIIMS Nagpur, specializing in developmental pediatrics. Her research explores the nutritional and practical potential of millet-based dietary approaches for children with autism spectrum disorder, combining pediatric nutritional assessment, food formulation and culturally appropriate dietary strategies. Dr. Sachin Mandavgane is a Professor of Chemical Engineering at VNIT Nagpur, whose work includes the development of innovative food products. This Expert Opinion brings together their findings from a 12-week pilot study on millet-based gluten-free and casein-free (GFCF) diets and their broader research on nutri-cereals. It highlights the importance of nutritional adequacy, sensory preferences, cultural relevance and family feasibility, while emphasizing the need for further rigorous research to evaluate the effectiveness of these dietary approaches.



| EXPERT OPINION | DOI: https://doi.org/10.67831/Sci.Factors.2026.1633

When Light Becomes the Switch: A New Molecular Framework for Precision Cancer Therapy



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Areas of Expertise: Nanobiotechnology | Phototheranostics | Drug Delivery | Metal Organic Frameworks

Cancer develops when cells in our body are dysregulated. For decades, our approach to treat cancer has felt like “fighting a kitchen fire with a flood”. Cancer cells exist within the same complex biological environment as healthy cells, therefore traditional treatments like chemotherapy destroy healthy cells along with deregulated cells. Imagine a future where medicine is traveling through blood stream silently without causing a single side effect and latching only onto tumor cells, until a doctor shines a harmless beam of light on exact site and it activates killing of tumor cells. This is not science fiction; this is an emerging discipline of light responsive nanomedicine.

Nanomedicine is the branch of medicine that uses materials engineered at microscopic scales, a size that is thousand times smaller than human hair, to treat, diagnose and monitor diseases from inside the body. At this microscopic level, scientists can design a material that can act as tiny delivery vehicles and deliver the cargo at precise locations. What is even more amazing is the rise of field of theranostics where these nanomaterials can package diagnosis and therapy into every single unit. This packaging saves the patients from going through grueling cycles of diagnosis and therapy separately. Going one step further, these packages can be tailored to the specific needs of the individual patient, choosing the cargo based on the specific type of cancer and its stage. Finally, when these materials are loaded with desired cargo and injected into the body, they can be activated with precision using different external stimuli like magnetic field, ultrasound, temperature, electric field and light.

Light as a Switch for Cancer Therapy

Among various stimuli, light is particularly attractive as therapeutic trigger because it can be delivered at a defined location and time. The important point, however, is that the light used must be able to reach the target tissue, and the therapeutic response must be generated efficiently without causing unacceptable damage to surrounding tissues. In the electromagnetic spectrum, near-infrared (NIR) wavelengths are particularly well suited for this role. Unlike visible or ultraviolet light, NIR wavelengths (roughly 700–2500 nm) penetrate several centimeters into soft tissue without being strongly absorbed by water or he-

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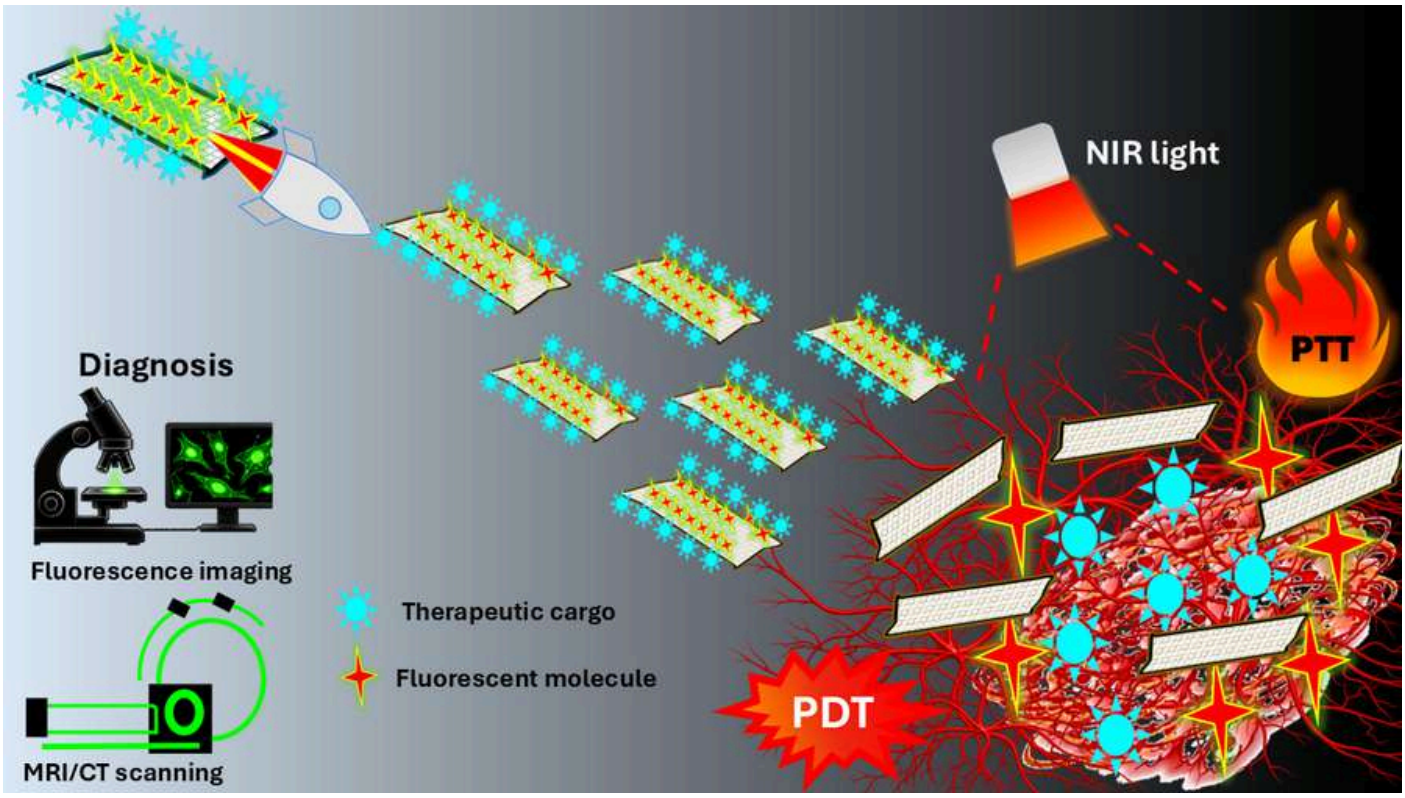


Figure 1: NIR-activated nanomedicine enables localized cancer treatment through photothermal therapy (PTT) and photodynamic therapy (PDT). Multifunctional nanoplatforms can also integrate imaging capabilities for simultaneous visualization and therapy.

moglobin. This "biological transparency window" means NIR light can reach tumors non-invasively while leaving surrounding tissue largely undisturbed and it can be switched on and off with millimeter-scale precision, giving clinicians a level of spatial and temporal control that few other trigger mechanisms offer. The challenge has never really been light; it's been building a material that responds to it usefully.

Most light responsive cancer therapies so far work through in any one of the two mechanisms. Photothermal therapy (PTT) uses light absorbing nanomaterials to convert NIR energy into localized heat, thermally damaging tumor cells. Photodynamic therapy (PDT) instead uses a photosensitizer, a molecule/material that becomes chemically reactive when exposed to light. This photosensitizer, when excited with light, generates reactive oxygen species causing oxidative damage in tumor cells. Each PTT and PDT has real clinical promise and each has real limitation. PTT can under-treat tumor margins where heat dissipates, while PDT depends heavily on tissue oxygenation, which is often poor in the hypoxic core of solid tumors. Combining the two mechanisms therefore offers a compelling possibility: a single light stimulus could generate complementary forms of cellular stress within the same therapeutic platform. The central question then becomes: Can one material be molecularly engineered to perform both functions efficiently, while also incorporating diagnostic capabilities?

Molecular Architecture: Building a Multifunctional Platform

This is where metal-organic frameworks (MOFs) offer a genuinely uncharted and unique design space. MOFs are microscopic sponge like molecular LEGO cages built from metal ions and organic molecules. The most exciting part of MOFs is their modular design and multifunctionality. Just like selecting different LEGO blocks, scientists can mix and match thousands of organic linker molecules and metal ions to build a customized cage. MOFs can be customized for cage size, stimuli, pore size and safety profile. Since they are sponge like porous materials, MOFs have very high surface area. Scientists can pack cancer fighting drugs and diagnostic imaging agents for theranostic purposes. On the other hand, MOFs can also be designed in such a way that PTT, PDT and imaging modality are intrinsic to the MOF making them multifunctional.

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In our recent work, we took this modular concept in an unconventional direction by using tetraniline (TANI) as the organic linker for a nickel-based metal organic framework. TANI is a conjugated oligoaniline linker with no prior precedent as a primary MOF-coordinating ligand. TANI's extended conjugation gives the framework strong, broad NIR absorption, which drives efficient photothermal conversion. At the same time, the assembled framework generates Type I reactive oxygen species under NIR irradiation, providing a photodynamic effect that doesn't depend on the same oxygen-rich conditions PDT normally requires. The nickel centers, meanwhile, offer a route toward imaging functionality, so the framework's therapeutic action and its visibility to imaging techniques come from the same underlying structure rather than requiring separate agents bolted together. The result is a single nanoplatform where photothermal and photodynamic mechanisms operate concurrently rather than sequentially, with a shared trigger, one wavelength of light, one material, multiple modes of action. That multifunctional, combinatorial design, rather than any single mechanism in isolation, is what makes this class of material interesting.

Multifunctionality is not just a buzzword, but its biological rationality is concrete. Tumors are heterogeneous, different regions of the same mass vary widely in oxygenation, vascularization, and cell density. A therapy that only works well under one set of conditions will inevitably underperform somewhere in that tumor. Combining PTT and PDT within one platform means the treatment isn't solely reliant on tissue oxygen availability. The heat generated by the photothermal component can raise the local temperature enough to kill tumor cells, while potentially improving local blood flow and oxygenation. This in turn can make the photodynamic component more effective, a self-reinforcing loop rather than two independent treatments competing for the same light dose. Given the LEGO cage kind of structure MOFs are easier to build as a multifunctional vehicles compared to other nanoparticles.

From the Laboratory to the Clinic

One should be very cautious and none of this should be read as a claim that NIR responsive nanomedicine is close to standard clinical use and this gap is worth being honest about. Most work in this space, including our own, is still at the level of in vitro and early in vivo demonstration. Moving toward clinical relevance requires understanding few more questions about interaction between material and

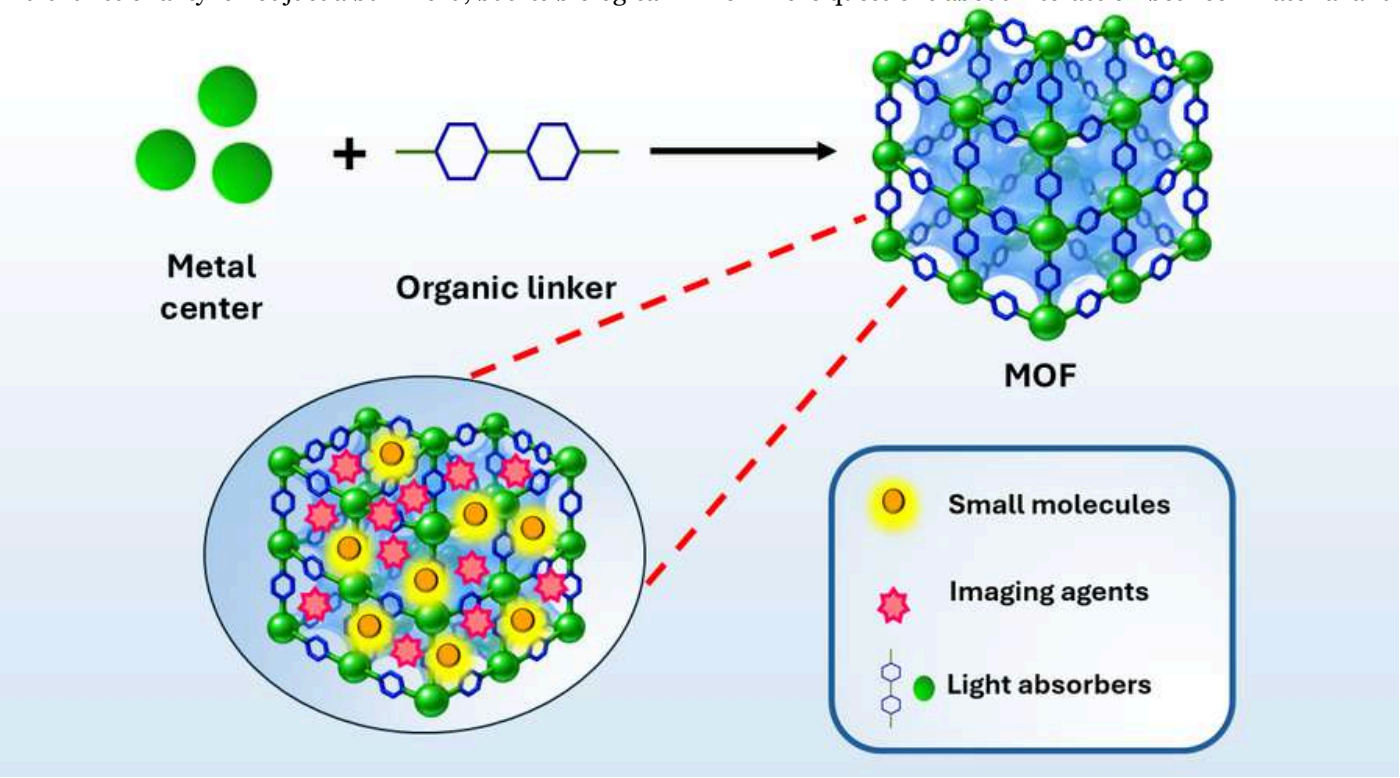


Figure 2: MOFs are assembled from metal centers and organic linkers to form modular, porous architectures. Their flexibility allows therapeutic cargo, imaging agents, and light-responsive components to be incorporated within a single platform

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complex biological environment, how these materials clear from the body, what their long-term biocompatibility is and what their degradation products are. Another important consideration is whether NIR penetration is sufficient for anything beyond superficial or endoscopically accessible tumors. The primary roadblock is that deep-penetrating infrared light lacks the raw energy needed to trigger cancer-killing reactions, forcing researchers to build incredibly complex nanoparticles that are difficult to manufacture and hard for the body to clear safely. However, MOFs offer a promising breakthrough because their unique, customizable "LEGO-like" structure allows scientists to perfectly mix and match materials like packing tiny energy-multiplying "antennas" and protective components into a single cage. While it remains a difficult scientific hurdle, this ultimate adaptability is exactly why researchers believe MOFs could finally bridge the gap between advanced physics and safe, real-world medicine.

Perhaps the broader significance of this work lies not in any single performance metric, but in a shift in the underlying question. Traditional pharmacology asks what molecule can kill the cancer cell. Nanomedicine adds a second question: how can we control where and when that molecule, or that mechanism, becomes active? The MOF platform described here is one illustration of that shift, but the principle it points to is larger than any one material. The aim isn't to build increasingly elaborate nanoparticles simply because they can perform more functions; it's to build toward a future where cancer treatments are precise by design, not by accident. Getting there will take sustained, unglamorous work, on targeting, pharmacokinetics, degradation, and scale-up, across the platforms that carry this principle forward. But the underlying idea, light as a switch and chemistry as the circuit, is one worth continuing to build on.

REFERENCES

- Hiremath, N., Sanyal, P., Jena, A. K., Bhattacharyya, S., Kannan, D. K., Agarwala, P., et al. (2026). Tetraniline-engineered nickel molecular frameworks for combinatorial NIR-triggered photothermal and photodynamic cancer therapy. ACS Applied Materials & Interfaces, 18(32), 43828–43844. DOI
- Vankayala, R., & Hwang, K. C. (2018). Near-infrared-light-activatable nanomaterial-mediated phototheranostic nanomedicines: An emerging paradigm for cancer treatment. Advanced Materials, 30(23), 1706320. DOI
- Li, H., Eddaoudi, M., O'Keeffe, M., & Yaghi, O. M. (1999). Design and synthesis of an exceptionally stable and highly porous metal-organic framework. Nature, 402, 276–279. DOI
- Hiremath, N., Kumar, R., Hwang, K. C., Banerjee, I., Thangudu, S., & Vankayala, R. (2022). Near-infrared light activatable two-dimensional nanomaterials for theranostic applications: A comprehensive review. ACS Applied Nano Materials, 5(2), 1719–1733. DOI

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> *"The challenge has never really been light; it's been building a material that responds to it usefully."*

| EXPERT OPINION | DOI: https://doi.org/10.67831/Sci.Factors.2026.1640

Beyond Better Delivery: When Does Antimicrobial Nanomedicine Earn Its Complexity?



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Areas of Expertise: Antimicrobial Nanomedicine | Antimicrobial Resistance and Biofilms | Natural-Product-Based Antimicrobials



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| Scientific Profile | | Organization Link | | Research Lab Page | | Factors Press |

Areas of Expertise: Plant Biotechnology | Ethnobotany and Medicinal Plants | Sustainable Bioresource Use

For decades, antimicrobial development has often been framed around a deceptively simple question: how can we kill the pathogen? The harder translational question is why an antimicrobial that works under controlled laboratory conditions sometimes fails in the biological environment where treatment actually occurs.

Resistance is only part of the answer. Resistance, tolerance and persistence are biologically distinct, yet all can contribute to treatment failure. Drug exposure may be inadequate at the infection site; biofilms may restrict access; intracellular reservoirs may limit antimicrobial exposure; and toxicity may constrain effective dosing. These problems shift the challenge from simply finding a more potent antimicrobial to overcoming the conditions that prevent an existing antimicrobial from working.

Nanomedicine provides powerful tools for modifying stability, release, localization, exposure and interactions at microbial or host interfaces. Recent work has increasingly linked nanomaterial design to defined infection barriers and disease-relevant outcomes rather than to material classes alone. Yet this progress raises a more fundamental question: when does adding a nanoparticle constitute a therapeutic advance rather than simply a more elaborate formulation?

The starting hypothesis should therefore be the therapeutic failure-not the nanoparticle. A rational antimicrobial nanomedicine should begin by identifying what prevents an otherwise useful antimicrobial from achieving its intended effect. If poor solubility limits exposure, a delivery system may be justified. If rapid degradation reduces effective concentration, controlled release may provide a meaningful function. If a biofilm limits access, improved penetration or barrier disruption may matter. If intracellular localization is the limitation, nanoscale trafficking may offer an advantage that conventional administration cannot readily achieve.

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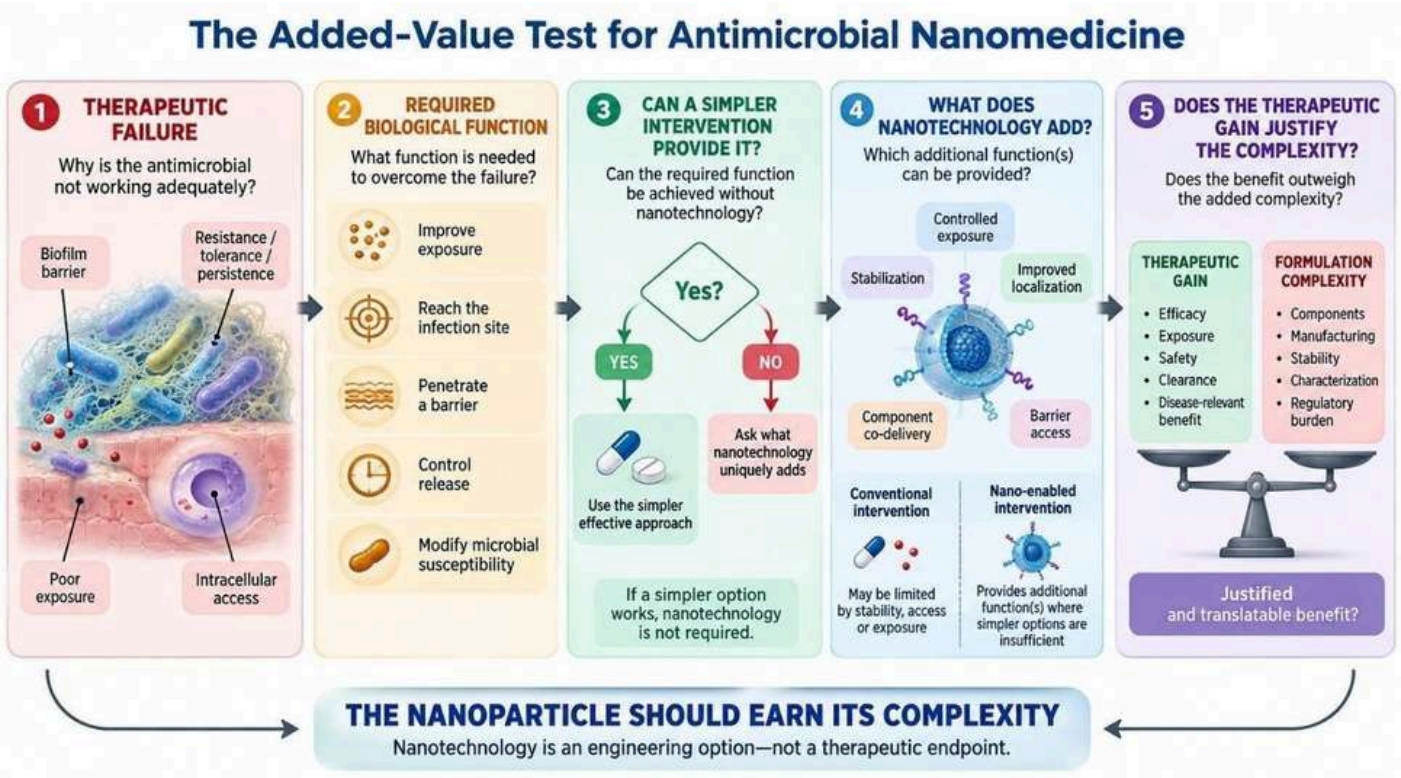


Figure 1: The proposed added-value test for antimicrobial nanomedicine. The framework begins with a defined therapeutic failure and identifies the biological function required to overcome it. Simpler interventions are considered before nanotechnology is introduced. Where nanoengineering provides an additional function, that contribution should be demonstrated and weighed against the complexity required for therapeutic translation.

But one question should come before formulation design: Can the required function be achieved through a simpler intervention? If yes, the nanoformulation should demonstrate an additional benefit. If no, the next question is what nanotechnology uniquely contributes and whether that contribution can be demonstrated. This suggests a simple counterfactual: What therapeutic function disappears when the nanoparticle is removed? This is not a new assay. It is a way of interpreting evidence. A lower minimum inhibitory concentration can demonstrate improved in-vitro activity, but it does not by itself establish therapeutic added value. A stronger case exists when removing the nanomaterial also removes a demonstrated advantage in exposure, localization, barrier access, toxicity, bacterial clearance or another meaningful therapeutic outcome.

Added antibacterial activity is therefore not necessarily added therapeutic value. The relevant comparison is not simply “nano versus no nano”. It is whether the nanoformulation provides a benefit that a simpler intervention cannot provide with comparable effectiveness, safety and feasibility.

Make the added function earn its evidence

The field is increasingly moving toward mechanism-linked and disease-relevant evaluation of antimicrobial nanomedicine. Recent work has connected nanomaterial strategies with biological barriers, quantitative outcomes and translational considerations beyond the in-vitro minimum inhibitory concentration. The important question now is not simply what can nanotechnology do? but what does it add that matters therapeutically?

That added value can be considered at three levels. First, biological value: does the nanomaterial perform a defined function, and has that function actually been demonstrated? Second, therapeutic value: does that function improve an outcome beyond a simplified laboratory measurement? Third, translational value: does the benefit remain meaningful after accounting for stability, safety, reproducibility, manufacturing, dosing and regulatory requirements?

This creates an evidence ladder:

Activity is not mechanism; mechanism is not resensitization; resensitization is not clinical efficacy; and clinical efficacy alone does not guarantee translation.

This distinction is particularly important when discussing resistance modification. A reduction in the antimicrobial concentration required to inhibit a resistant isolate demonstrates altered susceptibility; it does not, by itself, establish reversal of the underlying resistance mechanism.

Our recent work illustrates why this distinction matters. A plant-volatile nanoemulsion altered the susceptibility of benzalkonium-chloride-resistant Pseudomonas aeruginosa to benzalkonium chloride, with evidence of increased membrane permeability, biofilm activity and enhanced performance in an ex-vivo porcine-skin model. Because benzalkonium chloride is a quaternary ammonium biocide rather than a conventional therapeutic antibiotic, these findings should be interpreted as a proof of concept for resistance-modifying antimicrobial design, rather than evidence of clinical antibiotic resensitization. The broader lesson is simple: the formulation should be judged by the function it adds, not merely by the magnitude of the numerical improvement it produces.

Natural products expose the same problem

Natural products provide a useful test case because their chemical complexity can contain multiple biological activities. Membrane perturbation, efflux modulation, biofilm interference and altered cellular permeability may modify antimicrobial susceptibility or improve antimicrobial access. But chemical complexity must become functional definition. The translational question should therefore move from “what does this extract do?” to “which defined function within it changes the therapeutic response, and can that function be reproduced?”

Nanotechnology may help by stabilizing labile constituents, improving dispersion, controlling exposure or bringing complementary components into proximity at a relevant biological interface. But the same test applies: if the free compound or extract already provides the required function with comparable benefit, nanosizing alone does not establish therapeutic necessity.

This distinction matters because natural-product nanomedicine is itself becoming a crowded field. The opportunity is therefore not to add another catalogue of natural-product nanoformulations, but to determine what the nanoarchitecture contributes beyond the natural product itself. Natural origin should likewise never be treated as a surrogate for safety or efficacy. Composition, dose, reproducibility, host exposure and mechanism remain essential.

Make complexity earn its place

Nanomedicine can add functions to antimicrobial therapy, but every added function can also add complexity. A second active component may introduce a new interaction. A targeting ligand may create additional manufacturing and characterization requirements. A sophisticated release mechanism may increase formulation sensitivity. A multifunctional platform may create additional questions around stability, pharmacokinetics, safety and regulatory control.

This leads to a principle of minimum effective complexity: The goal is not the simplest formulation imaginable; it is the least complexity required to deliver a demonstrated therapeutic function.

And this principle has an important corollary: As formulation complexity increases, the evidence should become stronger that each added component delivers meaningful therapeutic value.

A simple nanoformulation that solves a genuine exposure problem may therefore be more compelling than a highly multifunctional platform whose individual contributions cannot be separated.

Translation must also consider evolutionary consequences. Altered antimicrobial exposure can change the selective environment experienced by microbial populations, making dose, duration and exposure profiles relevant to stewardship as well as efficacy.

The objective, therefore, is not to make antimicrobial nanomedicine increasingly complicated. It is to make it increasingly justified. Nanotechnology should be treated as an engineering option, not a therapeutic endpoint. The nanoparticle should not be the starting hypothesis; the therapeutic failure should be. The central question is not simply whether nanotechnology can make an antimicrobial work better, but what it makes possible that simpler therapy cannot-and whether that gain is worth the complexity.

Key Messages

The starting hypothesis should be the therapeutic failure-not the nanoparticle-because formulation design should follow biological need. Added antibacterial activity is not n-

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ecessarily added therapeutic value; the critical question is what function nanotechnology uniquely contributes. As formulation complexity increases, the evidence should become stronger that each added component delivers meaningful therapeutic value.

REFERENCES

- Sun, L., Zhao, Y., Gao, Y., Gao, S., & Wang, L. (2026). Nanomaterial strategies for antibiotic-resistant infections: Mechanistic frameworks, rational design, and clinical translation. Materials Today Bio, 38, Article 103281. DOI
- Nisha, N., Das, P., Ango, K., Mahanta, D., & Kalita, S. (2026). Plant volatile nanoemulsion resensitize Pseudomonas aeruginosa to benzalkonium chloride. Current Microbiology, 83(9), Article 480. DOI

ABOUT THE AUTHORS

Dr. Debajit Mahanta and Dr. Sanjeeb Kalita are pursuing translational biotechnology research to address therapeutic and preventive needs through traditional knowledge-inspired, cost-effective approaches. Their work focuses on medicinal, aromatic, and foam-forming plant resources of Arunachal Pradesh and the translation of innovations into phytopharmaceutical, phytonutraceutical, and antimicrobial solutions. Their expertise spans bioresource-based sustainable development, Indigenous Knowledge Systems, natural products, antimicrobial nanomedicine, nanoparticle drug delivery, antimicrobial resistance, and technologies, transforming resources and traditional knowledge into scientifically validated, scalable, and application-oriented solutions.



| EXPERT OPINION | DOI: https://doi.org/10.67831/Sci.Factors.2026.1647

Beyond Kidney Stones: How Inflammation and Cellular Stress Affect Long-Term Kidney Health



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| Scientific Profile | | Organization Link | | Research Lab Page | | Factors Press |

Areas of Expertise: Molecular | Cellular Biology

Nephrocalcinosis is a pathological condition characterized by the deposition of calcium-containing crystals (calcium oxalate or calcium phosphate crystals or both) or mineral salts within the renal parenchyma, particularly in the renal tubules and interstitium. Unlike nephrolithiasis (Kidney stone), in which crystals aggregate to form discrete stones within the urinary tract, nephrocalcinosis involves diffuse or localized mineral deposition within the kidney tissue itself. Although the two conditions can coexist, they represent distinct pathological processes. However, both may involve calcium crystal deposition, inflammation, oxidative stress, renal cellular injury, and, in recurrent cases, chronic renal damage. Deposition of calcium oxalate (CaOx) crystals forms the bulk of the nephrocalcinosis cases and represents more than a physical consequence of urinary supersaturation or a precursor to nephrolithiasis. Increasing evidence indicates that CaOx crystals are biologically active stimuli, capable of inducing tubular epithelial injury, oxidative stress, innate immune activation, and progressive tissue remodeling. The emerging concept is that crystal deposition initiates a self-amplifying cycle of epithelial damage, inflammation, crystal retention, and fibrosis, providing a mechanistic link between recurrent crystal exposure and chronic renal dysfunction.

The notion that nephrocalcinosis merely represents a physical consequence of urine supersaturation or a precursor to nephrolithiasis has seen a drastic shift. The conventional view of calcium oxalate disease has largely focused on crystal formation, aggregation, adhesion, and urinary obstruction. However, latest evidence suggests that crystal nucleation, growth, aggregation, adhesion, and retention are influenced by urinary inhibitors, epithelial surfaces, tubular transport, and local tissue injury. Additionally, it has become evident now that crystals can directly interact with renal tubular epithelial cells and resident immune cells and that crystal uptake or surface interaction can disrupt cellular membranes, lysosomal integrity, intracellular calcium homeostasis, and mitochondrial function. These events promote the generation of reactive oxygen species (ROS) and release of damage-associated molecular patterns (DAMPs). Generation of ROS and DAMPs activate immune pathways; inflammatory cytokines then further compromise neighboring epithelial cells and potentially increase susceptibility to additional crystal adhesion and retention. Importantly, the capability of CaOx exposure to induce epithelial–mesenchymal transition (EMT) is particularly relevant. Evidence indicates that CaOx exposure can activate TGF-β-associated pathways and promote phenotypic changes consistent with EMT. Although the precise contribution of EMT to human renal fibrosis remains an area of continuing investigation, its association with chronic crystal-induced renal remodeling makes it an important mechanistic pathway to investigate. The role of CaOx crystals in triggering the fibrogenic cascade by upregulating markers such as vimentin, α-SMA, and collagen, ultimately resulting in excessive ECM deposition and tubulointerstitial fibrosis, suggests a pathologically significant damaging effect brought upon by the deposition

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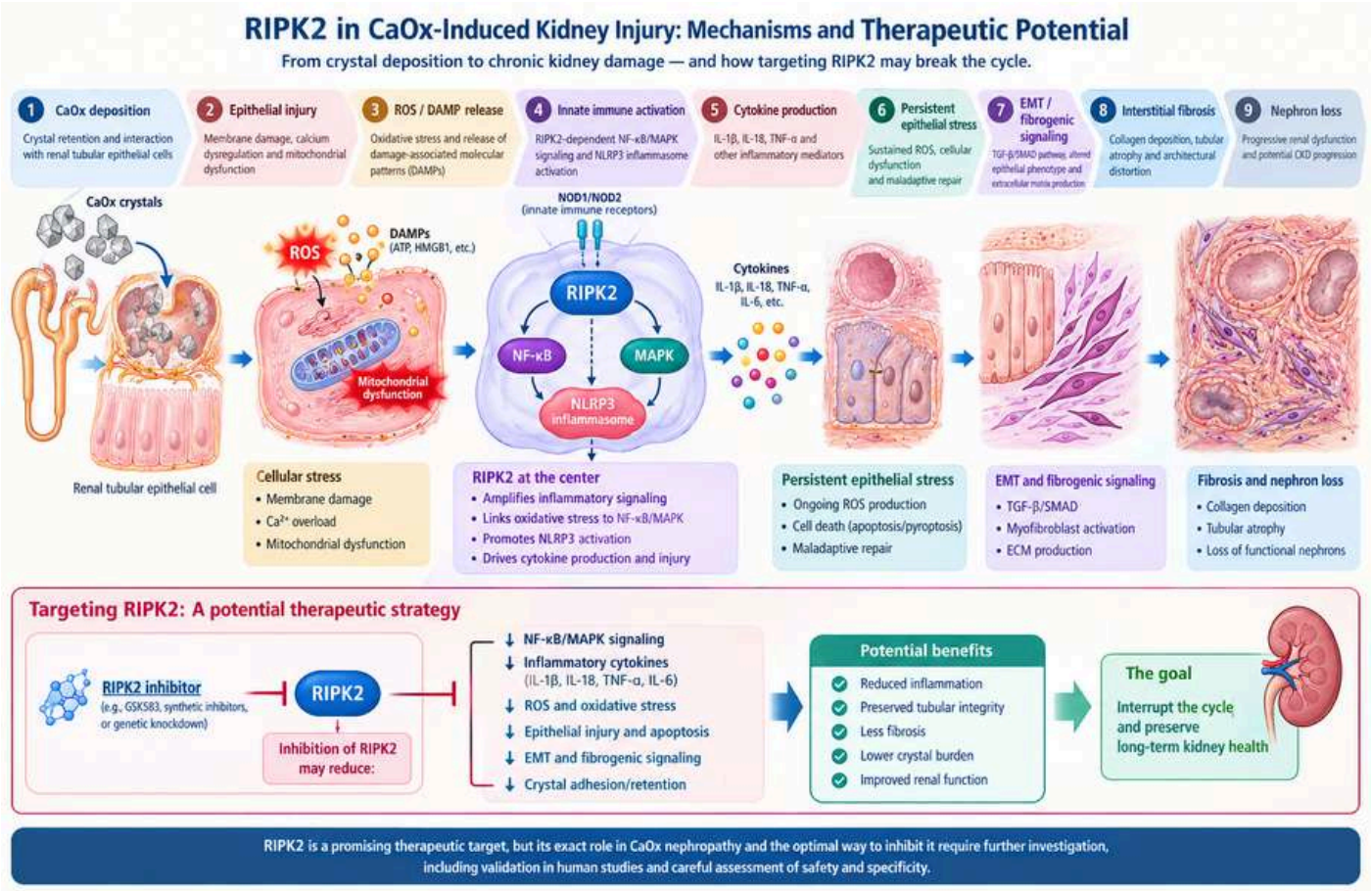


Figure 1: Deposition of CaOx crystals within the renal parenchyma can induce cellular injury, promote the generation of ROS, and trigger the release of DAMPs, thereby activating inflammatory responses. Persistent oxidative stress and inflammation may further initiate fibrogenic signalling, characterised by increased expression of markers such as vimentin, α-SMA, and collagen, ultimately promoting excessive ECM deposition and tubulointerstitial fibrosis. RIPK2 appears to contribute to these pathological processes by regulating inflammatory and profibrotic signalling. Inhibition of RIPK2 has shown potential to attenuate these changes and restore cellular homeostasis in experimental models, highlighting RIPK2 as a promising therapeutic target for preventing or limiting CaOx-induced renal injury and fibrosis. CaOx, calcium oxalate; DAMPs, damage-associated molecular patterns; ECM, extracellular matrix; EMT, epitheial to mesenchyme transition; NOD1/NOD2, nucleotide-binding oligomerization domain-containing protein 1/2; ROS, Reactive oxygen species; RIPK2, receptor-interacting serine/threonine-protein kinase 2; α-SMA, α-smooth muscle actin.

of these crystals.

Our research findings linking CaOx crystal deposition in the kidney with oxidative stress, innate immune activation, mitochondrial dysfunction, and renal fibrosis through RIPK2 kinase signaling are particularly significant. These findings shift the therapeutic paradigm from merely preventing crystal formation toward protecting renal cells from the pathological consequences of crystal deposition. By targeting the molecular pathways that drive crystal-induced inflammation and tissue remodeling, this approach may open new avenues for preventing the progression of nephrocalcinosis and recurrent crystal-induced renal injury to chronic kidney disease.

In addition, our research group has identified Nesfatin-1 as a promising potential therapeutic agent that has demonstrated protective effects against CaOx-induced renal cellular injury. Its beneficial effects in experimental models suggest that Nesfatin-1 may help counteract crystal-induced cellular stress and preserve renal epithelial integrity. Together, these findings highlight two complementary therapeutic strategies: targeting RIPK2-mediated inflammatory signaling to interrupt the mechanisms underlying renal injury, and exploring Nesfatin-1-mediated cytoprotection to promote cellular resilience and recovery. Further mechanistic investigations and in vivo validation will be essential to establish their therapeutic potential and translational relevance in preventing long-term renal damage.

Despite major advances in understanding the underlying

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causes and consequences of calcium and other mineral depositions in the kidney, several important challenges remain. The central challenge is to move beyond preventing or removing crystals and develop therapeutic strategies that protect renal tissue and prevent chronic damage. Although current clinical interventions can remove stones and reduce their recurrence, they do not necessarily prevent ongoing renal epithelial injury or fibrosis, particularly when crystals accumulate intracellularly. Emerging evidence suggests that crystal-induced renal injury involves a complex network of interconnected signalling pathways. However, the interplay among reactive oxygen species (ROS), mitochondrial dysfunction, NF-κB and MAPK signalling, NLRP3 inflammasome activation, and pro-inflammatory cytokine release remains incompletely understood. Although inflammatory signalling represents a promising therapeutic target, its inhibition must be approached cautiously, as these pathways also contribute to normal host defence, tissue repair, and physiological homeostasis.

Another major challenge is to identify the factors that determine whether crystal deposition results in transient epithelial injury or progresses to persistent inflammation, impaired tissue repair, fibrosis, nephron loss, and chronic kidney disease (CKD). The observation that not all patients with nephrolithiasis or nephrocalcinosis develop progressive renal dysfunction suggests that additional determinants, including genetic susceptibility, metabolic differences, and variations in inflammatory and cytoprotective responses, may influence disease progression. Longitudinal studies and diverse, multicentre cohorts are therefore essential to identify high-risk populations and clarify the contributions of age, geographical variation, dietary factors, inherited disorders, and access to healthcare.

Our investigations of RIPK2 and Nesfatin-1 provide a potential framework for developing targeted therapeutic strategies. The key challenge now is to establish whether modulating RIPK2-associated inflammatory signalling and enhancing endogenous cytoprotective mechanisms can preserve renal structure and function despite crystal exposure. Elucidating the underlying causal mechanisms, demonstrating reproducible protection in relevant in vivo models, and validating these findings in human tissues and clinical cohorts will be crucial steps towards translating these approaches into effective disease-modifying therapies.

The field of nephrolithiasis and nephrocalcinosis research is transitioning from a predominantly physicochemical view of mineral deposition towards a more integrated understanding of crystal-induced cellular injury, inflammation, and tissue remodelling. Current clinical approaches are effective in removing stones and reducing recurrence in many patients, but strategies that directly prevent or reverse crystal-induced epithelial injury and renal fibrosis remain limited. Emerging evidence implicates oxidative stress, mitochondrial dysfunction, innate immune activation, and interconnected inflammatory signalling pathways as important contributors to disease progression. However, their causal relationships, relative contributions, and therapeutic relevance require further investigation. In this context, RIPK2-mediated inflammatory signalling and endogenous cytoprotective mechanisms involving Nesfatin-1 represent promising avenues for exploration, rather than established therapeutic solutions. The next major advance will depend on integrating mechanistic studies with robust preclinical validation, genetic and clinical investigations, and longitudinal assessment of renal outcomes. Ultimately, the field must move beyond understanding how crystals form towards determining how crystal-induced tissue damage can be prevented, limited, or reversed to preserve long-term kidney health.

REFERENCES

- Lahane G. P. et al., Biochemical Pharmacology, 2026, 254: 118398. DOI
- Lahane G. P. et al., Biochemical Pharmacology, 2026, 249: 117894. DOI
- Lahane G. P. et al., Life Sciences, 2026, 402: 124544.
- Prochaska M. L. and Zisman A. L., Advances in Kidney Disease and Health, 2024, 31(6): 529–537. DOI

ABOUT THE AUTHORS

Dr. Audesh Bhat is a biomedical researcher whose work focuses on kidney diseases, cancer biology, inflammation and cellular signalling. In collaboration with Prof. Arti Dhar of BITS Pilani, Hyderabad Campus, his team has identified RIPK2 as a key protein involved in kidney cell damage caused by calcium oxalate crystals, a major component of kidney stones. Their research also revealed the protective role of Nesfatin-1, a naturally occurring peptide that helps reduce kidney inflammation, oxidative stress and tissue damage. These findings highlight promising approaches for developing future treatments for kidney stone-related complications. His broader research aims to translate molecular discoveries into therapeutic strategies for improving human health.

| EXPERT OPINION | DOI: https://doi.org/10.67831/Sci.Factors.2026.1651

India's Biomedical Research Funding: Progress, Priorities, and Gaps



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Areas of Expertise: Pathology | Medical Devices | Oral Cancer Research Artificial Intelligence in Health | Research Funding and Policy Analysis



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Areas of Expertise: Oral medicine | Oral radiology | Cancer | CBCT

Every year, thousands of Indian researchers ask the Indian Council of Medical Research (ICMR), the country's apex body for biomedical research, to back an idea: a low-cost diagnostic, a fresh approach to drug-resistant tuberculosis, a sensor that could work in a village clinic. Only a fraction are funded. The approved lists are public, yet they are rarely read as a whole. Read together, they show how a nation decides which health problems to tackle, who gets to tackle them, and where the answers are likely to come from.

Funding debates usually focus on total budgets. Who receives the support, and for what, matters just as much. We therefore analysed all 1,766 projects approved under ICMR's Small and Intermediate Grant schemes between 2023 and 2025, recording each project's institution, its type and location, and its research theme.

Progress: medicine and engineering are converging

The clearest trend is a change in who is doing health research. In 2023, about 35% of approved projects came from non-medical institutions such as the IITs, the Indian Institute of Science, NITs, CSIR laboratories, and universities. By 2025 that share had risen to 42%. Engineering institutes were the largest group among them, accounting for nearly half of all non-medical projects, with work on medical devices, biosensors, microfluidics, robotics, and AI-based diagnostics. IIT Delhi and IIT Madras, for example, frequently appear as recipients for projects on microfluidics, biosensors, and AI diagnostic tools. The rise peaked in 2025, possibly because the latest call for proposals stressed indigenous device development and digital health.

Small Grants, meant for early-stage and high-risk ideas, appear to be doing what they were designed to do. They let engineers build prototypes that clinicians can then test with patients. This matters for a country that imports much of its medical technology. A device designed in India, for Indian conditions and budgets, is far more likely to reach the patients who need it.

There is also a sign of a working pipeline. Investigators who deliver on a Small Grant are often funded again, under an Intermediate Grant, to scale up their findings. And the split

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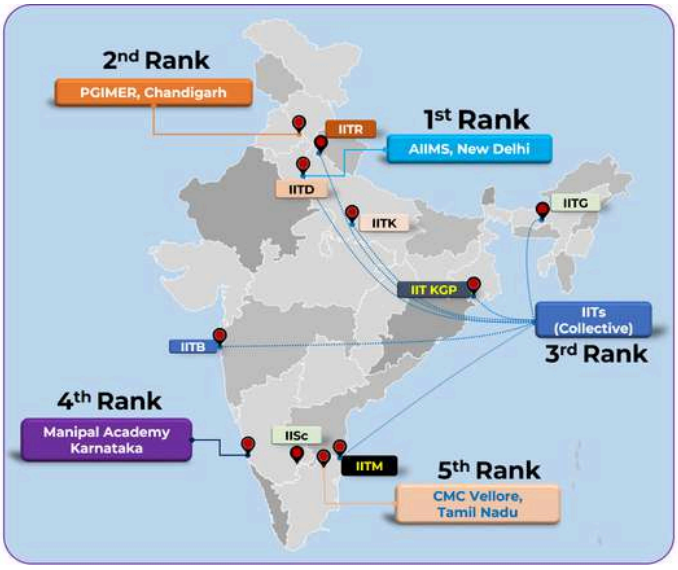


Figure 1:Leading grant-receiving institutes of ICMR (2023-2025) on the map of India, ranked by number of approved Small and Intermediate Grant projects: AIIMS New Delhi, PGIMER Chandigarh, the IITs (collectively), Manipal Academy of Higher Education, and CMC Vellore.

between government institutions (about 69% of projects) and private or trust-run institutions (about 31%) barely moved across the three years, which hints at a settled, deliberate approach to allocation. Private centres such as CMC Vellore are clearly part of the national research effort.

Priorities: the burden of disease shapes the portfolio

Funding largely follows the country's health needs. Infectious diseases (18%), non-communicable diseases such as diabetes and stroke (16%), and cancer (16%) together account for just over half of all projects. India carries all three burdens at once, and the portfolio reflects it. Tuberculosis is the single most funded disease, with projects ranging from drug resistance to host-directed therapies. Maternal and child health (9%) and mental health (6%) also appear as distinct themes (Figure 2).

Technology-focused work is growing alongside them. Bio-engineering and AI or digital health together make up about one in five projects, a large share for fields that barely featured in health research funding a decade ago.

Gaps: concentration, geography, and the missing middle

The same lists show where the system is uneven. The top seven institutions received roughly 35% of all approved projects, led by AIIMS New Delhi (about 13%) and PGIMER Chandigarh (about 6%). Concentrating resources where capacity exists is understandable, but funding follows track record and track record follows funding, so institutions that start ahead tend to stay ahead. Figure 1 maps the leading recipients, from AIIMS New Delhi and PGIMER Chandigarh in the north to the IITs spread across the country and CMC Vellore in the south.

Geography tells a similar story. Northern India received 38% of projects and Southern India 32%. Western India received about 15%, Eastern India under 10%, and Central and North-East India together only 5%. Delhi and the National Capital Region alone accounted for nearly a fifth of the total. Meanwhile, state medical colleges and state universities, which see large patient numbers and could ask locally relevant questions, appear far less often in the funded lists. There are encouraging signs at the margins, with AIIMS Bhopal, AIIMS Guwahati, IIT Guwahati, and the research hubs of Kolkata and Bhubaneswar all showing up in the lists, but the volume there remains small. A small group of investigators also won more than one award in a single year. That may reflect proven expertise, but it raises a fair question about how widely opportunity is spread. The concern is practical as well as fair. Disease burden is not concentrated in the same places as research infrastructure, and the questions that matter most to a patient in a district hospital are best asked by people who work alongside that patient.

Reading the Numbers with Care

Our contribution is to make these patterns visible. We counted approved projects, not rupees, so our figures show how projects are distributed rather than how much money each group received. We also had no data on unsuccessful applications, so we cannot say who applies and fails. Themes were assigned from project titles, which is an approximation. Even so, three years of consistent patterns are hard to dismiss. They describe a system that is modernising quickly and that still leans on a small number of well-established centres, and that is the starting point for any serious conversation about where the next rupee should go.

The Way Forward: Widening Research Opportunities

India's biomedical research funding is moving in a healthy direction. It is more technological, more collaborative across disciplines, and broadly matched to the country's disease burden. The next challenge is reach. First, we should invest in research capacity, not only projects, through mentoring, proposal-writing support, and shared

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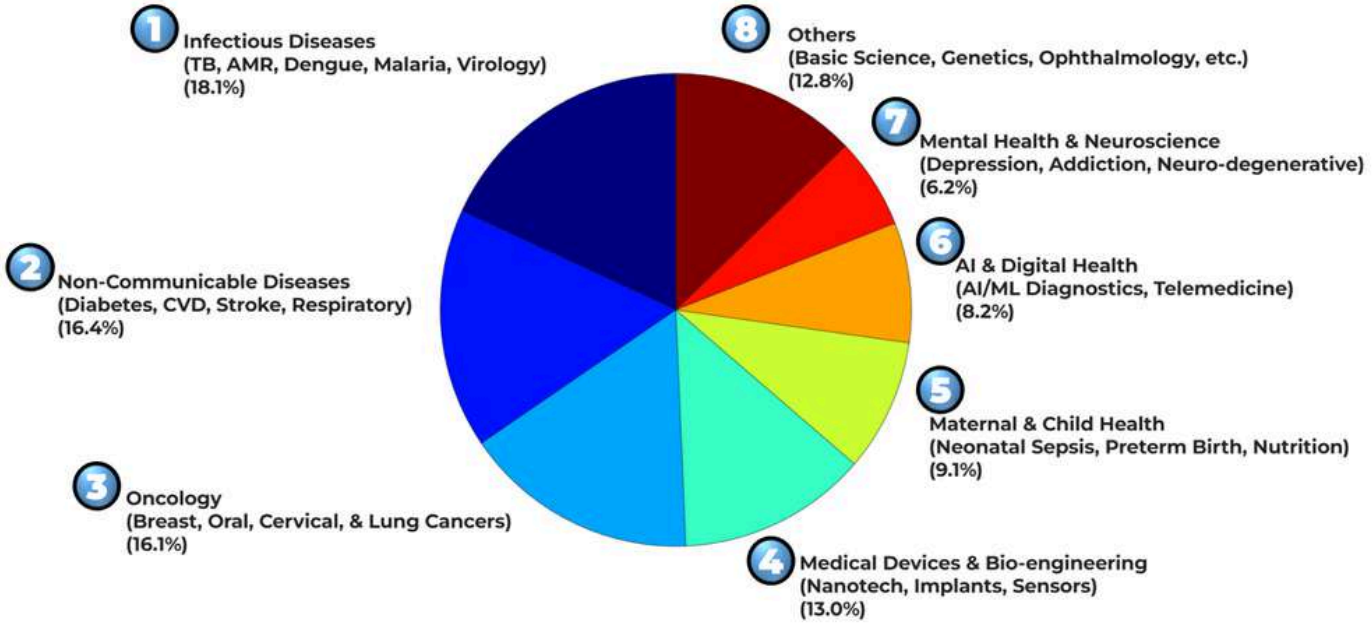


Figure 2: Share of the 1,766 approved projects by priority area, 2023-2025. Infectious diseases (18.1%), non-communicable diseases (16.4%), and oncology (16.1%) together account for just over half; medical devices and bio-engineering (13.0%) and AI and digital health (8.2%) reflect the growing med-tech convergence.

laboratories for colleges that rarely appear in the lists. Second, we should pair strong and emerging institutions so that local clinical questions shape technology-driven work. Third, funders should publish applicant numbers, success rates, and amounts by institution type and region. Finally, we should follow projects through to their outcomes, since counting grants does not tell us whether they produced better care.

A research system is strongest when good ideas can come from anywhere, whether an IIT laboratory in Delhi or a district hospital in Odisha. Funding the best of what already exists is necessary. Building the capacity that lets more people compete will make the system fairer and more productive.

ABOUT THE AUTHORS

Dr. Varun Surya and Dr. Priyanka Verma conduct research on oral health and biomedical science. Dr. Surya is affiliated with the All India Institute of Medical Sciences (AIIMS), with research interests in oral cancer, artificial intelligence and data science. Dr. Verma holds an MDS in Oral Medicine and Radiology, with interests in oral diseases and diagnostic imaging. Together, they have examined the distribution of ICMR research grants to better understand the priorities and gaps in India's biomedical research funding.

REFERENCES

- Verma, P., Kumar, A., Mishra, D., & Surya, V. (2026). Patterns in biomedical research funding in India: An analysis of ICMR small and intermediate grants (2023–2025). Indian Journal of Medical Research, 164(3), 482–488. DOI
- Tandon, N., & Yadav, S. S. (2017). Contributions of Indian Council of Medical Research (ICMR) in the area of medicinal plants/traditional medicine. Journal of Ethnopharmacology, 197, 39–45. DOI

> *When funding follows track record, and track record follows funding, the best-resourced institutions stay ahead while good ideas elsewhere go unheard.*

| EXPERT OPINION | DOI: https://doi.org/10.67831/Sci.Factors.2026.1656

Biomolecular Condensates: A New Frontier in Cell Biology and Materials Science



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| Scientific Profile | | Organization Link | | Research Lab Page | | Factors Press |

Areas of expertise: Biomimetics | Life-like materials | Nanotechnology | Healthcare

Creating synthetic life from scratch is a long-standing scientific goal that could help understanding origins of life and also advance drug discovery, bioremediation, and materials science. A key feature of living systems is Compartmentalization, which allows biochemical reactions to occur in organized and controlled environments. In cells, compartments can be membrane-bound organelles or membrane-less organelles, which form through a process called liquid–liquid phase separation (LLPS). These biomolecular condensates help organize cellular reactions and regulate processes such as information storage and signaling. Many condensates also contain multiple internal phases, allowing different biological activities to occur in different parts of the same compartment. Understanding how these dynamic structures form and function can provide important principles for designing synthetic cells and artificial biological systems.

The important roles of intracellular condensates have inspired the development of synthetic condensates that mimic key features of cellular compartments. Their composition, size, structure, viscosity, and fluidity can be controlled by adjusting molecular interactions, while responsive components can enable them to form, change or dissolve in response to environmental signals. These properties make synthetic condensates useful for studying biological phase separation and developing dynamic, life-like systems. They can selectively concentrate molecules and act as small reaction compartments, potentially improving chemical reactions. Their ability to respond to biological, chemical, and physical signals also creates opportunities in biotechnology, biomedicine, and materials science, while providing simplified models for understanding cellular organization and early life.

In our recent work published in Advanced Materials (Adv. Mater. 2026, 38, e73940), we designed short peptides inspired by a minimal sticker-and-spacer model that best represents the intrinsically disordered proteins and regions (IDPs/IDRs) which form biomolecular condensates in living cells. These peptides formed synthetic condensates that mimic key features of cellular condensates, including spatial organization and structural compartmentalization. This study demonstrated how minimal peptide sequences can encode emergent organizational principles characteristic of biomolecular condensates.

Life-Like Behaviors

Similar to intracellular liquid–liquid phase separation (LLPS), the designed peptides underwent self-association through multiple weak, non-covalent interactions, including π–π stacking, hydrophobic interactions, cation–π interactions, and hydrogen bonding. When the peptide concentration reached a critical threshold, these cumulative interactions promoted phase separation of the initially homogeneous solution into two distinct phases: a highly concentrated condensed phase and a surrounding dilute phase. This process resulted in the formation of macroscopically observable coacervate-based liquid droplets. Initially, a large number of small condensates, approximately 300 nm in size, were formed. Over time, these droplets underwent coalescence, resulting in the formation of larger condensates, similar to the fusion, mimicking the chemically transduced process found in cell. Subtle modifications to the peptide molecular design could

modulate the interactions and alter the size, morphology, dynamics, and material properties of the resulting condensates.

Multiphasic structure of Synthetic Biomolecular Condensates

Many cellular organelles, such as nucleoli and stress granules, are multiphasic containing distinct regions within a single compartment. Most synthetic multiphasic coacervates are constructed from multiple building blocks, such as proteins, polymers, and nucleic acids, often relying on strong ionic interactions. In contrast, we demonstrated that complex multiphasic condensates can be formed using a single peptide building block. By tuning interactions within the peptide's sticker and spacer regions, we were able to control the condensate architecture from homogeneous to core–shell and multiphase structures. Single-crystal structural analysis provided insights into the molecular interactions responsible for forming these distinct regions. In core–shell structures, stronger peptide–peptide interactions could promote an ordered, solid-like core, while weaker interactions and greater peptide–water interactions could support a more disordered shell. By controlling the number and strength of interactions between sticker and spacer regions, the number and arrangement of phases could be tuned. This approach therefore provides a simple strategy for controlling the structure and spatial organization of synthetic condensates. Such precise spatial organization could help compartmentalize biomolecules, regulate biochemical reactions, and enable the design of complex reaction networks for biotechnology.

Dynamic Control

Biomolecular condensates can dynamically assemble and disassemble in response to environmental changes and biochemical signals, allowing cells to regulate their functions. Inspired by this behavior, we developed redox-responsive peptide condensates that reversibly formed and dissolved in response to changes in the oxidation state. The designed peptides contained a disulfide linker that enabled redox-controlled phase separation. Treatment with tris(2-carboxyethyl)phosphine (TCEP) reduced the disulfide bonds, disrupting peptide interactions and dissolving the condensates. Conversely, potassium ferricyanide ($K_3Fe(CN)_6$) promoted disulfide-bond formation, restoring the condensates. This process could be repeated over multiple cycles, demonstrating reversible and dynamic control of condensate formation. Such redox -responsive coacervates provide a simple model for studying how redox processes regulate biomolecular organization in cells and offer opportunities for developing adaptive materials and biotechnology applications.

Artificial Condensates as Catalytic Microreactors

Inspired by the nature's principle, synthetic coacervates can be designed as catalytic compartments that mimic the functional features of biological systems. We investigated whether our peptide condensates could selectively sequester molecules with different chemical properties. We found that the condensates efficiently encapsulated positively charged, hydrophobic, and negatively charged guest molecules which were likely concentrated through π–π, hydrophobic, and charge-dependent interactions with the peptides. The ability to concentrate diverse molecules within the condensates suggested their potential as microreactors. To test this, we used the non-enzymatic hydrazone formation reaction between an aldehyde and a hydrazine. The reaction proceeded significantly faster in the presence of the peptide condensates, demonstrating their ability to create a favorable microenvironment for chemical reactions. These results highlight the potential of peptide-based condensates as biocompatible and environmentally friendly catalytic microreactors.

Solidification of Peptide Condensates and Biomineralization

Conventional LLPS in bulk often produces droplets that rapidly fuse and coalesce, making long-term stabilization challenging. Designing condensates that resist coalescence is therefore important for maintaining small, distinct droplets with functional properties over extended periods. We found that our peptide condensates remained stable in solution for extended periods and can solidify upon solvent evaporation, forming stable peptide microparticles. These particles could encapsulate and protect molecular cargo during drying, providing a simple strategy for molecular storage and protection, similar to the protective strategies of biological condensates during desiccation. Furthermore, the solidified peptide particles could function as artificial bioreactors and support biomineralization, enabling the formation of metal–peptide hybrid materials. Such materials have potential applications in catalysis, environmental remediation, biomedicine, and other industrial fields.

Challenges Towards Synthetic Biomolecular Condensates

Despite significant progress in designing synthetic biomol-

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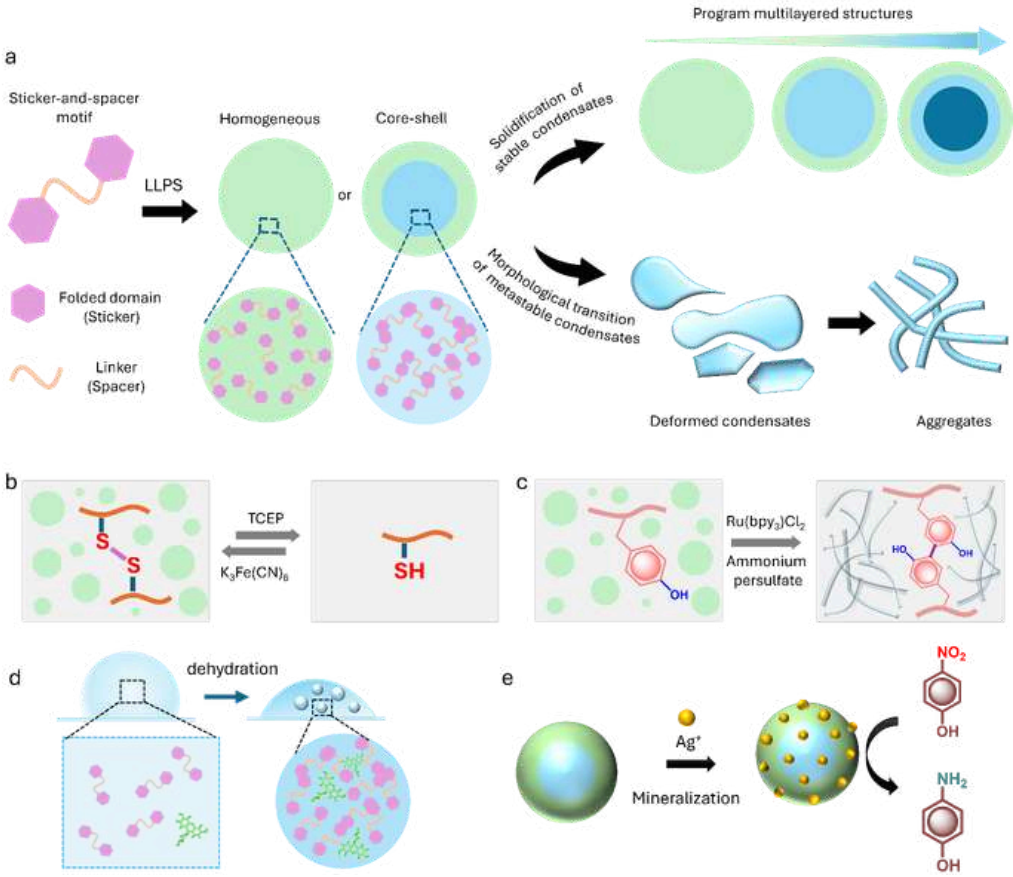


Figure 1: a) LLPS-driven peptide droplets forming programmable multilayered condensates (top) or undergoing coalescence to form aggregates (bottom) via peptide composition. b) Dynamic formation and dissolution of peptide condensates through redox regulation. c) Transformation of condensates into fibrillar aggregates via post-synthetic modification. D) Encapsulation of pay loads inside synthetic condensates. e) Biomineralized metal-peptide nanohybrids.

ecular condensates with life-like properties, several major challenges remain. Synthetic condensates can be unstable and may merge easily, while their complex compositions can make them difficult to control and reproduce. Key properties such as stability, composition, selective permeability, functionality, scalability, and reproducibility have not been properly established yet. Moreover, the structure-dynamics-functions relationship remain unclear for these designed biomolecular condensates. Understanding these phenomena will be essential for developing reliable biomimetic systems and exploring their potential applications in artificial cells and advanced materials.

Future perspective

Synthetic condensates share several important features with biological condensates found inside cells. Their dynamic nature, ability to create cell-like compartments, and tunable properties make them useful for studying molecular interactions and biological processes in controlled artificial environments.

These droplets can also act as versatile carriers for a wide range of molecules, including drugs, proteins, enzymes, RNA, catalysts, and nanoparticles that could enable new approaches for targeted and combination delivery. Furthermore, coacervates can reversibly form and respond to changes in different stimuli like pH, temperature, or biological signals. By controlling these properties through molecular design, synthetic coacervates can be developed as adaptable platforms for applications in biotechnology, biomedicine, artificial cells, and advanced functional materials.

ABOUT THE AUTHORS

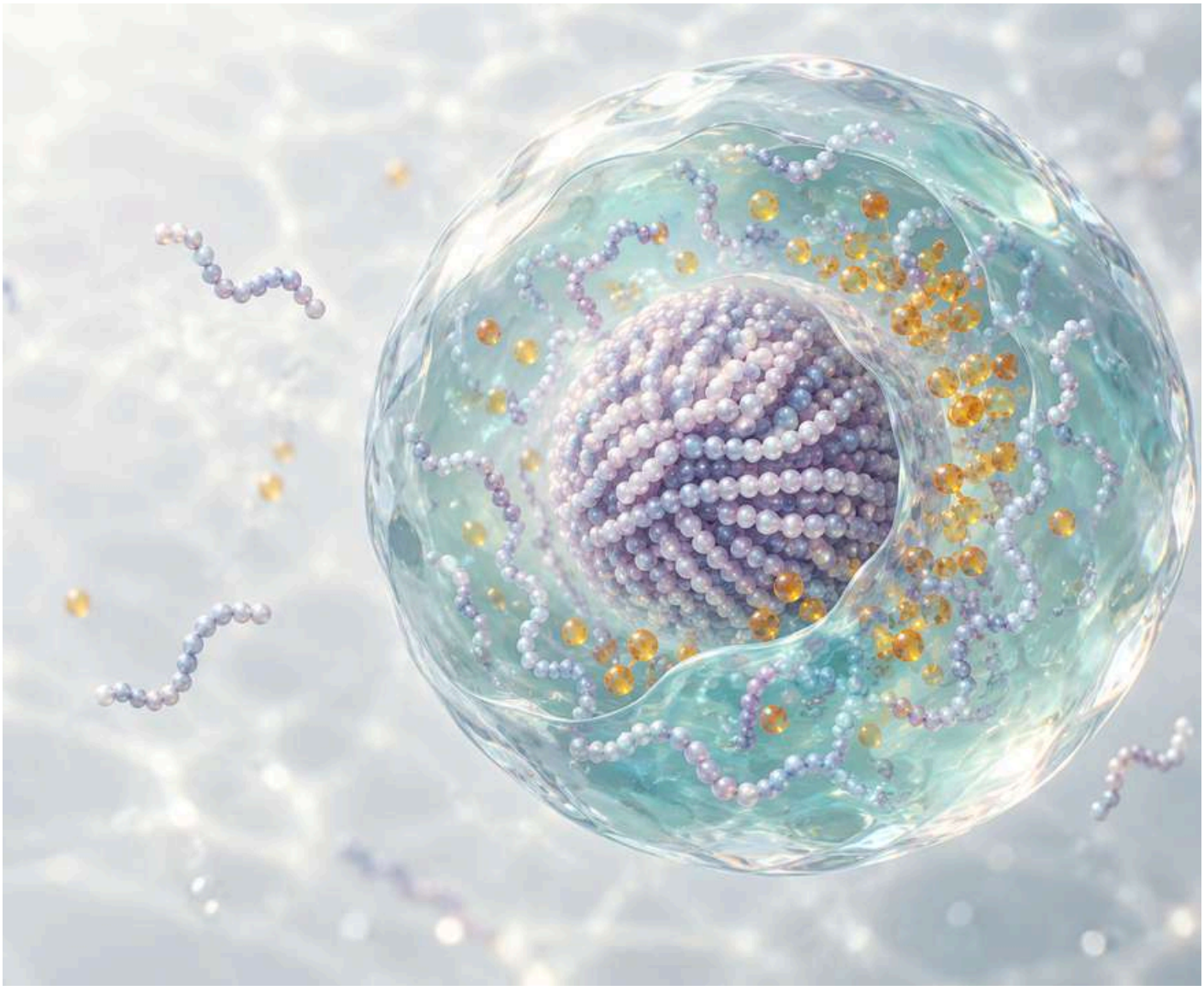
Dr. Santu Bera and his group at Kalinga Institute of Industrial Technology (KIIT) Deemed to be University, Bhubaneswar and Ashoka University, Haryana investigate natural principles to develop biomimetic systems with potential applications in technology and biomedicine. The group's recent research focuses on designing phase-separation-driven synthetic biomolecular condensates as models for protocell-like systems.

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REFERENCES

- Siyu Song, Tsvetomir Ivanov, Thao. P. Doan-Nguyen, Lucas Caire da Silva, Jing Xie, Katharina Landfester and Shoupeng Cao, Synthetic Biomolecular Condensates: Phase-Separation Control, Cytomimetic Modelling and Emerging Biomedical Potential, Angew. Chem. 2025, 137, e202418431/ DOI
- Rohit Kumar, Sukantha Dey, Priyanshu Rajput, Snigdha Singh and Santu Bera, Programmable Multiphasic Condensates Formed via Evaporation-Induced Phase Separation of Minimal Peptide Model, Adv. Mater. 2026, 38:e73940 / DOI
- Manzar Abbas, Wojciech P. Lipiński, Karina K. Nakashima, Wilhelm T. S. Huck and Evan Spruijt. A short peptide synthon for liquid–liquid phase Separation. Nat. Chem. 2021, 13 , 1046–1054/ DOI

> *The engineered artificial condensates exhibited promising potential for diverse applications, including molecular delivery, biocatalytic microreactors, and biomineralization.*



| EXPERT OPINION | DOI: https://doi.org/10.67831/Sci.Factors.2026.1660

Safer Workplaces, Stronger Industries: Rethinking Occupational Health in India's Small Steel Enterprises



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Areas of Expertise: Occupational health and safety | Industrial hazards | Worker welfare | Workplace risk assessment | SME environments



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Areas of Expertise: Occupational health and safety | Industrial hazards | Worker welfare | Workplace risk assessment | SME environments

Small and medium enterprises (SMEs) are one of the most dynamic building blocks of India's economy and built environment. They are pertinent to create jobs, empower local economies, sustain industrial supply chains, and help give millions of families to procure jobs and livelihoods. However, production or output or industrial contribution to economy cannot solely determine the performance of Industrial sector. It is strengthened by measuring the health and safety of the people who are the main operators the machines, weld steel, handle hot metal, cut parts, paint the surfaces, and work for long shifts. This is particularly crucial in iron and steel manufacturing. The steel fabrication or manufacturing involves exposure to high temperatures, large machinery, sharp materials, electrical systems, welding activities, metal dust, fumes, noise, and strenuous labor. Each hazard can be reduced with engineering controls, personal protective equipment (PPE), health surveillance, and safety training. But in the absence of more than one control measure, a regular working day can lead to a real occupational health hazard. Our research therefore asked a broader question that whether workplace accidents occur: what does the complete occupational environment of workers in SMEs presents considering physical hazards, mechanical risks and psychological well-being all together? This integrated approach was significant because evidence on occupational health in smaller industries, a relatively more informal sector in India, is rare compared to the available evidence for large organized industries.

Bhiwadi as a window into the SME workplace hazards

The study was carried out in the Khuskhera industrial area of Bhiwadi in state of Rajasthan. Bhiwadi is a fundamental and fast-growing industrial cluster. The production environment provides valuable contextual insights into the nature and extent of occupational risks. Scrap metal may be remelted in electric furnaces followed by casting the molted metal into desired or required shapes. The cast components may undergo cutting, welding, grinding, polis-

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hing and painting. Organic solvents may be employed during painting processes, while integrated operations, such as painting, welding and furnace operations, may simultaneously generate heat, noise, fumes, and particulate matter. These all processes contribute to the overall occupational exposure profile. One worker could be exposed to excessive noise, inadequate lighting, heat, inadequate ventilation, metal dust, exposed machinery, electrical hazards, and long work hours during the same workday. Under these circumstances, occupational health cannot be viewed as discrete hazards in isolation.

Looking beyond accidents

A cross-sectional exploratory mixed-methods design was used to explore occupational health, safety, and welfare conditions. Steel-sector SMEs were randomly selected from 45 registered industries in the Khuskhera area, from which 10 were chosen. Five workers from each enterprise were selected, for a total of 50 workers from different occupational groups, including machine operators, welders, supervisors, and foremen. The study also evaluated one major industrial facility in the same area to serve as a background reference. Data collection involved a walk-through audit, a structured questionnaire, and group interviews. Where operational conditions allowed, the study assessed environmental conditions by measuring noise, illumination, temperature, and humidity. Existing international questionnaires did not adequately address some Indian SME employment practices, language, and the physical, mechanical, and psychological aspects of risk; therefore, the study developed a context-specific instrument that was translated and back-translated, piloted, and validated for reliability through expert review. This is important because occupational health cannot be understood simply by counting injuries. Knowledge of hazards, protective equipment, rest, medical support, and psychological distress is a part of the same occupational health system.

A young, mobile, and economically vulnerable workforce

The workforce was very young. Fifty-two per cent of the 50 workers were aged 20-25 years, and another 32% were be-

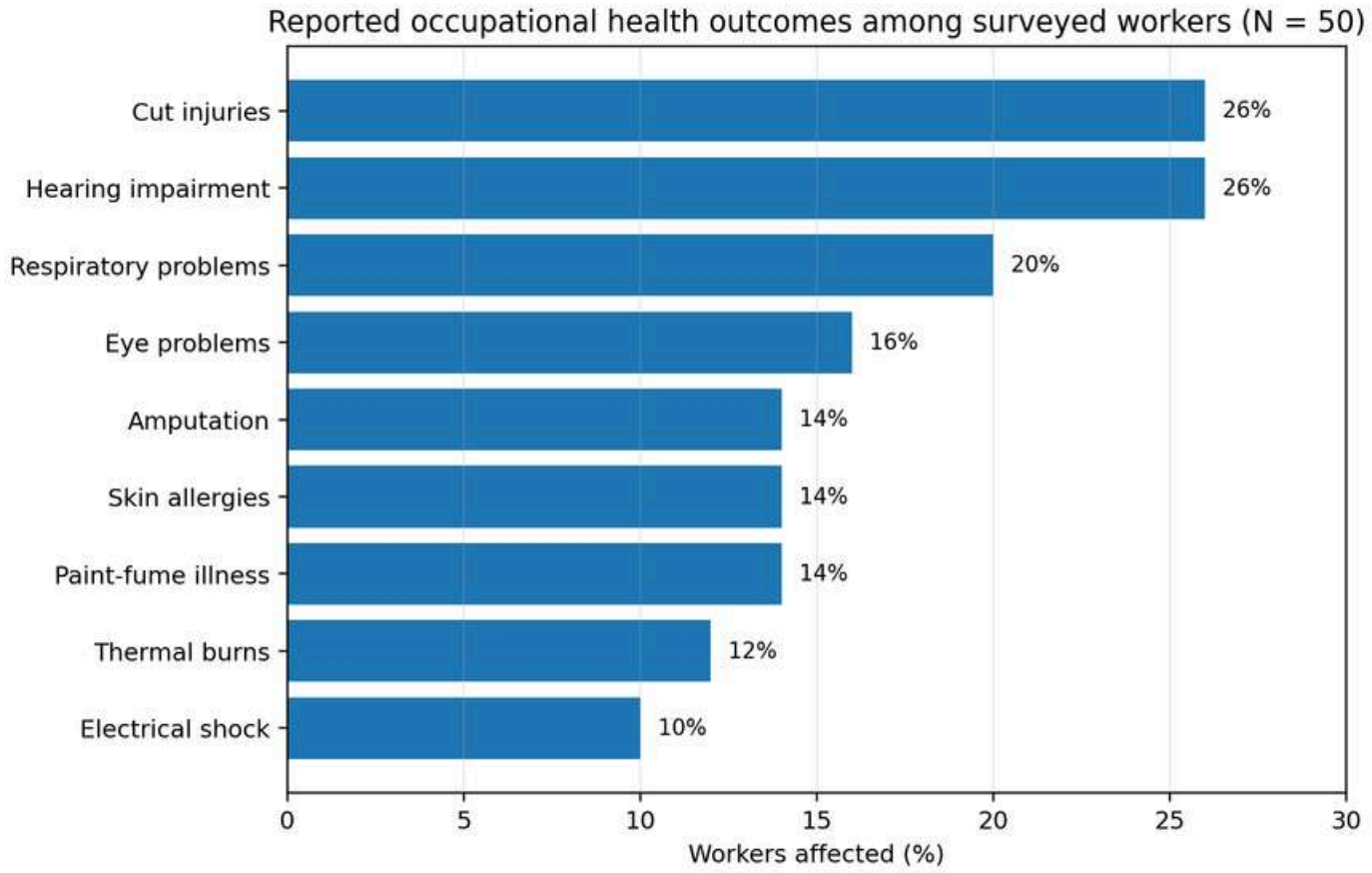


Figure 1: Reported occupational health outcomes among surveyed workers in the Bhiwadi SME steel-industry study. Categories are not mutually exclusive.

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low 20; none were older than 35. The educational profile of the workers was also relatively inadequate, with 54% of them having secondary education, 28% having only primary education, and only 12% holding technical diplomas. Further, most of them have migrated from Uttar Pradesh (58%), Bihar (26%), and Jharkhand (12%), with little being the local residents. This workforce profile is an important consideration in assessing occupational safety and risk. Technical education influences the worker' capacity for hazard identification and risk recognition, while migrant workers may have limited access to weaker local support networks and fewer alternatives when exposed to poor or adverse employment conditions. Therefore, safety interventions in such workplaces must be designed according to the characteristics, needs and vulnerabilities of the workers actually employed in these settings rather than an idealized industrial worker.

When a long working day becomes a hazard

One of the clearest concerns was working duration. Only 17% of workers work 8 hours per day. In contrast, 57% reported working 12-hour shifts, 23% reported working about 10 hours, and fewer worked more than 12 hours. Overall, 83% exceeded an 8-hour shift, and workers who worked more than eight hours per day reported more health complaints. Exposure should not be separated from working time. After 10 or 12 hours, a noisy machine, a hot furnace, or even some solvent fumes can have more consequences. Long shifts can result into fatigue, reduced concentration, and slower reaction times. In environments with sharp objects, heavy machinery, hot surfaces, and electrical hazards, fatigue can itself become an additional occupational safety risk, increasing likelihood of errors, accidents and injuries.

Noise, heat, lighting, and Ventilation

Noise is a significant physical hazard in the workplace that often goes un-noticed. Measurement taken across different work areas ranged from approximately 88 dB to 105 dB and 85% of measured locations exceeded the 85 dB occupational noise exposure limit used as a reference level in this study. Hearing protection was rarely used, and 26% of the workers reported hearing impairment. Occupational hearing loss is of particular concern because it often develops gradually and may become permanent before the extent of impairment gets recognized. Other workplace conditions further exaggerate the occupational burden. Nearly 70% of the work areas were inadequately illuminated. Temperatures around the furnaces and welding operations ranged from approximately 35°C to 48°C, with 60% of work areas exceeding safe working temperature limits during peak working hours. Mechanical ventilation was absent in approximately 80% of the facilities, and poor ventilation was associated with respiratory health complaints. These hazards interact to amplify overall occupational risk. Increased heat intensified fatigue, inadequate lighting increased the chance of errors near cutting equipment, and poor ventilation increased exposure to fumes, dust, and solvents. These risks were further exacerbated during longer working hours or shifts.

Mechanical hazards and the PPE gap

Mechanical hazards were also a major concern in the asse-

Table 1: Contextual comparison reported in the original study.

Indicator	SME average	Large-scale comparison
Injury rate (per 100 workers/year)	47.8	2.1
PPE compliance	48%	98%
Health-screening coverage	0%	100%
Annual safety training	0 h/worker	24 h/worker
Safety investment	₹450/worker/year	₹8,500/worker/year
Injury-related cost	₹6,800/worker/year	₹1,200/worker/year

The large-scale comparison involved a single facility and should not be generalized to all large industries.

ssed workplaces. Approximately 68% of the machines examined did not have adequate guards or protective barriers. Visible electrical hazards were observed in 45% of the relevant connections. Poor housekeeping facilities were identified in nearly 90% of the facilities, with oil spills, metal shavings, and other obstructions present in the work areas. Heavy materials were also frequently handled manually without appropriate mechanical assistance, increasing the possibility of musculoskeletal injuries and accidents. The findings related to personal protective equipment (PPE) perhaps most clearly demonstrated the gap between known prevention and their implementation in the workplace. 52% of workers used no protective equipment. 32% used eye protection, 16% wore safety shoes, 12% used gloves, and 8% used respiratory protection. Among surveyed workers, no one wore occupational hearing protection despite being exposed to high noise levels. Seven out of ten SMEs did not provide any PPE, while only one SME provided comprehensive PPE. The difference in injuries was significant. Injury prevalence was 37.5% among workers using PPE, and 65.4% among workers not using PPE. The study's logistic regression also showed that non-use of PPE was an independent predictor of injury (OR = 3.8; 95% CI: 1.6-9.1). Although PPE should never replace engineering controls, where welding, cutting, grinding, and handling metal cannot be avoided, the right PPE provides a protective barrier.

The human consequences behind the statistics

The most important findings were the health consequences workers experienced. Cut injuries and hearing impairment affected 26% of surveyed workers each. Respiratory problems were reported by 20%, eye problems by 16%, amputations by 14%, skin allergies by 14%, paint-fume-related illness by 14%, thermal burns by 12%, and electrical shocks by 10%. Overall, 72% of surveyed workers experienced at least one work-related health issue. These percentages represent more than clinical categories. A cut injury can reduce a worker's ability to earn; hearing impairment may be permanent; an amputation can create lifelong disability. In a low-income or informal employment setting, occupational injury can affect an entire household, not only the individual worker.

The overlooked dimension: psychological health

One of the most revealing findings concerned a less visible form of occupational risk. Eighty-six per cent of workers were either unaware of psychological occupational-health effects or gave a neutral/no-effect response. Among those who did recognize psychological problems, sleep disturbance, hypertension, and job dissatisfaction were reported. Qualitative analysis also identified psychological-health stigma and unawareness, economic pressure overriding well-being, normalization of workplace stress, and lack of support systems. A low rate of reported psychological problems should not automatically be interpreted as excellent mental well-being. When awareness is limited, workers may not recognize persistent stress, sleep disturbance, or emotional exhaustion as occupational health problems. Modern occupational health must therefore protect both the body and the mind.

Welfare, emergency preparedness and health surveillance

Workers' protective equipment is not the only part of occupational health. Employee State Insurance coverage and basic sanitation facilities were available, but other welfare provisions were limited. Only 30% of the SMEs had lunch facilities. None of the facilities maintained appropriate first-aid facilities or designated rest areas, and there were no arrangements for transporting injured persons. Similarly, work uniforms and formal occupational safety training programmes were not provided. Emergency preparedness was particularly poor. The average distance to the nearest hospital was about 12.5 km, with injured workers relying on private cars or auto-rickshaws to reach the hospital. The estimated time required to reach medical care was 25 to 40 minutes while none of the workers and even the supervisors had received basic first-aid training. A systematic health surveillance program was also lacking. None of the ten SMEs conducted any pre-employment health examinations for production workers or periodic occupational health examinations. Even the occupational health records were not maintained. In the absence of baseline and periodic health screening, conditions such as progressive hearing loss, respiratory disease, and other work-related health problems may remain undiagnosed until they become more severe or result in significant health impairment.

What the large-industry comparison taught us

The comparison with a large-scale industry operating in the same geographical region provided useful context for interpreting the findings. The larger organization employ-

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ed a dedicated environmental health and safety professional and had several formal occupational safety and health measures in place. These included pre-employment and periodic health screening, comprehensive provision of PPE, first aid and CPR training, ambulance support, adequate ventilation and lighting, and regular safety training programmes. The contrast suggests that the occupational safety gap is more than something unavoidable consequence of manufacturing activities in the region. Although, the comparison included only one large-scale industry, requiring cautious interpretation, it indicates that implementation of improved occupational-health and safety systems are possible within the same broad regulatory and geographic environment.

From identifying problems to building solutions

The findings indicate a clear hierarchy of practical interventions for improving occupational safety in SMEs. Immediate worker protection should begin with proper selection, provision and use of PPE supported by adequate training and supervision. Engineering controls should focus on improving ventilation, machine guarding, noise control, electrical safety, workplace lighting, and safer material handling practices. Administrative controls should encompass regular safety training, pre-employment and periodic health surveillance, systematic occupational-health records, adequate rest periods, and effective emergency-response arrangements. Strengthening worker awareness is equally important, particularly regarding occupational hazards, safety rights, proper use of PPE, and the importance of reporting early symptoms workplace illness or injury. Regulatory implementation and compliance also need to be strengthened to recognize the resource constraints of SMEs. Smaller enterprises may not lack the financial resources, technical expertise and infrastructure to establish in-house occupational health and safety systems as large organizations. Cluster-based services, shared safety professionals, pooled PPE procurement, mobile occupational-health clinics and joint training programmes can provide feasible and sustainable solutions in this direction. The question should therefore be, not whether a small company can afford occupational safety, but how occupational safety can be designed and delivered so that effective protection for every enterprise, regardless of its size can be achieved.

Safety is an investment, not merely compliance

A persistent misconception in resource-limited enterprises is that safety represents an additional expense rather than a necessary investment. However, the consequences of occupational injuries extend beyond the immediate medical costs, lost work time, production interruption, compensation payments, employee turnover, and loss of experienced and skilled employees. The contextual comparison in this study indicated that that despite the substantial investment in occupations safety per worker in large industry would make the injury related costs much lower than the SMEs' average. Although a comparison involving a single large-scale industry cannot establish a universal economic relationship, it provides an important practical lesson that reduced expenditure on preventive does not necessarily result in lower overall costs. Occupational safety should therefore be better understood as an investment in worker protection, organizational productivity, and organizational resilience.

Where research must go next

This study serves as a baseline assessment of occupational health and safety in India's SME steel sector rather than a definitive evaluation of the sector as whole. It included 50 workers from 10 SMEs located within a single industrial area, along with one large-scale facility used for contextual comparison. The cross-sectional design limits the establishment of causal relationship as approximately 15% of planned instrumental measurements could not be completed due to operational or safety constraints. These limitations should be considered when interpreting the findings. Further studies should therefore involve larger and geographically diverse populations to provide a broader understanding. Longitudinal studies would be more appropriate to track or have insights into how hearing, respiratory health, musculoskeletal problems, and psychological well-being evolve with continued exposure. Intervention-based research can evaluate the effectiveness of measures such as subsidized PPE, improved ventilation, machine guarding, shorter shifts or structured safety training in reducing workplace injuries and health complaints. Multi-regional work across different industrial clusters can help develop context-specific yet scalable and applicable intervention strategies.

The larger message

India's manufacturing ambitions and the welfare of industrial workers should not be viewed as competing objectives rather they are fundamentally interconnected. A productive industrial system depends on healthy, capable and skilled workforce. Our Bhiwadi study identified substantial gaps including inadequate PPE, unsafe machi-

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nery, excessive noise exposure, poor ventilation and lighting, prolonged working shifts, absence of health surveillance, weak emergency preparedness, and extremely limited recognition of psychological health. At the same time, it points to practical and well-established preventive measures.

Appropriate PPE, machine guards work, adequate ventilation, safety training, health surveillance, First-aid preparedness can substantially strengthen worker protection. The key challenge is ensuring that these established measures move from policy documents and large corporate plants into the everyday reality of smaller industrial workplaces.

When a young worker enters a factory, earning a livelihood should not require accepting preventable hearing loss, respiratory disease, burns, amputations, or chronic psychological stress as unavoidable consequences of employment. Building a stronger culture of prevention is therefore not merely an occupational-health objective; it is an essential component of responsible and sustainable industrial development in India.

REFERENCES

- Sharma, A., Garg, S., & Arora, P. (2026). Occupational health, safety, and welfare of workers in small and medium enterprises: A case study of steel industries in Bhiwadi, Rajasthan. Work: A Journal of Prevention, Assessment and Rehabilitation. DOI
- Unnikrishnan, S., Iqbal, R., Singh, A., & Nimkar, I. M. (2015). Safety management practices in small and medium enterprises in India. Safety and health at work, 6(1), 46-55. DOI
- Cooper, M. D. (2000). Towards a model of safety culture. Safety science, 36(2), 111-136. DOI

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| EXPERT OPINION | DOI: https://doi.org/10.67831/Sci.Factors.2026.1666

Teaching Without Humiliation: Rethinking Resilience in Medical Education



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Areas of Expertise: Human Physiology | Health Professions Education

It is well accepted that learning medicine should be challenging since it is a difficult subject. Students must learn to make decisions under uncertainty, receive uncomfortable feedback, confront illness and death, acknowledge their limitations, and sometimes continue functioning when circumstances are far from ideal. These experiences demand resilience. But somewhere along the way, medical education has occasionally confused difficulty with harshness, challenge with humiliation, and resilience with endurance. Many educators were themselves trained in environments where public questioning, ridicule after an incorrect answer, intimidating ward rounds, or the instruction to simply "toughen up" were considered legitimate ways of producing competent doctors. Those who survived such systems may understandably believe that adversity made them stronger. The question for contemporary medical education is not whether future doctors need resilience. They unquestionably do. The more important question is: what should we ask them to become- resilient or capable of enduring difficult situation?

When Resilience Becomes Endurance

Resilience is generally understood as the capacity to adapt, recover, and continue to function when confronted by difficulty. In medicine, this capacity matters. A doctor cannot expect a professional life without uncertainty, failure, emotionally demanding encounters, difficult decisions, or unexpected outcomes. However, there is an important distinction between the inherent adversity of medical practice and the manufactured adversity of medical training. A critically ill patient is inherent adversity. Being humiliated for failing to recall an obscure fact is manufactured adversity. Receiving corrective feedback is necessary. Being publicly ridiculed while receiving it is not.

Managing uncertainty is a professional capability. Learning to remain silent when treated disrespectfully should never become one. When these very different experiences are placed under the same umbrella of "building resilience," responsibility subtly shifts from the educational environment to the learner. Instead of asking, Why does this learning environment repeatedly cause distress?, we ask, Why is this learner not resilient enough? That is a dangerous inversion. Recent syntheses of the hidden curriculum continue to identify hierarchy, mistreatment, stress, and incongruence between formally taught values and observed behaviour as important negative influences on learners.

Learners observe not only what educators teach but how senior professionals use authority, respond to mistakes, speak about colleagues, and treat those lower in the hierarchy. Recent syntheses of the hidden curriculum continue to identify hierarchy, mistreatment, stress, and incongruence between formally taught values and observed behaviour as important negative influences on learners. Studies investigating medical student mistreatment highlight its significant negative impact on learners and their career trajectories The lesson absorbed may therefore be very different from the lesson intended.An institution may formally teach empathy while informally rewarding emotional detachment. It may teach respectful communication while permitting humiliation during clinical teaching. It may encourage students to report unsafe behaviour while simultaneously demonstrating that challenging authority carries consequences. Resilience can-

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not repair such contradictions.

Productive Discomfort Without Psychological Harm

Removing humiliation does not mean removing challenge. This distinction matters because calls for psychologically safe learning environments are sometimes interpreted as demands for easier education. They are not. Medical students should encounter difficult questions. They should be required to defend clinical reasoning, identify gaps in knowledge, practise under observation, receive corrective feedback, and experience progressively increasing responsibility. Education without intellectual discomfort would prepare them poorly for clinical practice.The challenge is to create productive discomfort without destructive humiliation.

Consider a learner who gives an incorrect answer during a clinical discussion.

One teacher responds:"You don't know this? How did you reach final year?"

Another responds:"That conclusion worries me. Take me through your reasoning and let's identify where it went wrong."

Both teachers challenge the learner. Both identify inadequate performance. Both may create discomfort. But one preserves dignity and that turns the error into

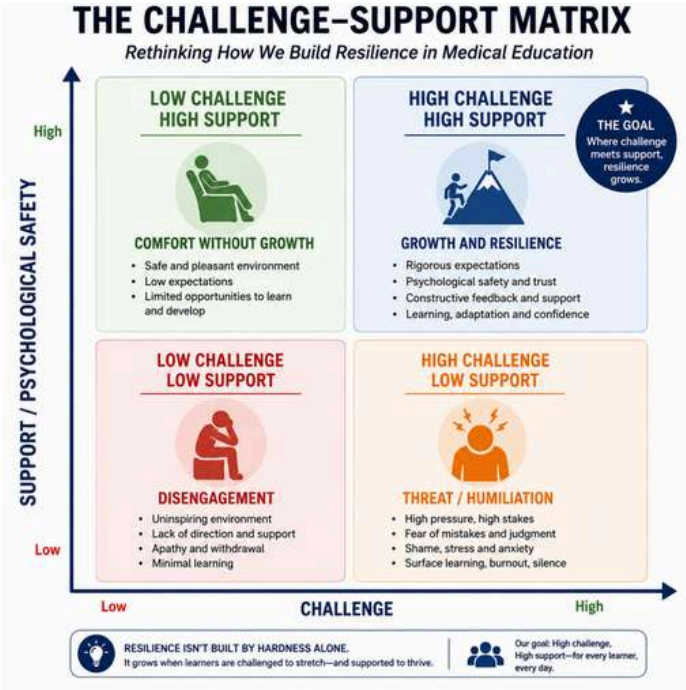


Figure 1: Challenge - Support Matrix

learning. This provides psychological safety. Learners are comfortable in exposing uncertainty, and acknowledging mistakes. They feel free to ask questions, and seek assistance without unnecessary interpersonal humiliation. This ensures more rigorous education. Psychological safety should be misinterpreted to be freedom from criticism and accuntability. It rovides the learner safe environment to be able to admit his mistakes and be accountable for his actions. This behaviour is transparent and more valuable for patient care.

From Resilient Learners to Resilient Learning Systems

The next evolution in medical education should therefore move resilience beyond the individual. Insights from medical educators emphasize that building resilience requires addressing systemic factors rather than treating it merely as an individual responsibility. For years, institutions have offered learners stress-management sessions, mindfulness programmes, wellness activities, counselling, and resilience workshops. These interventions can be valuable. But they become problematic when they are used to compensate for environments that remain unnecessarily harmful. Repeatedly exposing clinicians to an avoidable occupational hazard and then definong safety primarily as improving their capacity to withstand it is not the right way of training. Educational environments deserve the same systems thinking.

A resilient learning system would distribute responsibility across three levels- the learner, the educator and the institution. At the learner level, we should develop adaptive coping, reflective capacity, emotional regulation, help-seeking, tolerance of uncertainty, and the ability to recover from setbacks. Faculty should be trained through structired developmenalt activities that should include teaching techniques as well as responsible use of power, so that the trainers are equipped with the skill of challenging learners in workplace without ridiculing them. They should be able to provide feedback by maintaining identity and distinguish lack of conpetence from lack of confidence. Educators should also recognize incidents when traditional teaching methods create harmful behaviour and unsafe environment.

Finally, at the institutional level, medical schools should develop systems to identify teaching with humiliation by certain teachers. Addressing those mechanisms need to be incotporated into the system. Apart from reporting such

events, additional factors like leadership behaviour, faculty role-modelling, responses to complaints, workloads, assessment practices, hierarchy, and informal norms need to be considered to determine what the acceptable situation by learners. Collectively these can transform the cuture.The important opportunity of resilience education becoming a bridge between learner development and organisational responsibility can be created.

Future perspective: resilience for medicine, not resilience against medical education

The future doctor will arguably require greater resilience than previous generations. Healthcare systems are becoming more complex. Artificial intelligence will continually reshape professional roles. Information overload, uncertainty, changing patient expectations, resource constraints, ethical dilemmas, and rapid technological change will demand extraordinary adaptability.Because the future contains so much unavoidable uncertainty, educators should question the value of adding avoidable adversity.

The goal should not be to produce doctors who can tolerate humiliation. It should be to produce doctors who can remain thoughtful during uncertainty, recover constructively from failure, speak when something is unsafe, seek help without shame, challenge inappropriate authority, and continue to treat others humanely under pressure.

This requires a different educational equation: (Figure 1)

High challenge + high support + high accountability + preserved dignity = meaningful resilience

Such an approach does not weaken medical education. It makes its expectations clearer. Perhaps the most important test is to consider what happens when today's learner becomes tomorrow's teacher. A learner repeatedly taught that humiliation creates excellence may eventually reproduce the same behaviour while believing it to be educationally justified. In this way, mistreatment can become self-perpetuating: I endured it, therefore you should endure it.



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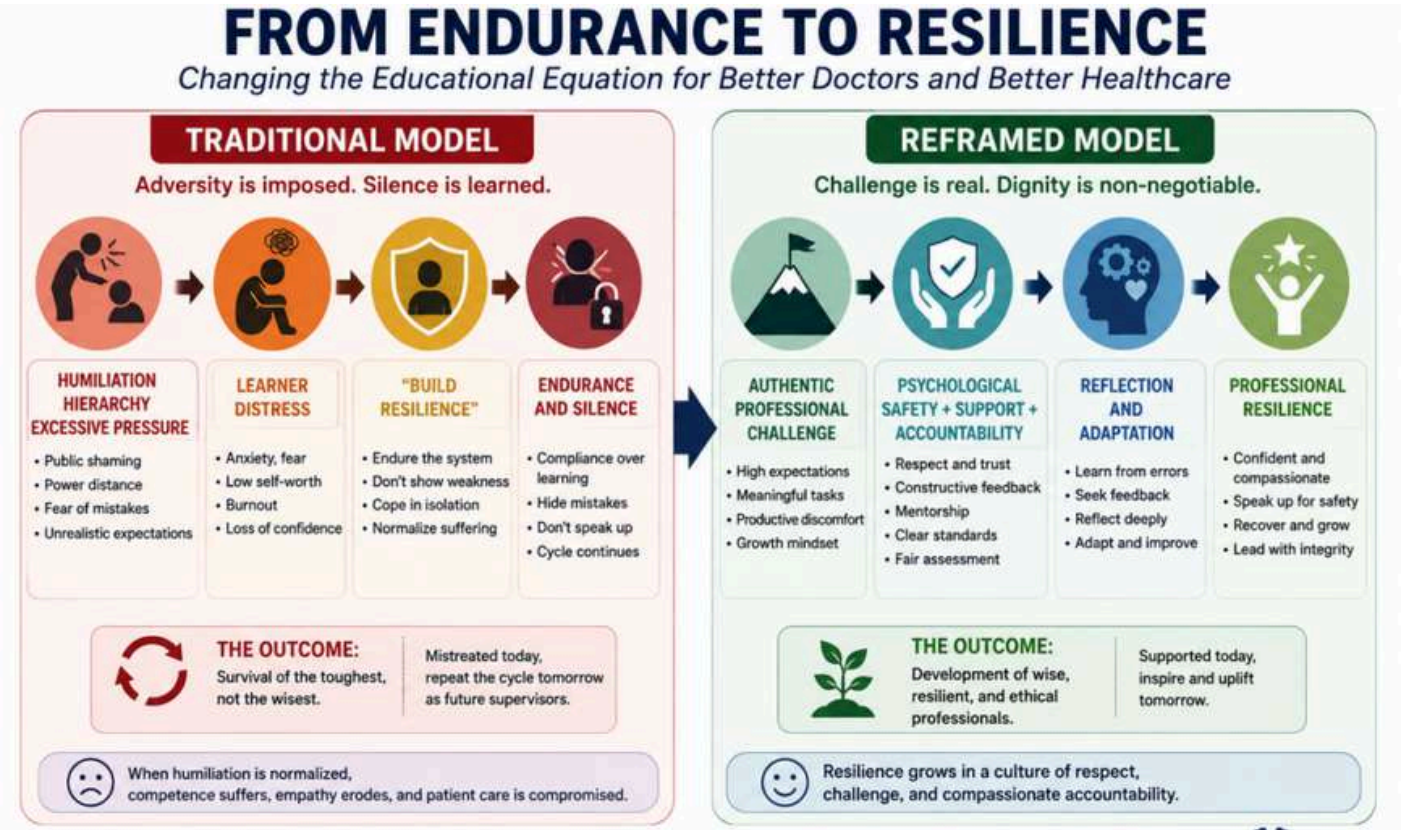


Figure 2: From Endurance to Resilience

A learner who instead experiences rigorous questioning, respectful correction, psychological safety, reflective dialogue, and compassionate accountability encounters a different professional model: I was challenged without being diminished; therefore I can challenge others without diminishing them.That may be one of the most important forms of resilience medical education can cultivate.The question, then, is not whether medical education should make learners tougher.It is whether we can prepare them for the genuine difficulties of medicine without becoming one of those difficulties ourselves. (Figure 2)

REFERENCES

- Ramani, S., et al. (2025). Effects of the hidden curriculum in medical education: Scoping review. JMIR Medical Education. DOI
- Oser, T. K., Haidet, P., Lewis, P. R., Mauger, D. T., Gingrich, D. L., & Leong, S. L. (2014). Frequency and negative impact of medical student mistreatment based on specialty choice: A longitudinal study. Academic Medicine, 89(5), 755–761. DOI
- Chan, L., & Dennis, A. A. (2019). Resilience: Insights from medical educators. The Clinical Teacher, 16(4), 384–389. DOI

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> *I was challenged without being diminished; therefore I can challenge others without diminishing them.*

| EXPERT OPINION | DOI: https://doi.org/10.67831/Sci.Factors.2026.1671

Beyond Glaucoma: The Overlooked Eye Condition That Starts with Sudden Vision Loss



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Areas of Expertise: Retinal Diseases and Surgery | Eye Inflammation (Uveitis) | Cataract Surgery

We chose to discuss Vogt–Koyanagi–Harada (VKH) disease because of its rarity, potential to cause severe visual loss, and the diagnostic challenges it may show during the initial presentation. In some cases of VKH, acute ocular pain accompanied by elevated intraocular pressure can mimic acute angle-closure glaucoma, potentially leading to an incorrect initial diagnosis. Prompt identification of VKH is crucial, as early initiation of appropriate systemic immunosuppressive therapy may help preserve visual function and limit complications involving the eyes, nervous system, auditory system, and skin.

VKH syndrome constitutes a multisystem autoimmune disorder, characterized by granulomatous inflammation targeting melanocyte-containing tissues, including the uveal tract, meninges, inner ear, and skin. Pathogenesis is attributed to T cell–mediated immune responses against melanocytic antigens in genetically susceptible individuals, with increased prevalence among patients of Asian, Hispanic, Middle Eastern, and Native American ancestry.

A disease that reaches beyond the eyes

Ocular: VKH primarily affects both eyes, producing granulomatous panuveitis and marked inflammation of the choroid. Accumulation of fluid beneath the retina may result in serous or exudative retinal detachments. Auditory: The inner ear may also be affected, particularly the melanocyte-containing structures. Patients can develop tinnitus, vertigo, and sensorineural hearing impairment. Neurological: In the early stage, inflammation of the meninges (coverings of the brain) may present with headache, fever, and neck stiffness. Cerebrospinal fluid examination may demonstrate an increased number of inflammatory cells. Cutaneous and hair changes: As the disease progresses, loss of pigmentation may become apparent. Typical findings include vitiligo, whitening of the eyelashes or eyebrows (poliosis), and areas of hair loss (alopecia). These changes are more characteristic of the later convalescent or chronic stages.

VKH generally progresses through four stages. The prodromal phase lasts for days to weeks and involves symptoms of malaise, headache, nausea, and/or neck and back stiffness, which was reported in about 50% of patients with VKH. The acute uveitic phase is characterized by phot-

ophobia, visual disturbance, ocular inflammation (granulomatous panuveitis), serous retinal detachments, and optic disc edema. In the convalescent phase, ocular inflammation gradually begins to subside while depigmentation of the fundus ("sunset-glow fundus") becomes more evident. In the chronic or recurrent phase, persistent or recurrent episodes of granulomatous anterior uveitis and other ocular complications may occur.

A diagnosis revealed by looking deeper

The case published as "A rare case of Vogt-Koyanagi-Harada syndrome misdiagnosed as bilateral primary angle-closure suspect" is from a tertiary clinic in the eastern part of India. It describes a middle-aged Asian woman who initially received peripheral iridotomy for presumed primary angle-closure before posterior segment evaluation established it as VKH.

On further evaluation, she had bilateral shallow anterior chambers despite prior iridotomy, anterior chamber inflammation with pigmented keratic precipitates, optic disc edema, and multilobular serous retinal detachments. Posterior segment imaging showed focal areas of delayed choroidal perfusion with multiple pinpoint leaks giving an appearance of "starry sky" and late pooling. Optical coherence tomography (OCT) confirmed multiple serous detachments and a wavy retinal pigment epithelium. Systemic findings of cutaneous hypopigmentation and unilateral sensorineural hearing loss completed the clinical picture consistent with complete VKH.

High-dose intravenous methylprednisolone followed by oral steroids and azathioprine led to marked visual recovery and resolution of subretinal fluid. But the therapy was discontinued due to patient factors, which produced persistent subretinal fluid that resolved when immunosuppressive treatment was resumed. Subsequently, it led to the development of a "sunset-glow" fundus.

Lessons from a missed diagnosis

This case clinically instructs on several aspects. First, it highlights that VKH can clinically mimic primary angle-closure glaucoma (PACG) at presentation. Inflammatory choroidal thickening and ciliochoroidal effusion may shift the lens–iris diaphragm anteriorly, producing secondary angle-closure that is reversible with appropriate anti-inflammatory therapy. Failure to recognize posterior inflammatory signs risks unnecessary procedures such as iridotomy, as done in this case.

Second, the case reinforces that subtle anterior segment inflammatory signs (cells, keratic precipitates), bilateral symptoms, or posterior segment complaints should initiate posterior imaging before committing to any definitive angle-closure interventions.

Thirdly, from a therapeutic outlook, the favourable response from initiating high-dose systemic corticosteroids and the use of azathioprine for steroid-sparing maintenance are consistent with current practices: aggressive initial control of inflammation followed by sustained immunomodulation. This reduces relapse risk and chronic tissue damage. Lastly, the return of subretinal fluid after treatment discontinuation emphasizes the importance of patient counselling regarding the duration of therapy, adherence, and close monitoring. Follow-up to document visual function, choroidal thickness, and treatment toxicity is essential.

The clues that distinguish VKH from glaucoma

Bilateral involvement with systemic manifestations: VKH generally affects both eyes and may be associated with headache, tinnitus, hearing disturbances, or a recent flu-like illness. In contrast, PACG commonly begins in one eye and is not typically associated with systemic inflammatory symptoms. Posterior segment involvement: Findings such as diffuse thickening of the choroid, serous/exudative retinal detachment, and irregular alterations of the retinal pigment epithelium on OCT or ultrasonography are suggestive of VKH. In uncomplicated PACG, the posterior segment is not the primary site of disease. Cause of anterior chamber shallowing: A shallow anterior chamber can occur in VKH because inflammatory swelling of the choroid causes forward displacement of the uveal tissues. This differs from PACG, where angle closure is primarily related to anatomical crowding and pupillary block. Differences in treatment response: VKH is an inflammatory disorder and usually requires prompt systemic corticosteroid therapy and, when indicated, other immunosuppressive treatment. PACG, on the other hand, is managed by lowering intraocular pressure and opening the closed angle, often with medications and laser peripheral iridotomy.

Improving diagnosis and follow-up

To enhance educational value and reproducibility in future reports, it would be advantageous to incorporate anterior segment imaging such as ultrasound biomicroscopy (UBM) to objectively document ciliochoroidal effusion and

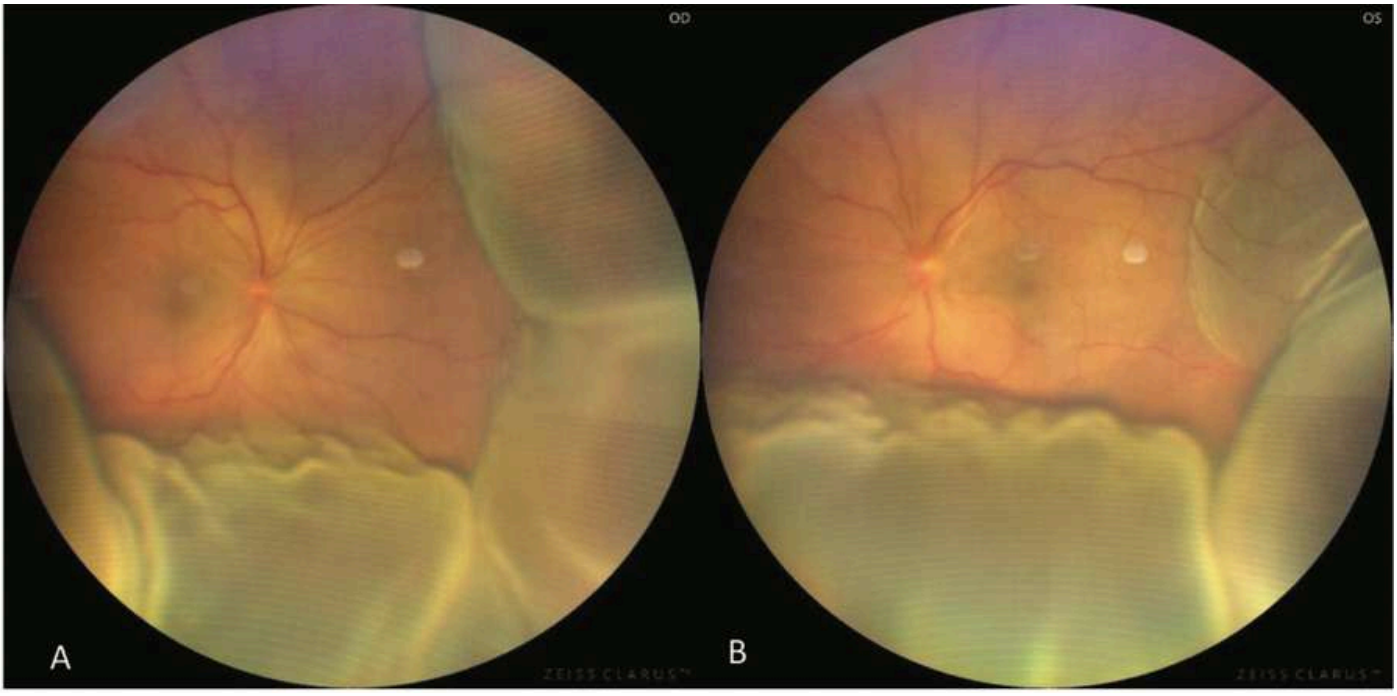


Figure 2: Wide field fundus image showing disc oedema and bullous retinal detachment in right eye (A) and left eye (B).

the position of the lens–iris diaphragm. Additionally, providing a detailed account of the immunosuppressive regimen, including specific agents, dosing schedules, and monitoring protocols, would strengthen the clinical utility of the case.

To summarise, this case serves as an important reminder that VKH should be included in the differential diagnosis of bilateral or atypical angle-closure scenarios. A thorough ocular and systemic evaluation, supported by multimodal imaging, timely initiation of systemic immunotherapy, and clear patient counselling regarding treatment adherence, are essential to preserving vision and minimizing the risk of chronic complications in VKH.

ABOUT THE AUTHORS

Dr Sanghamitra Kanungo and Dr Sasmita Das are senior ophthalmologists at Kar Vision Eye Hospital, Bhubaneswar. Dr Kanungo specialises in retinal disease and uveitis, while Dr Das specialises in glaucoma, including secondary glaucoma. Their combined expertise is central to this article: it brings together the signs of inflammation deep inside the eye with the features that can make VKH appear to be angle-closure glaucoma. Their perspective helps explain why examining both possibilities matters for an accurate diagnosis and appropriate treatment.

REFERENCES

- Kanungo, S., Das, S., & Pattnaik, S. (2026). A rare case of Vogt–Koyanagi–Harada syndrome misdiagnosed as bilateral primary angle-closure suspect. Clinical and Experimental Optometry, 109(5), 1078–1081. DOI
- Tayal, A., Daigavane, S., & Gupta, N. (2024). Vogt–Koyanagi–Harada disease: A narrative review. Cureus, 16(4), e58867. DOI
- Bai, X., & Hua, R. (2022). Case report: Vogt–Koyanagi–Harada syndrome mimicking acute angle-closure glaucoma in a patient infected with human immunodeficiency virus. Frontiers in Medicine, 8, 752002. DOI
- Alvarez-Guzman, C., Valdez-Garcia, J. E., Ruiz-Lozano, R. E., et al. (2022). High prevalence of angle-closure glaucoma in Vogt–Koyanagi–Harada disease. International Ophthalmology, 42(12), 3913–3921. DOI
- Bhedasgaonkar, S. S., Manral, H., & Nadkarni, S. U. (2022). Case report of an unusual presentation of Vogt–Koyanagi–Harada disease as bilateral acute angle closure. Journal of Clinical & Experimental Ophthalmology, 13(3), 1–3. Article link

SCIENCE STORIES RESEARCH & EXPLORATIONS

Behind every discovery lies a story of curiosity, perseverance, and wonder. Science unfolds through relentless research and bold explorations into the unknown. These are the journeys that shape our understanding of the world—and beyond.

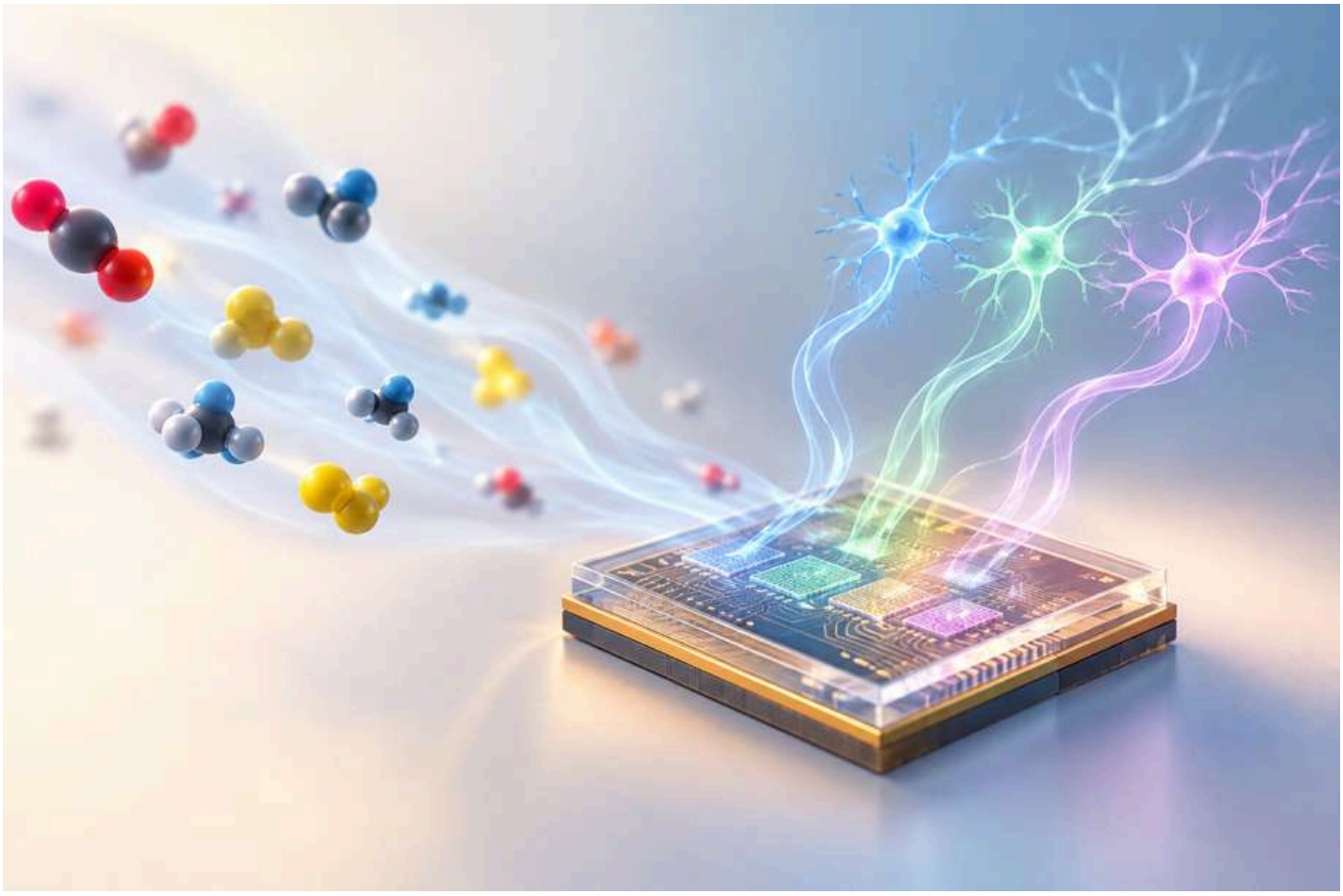
| By Dr. Dhanashree Mundhe

THE ARTIFICIAL NOSE THAT LEARNS WHAT TO IGNORE

One quiet morning at Seoul National University, Han Seo-yeon stared at a tiny chip under a microscope and asked a strange question: "What if a machine could learn to ignore a smell?" Her friend Park Min-jae looked surprised. A machine that smelled things was not new. Scientists had been building artificial noses for years, using sensors to recognize gases. But there was a problem. A smell did not always look the same to a machine. The same gas could produce different sensor signals when the surrounding air changed. Humidity, leftover gases, and other chemicals could confuse the sensor, almost like trying to recognize one voice in a crowded room. For machines, this instability has remained a stubborn practical challenge. Seo-yeon pointed at the tiny device. "Our noses do something different," she said. "They adapt." That simple idea became the beginning of their investigation.

Seo-yeon and Min-jae began by studying how the human sense of smell handles changing surroundings. They learned that biological smell receptors can become more sensitive to a repeated smell, a process called sensitization. They can also become less sensitive to familiar background smells, called desensitization. This helps the brain notice something new instead of being overwhelmed by everything around it. The researchers wondered whether electronics could copy this clever trick. Their answer was a new device called an artificial olfactory nervous system, or AONS. Instead of keeping sensing, memory, and processing in completely separate parts, the system combined artificial receptor neurons, olfactory neurons, and cortical neurons on one substrate. This compact design allowed sensing and adaptation to occur together. The receptor neurons sensed gases and stored information about previous stimulation; the olfactory neurons adjusted the signals; and the cortical neurons processed those signals to produce gas identification.

Then came the experiment that made Min-jae lean closer to the screen. The team exposed the artificial nose to gases such as nitrogen dioxide, ammonia, nitrogen monoxide, and hydrogen sulfide. At first, the surrounding gases could interfere with the sensor patterns. But when the researchers used desensitization, the system adapted to the



| By Dr. Dhanashree Mundhe

background and reduced its influence. They then added another step called baseline correction, which helped make the signals easier to compare. The researchers trained the system in air and tested it in eight different surroundings containing strong residual-gas interference. Without these adaptation steps, the mean percentage error was 84.1 percent. With desensitization and baseline correction together, it fell to 0.1 percent. The dramatic improvement revealed how strongly environmental context shaped recognition. Seo-yeon smiled when she saw the result. The machine had not simply been given more examples to memorize. It had been designed to change how it sensed its surroundings.

But the researchers did not stop with carefully prepared gas mixtures. They wanted to know whether the artificial nose could face something found outside the laboratory. So they exposed the AONS to gases released by spoiling chicken tenderloins. The system detected patterns associated with the changing gases, including ammonia during the earlier stage of spoilage and hydrogen sulfide during severe putrefaction. The result suggested that the adaptation method could work with complex, real-world smells, not only controlled laboratory gases. Such monitoring could eventually help improve food safety and storage. The researchers also showed that sensitization could help the system recognize repeated familiar stimuli more quickly, while desensitization could help it identify new gases in changing backgrounds. Still, Seo-yeon reminded Min-jae that this was a research prototype, not a human-like electronic nose ready for every situation. The study demonstrated gas-identification abilities and practical potential, while broader applications would require further development.

That evening, as the lights of Seoul began to appear outside the laboratory windows, Min-jae looked again at the tiny chip. He had expected a sensor to simply detect a gas, but the experiment had shown something more interesting: sometimes a machine becomes better at sensing not by noticing everything, but by learning what to ignore. That principle could reshape how future sensors interpret complex environments. The AONS still has limits it demonstrated identification of eight gas species, and its sensitization and desensitization modes cannot operate simultaneously but the researchers believe the approach could support future artificial olfactory systems that work more reliably in complicated environments while using less training data and energy. Seo-yeon switched off the microscope and left the tiny device resting silently on the table. “Maybe the secret to giving machines better senses,” she said, “is teaching them when not to listen.” And as the laboratory fell quiet, one question remained in the air: if a machine can learn to forget yesterday’s smells, what new things might it one day learn to discover?

Future studies could test how reliably this adaptation works over longer periods and across more varied conditions. The challenge is to preserve sensitivity to important new signals while suppressing familiar interference, without overlooking changes that could matter for practical monitoring.



REFERENCE

Jung, G., Kim, J., Choi, K. et al. Intelligent artificial olfactory nervous system with sensory adaptation capabilities. Nat Commun 17, 9963 (2026). https://doi.org/10.1038/s41467-026-76918-1

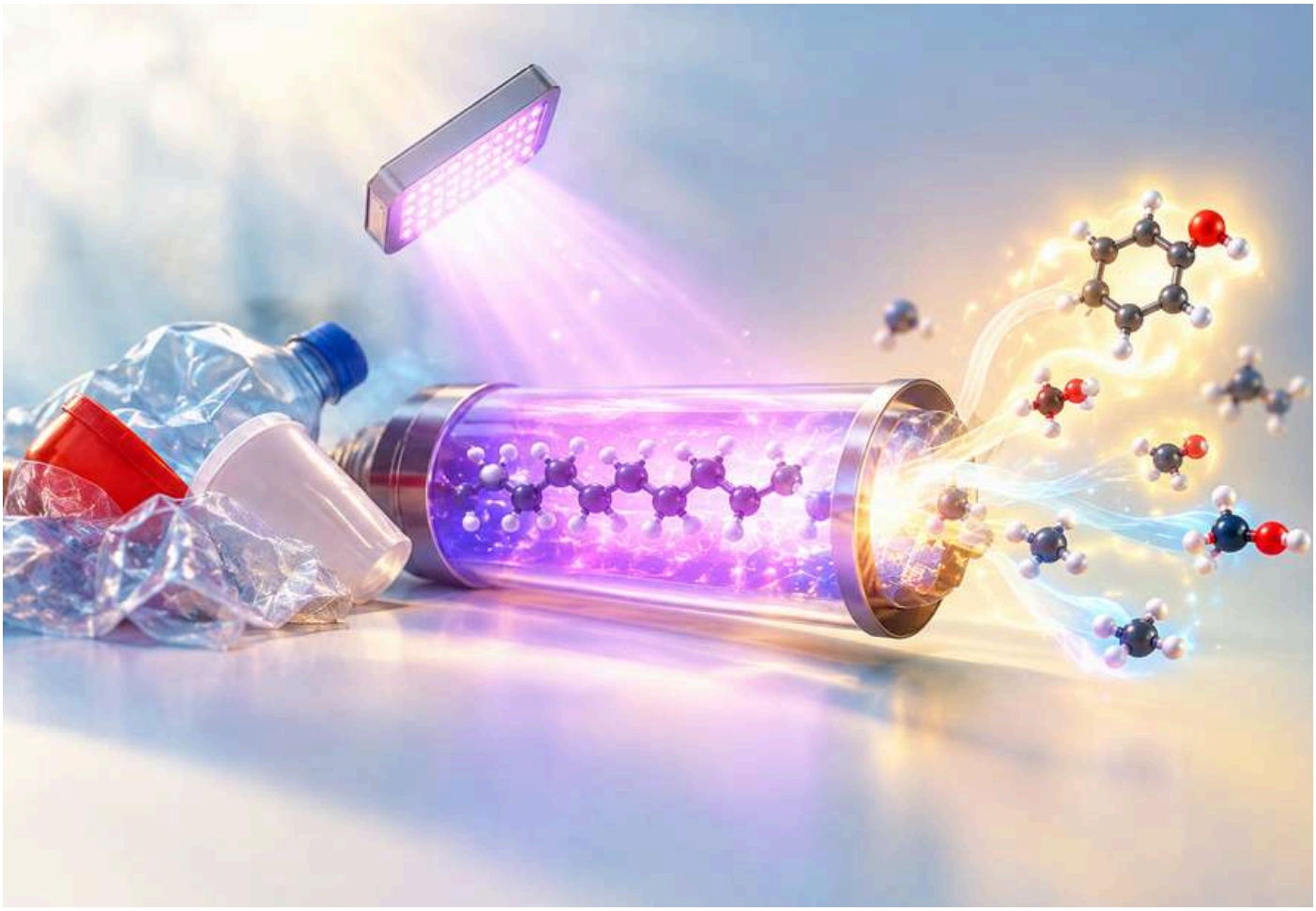
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| By Dr. Sudha Shankar

PLASTIC THAT HELPS RECYCLE ITSELF: LIGHT-DRIVEN UPCYCLING WITHOUT A CATALYST

When the purple light switched on, Li Wei stared at the small plastic sample inside the glass tube and frowned. “You mean we are going to recycle this without a catalyst?” he asked. Beside him in a chemistry laboratory at Sichuan University in Chengdu, Chen Yuhan smiled but pointed to the experiment. The material was polystyrene, a common plastic found in cups and other everyday products. Usually, turning such stubborn plastic into useful chemicals can require special photocatalysts, additives, or carefully controlled conditions. But the researchers had a strange idea: perhaps the plastic itself could help start the reaction when exposed to light. Such simplicity made an unusual idea especially intriguing. They placed polystyrene in a mixture of chloroform and acetonitrile, left it in air, and illuminated it with a 390-nanometer LED. Then they waited. Nothing dramatic happened at first. Yet beneath the quiet surface, something unusual was beginning.

Hours later, Yuhan returned to the reactor and noticed that the experiment was finally changing. “Look at the results,” she said. The polystyrene had produced benzoic acid, a useful small molecule, without an added photocatalyst. After 40 hours, the reaction gave benzoic acid in 35% yield, along with formic acid. But Wei had another question. Why did light work at all? The answer slowly emerged from a series of tests. Neither chloroform nor acetonitrile alone worked well, while their mixture did. Air and light were both necessary; when the researchers removed the oxygen or turned off the light, no products appeared. The team also found that different lights gave different results, with 370- and 390-nanometer LEDs performing better than longer-wavelength LEDs in the tested conditions. This revealed that wavelength influenced the reaction’s efficiency. It seemed that polystyrene was not simply sitting under the light—it was absorbing some of that energy and becoming part of the process itself.



| By Dr. Sudha Shankar

But then another mystery appeared. The reaction did not speed up smoothly from the beginning. Its progress showed an induction period, followed by faster degradation. Wei leaned closer to the graphs. “It is almost as if the reaction is learning how to continue,” he said. The researchers investigated further using spectroscopy, radical-trapping experiments, and calculations. They found evidence that excited polystyrene interacts with oxygen to generate superoxide. That superoxide can attack the chloroalkane solvent, helping produce reactive radicals, including alkoxy and chlorine radicals. These highly reactive species can help break carbon-hydrogen bonds in the polymer and begin oxidative chain cleavage. At the same time, oxidized pieces of polystyrene and HCl formed during the reaction could help accelerate the process. Each reactive product helped sustain further chemical transformations. The scientists called this behavior autoinductive because products formed during the reaction helped make the reaction proceed faster. The plastic, light, oxygen, and solvent were working together in a chemical chain that had not required an added catalyst.

The two students soon wondered whether the strange light-driven chemistry could handle real waste rather than only a clean laboratory sample. They tested different kinds of polystyrene, including post-consumer plastics, and even a gram-scale polystyrene cup. The method remained effective with materials containing common additives, including a black coffee lid and a red cup. Then the experiments became more ambitious. The same catalyst-free approach worked with other aromatic polymers, including PET, polycarbonate, and polyether sulfone. It also worked with lignin, a major component of plant biomass. When polystyrene was processed together with lignin or pine wood, the combined feed could still produce useful products. Even more surprisingly, polystyrene helped the researchers process some non-aromatic plastics that were otherwise much less reactive under the same conditions. This flexibility could matter when treating mixed waste. A mixture containing a polystyrene cup and PVC tubing underwent extensive degradation, producing small molecules including benzoic acid, formic acid, and acetic acid.

As evening settled over Chengdu, Wei switched off the purple LED and looked at the ordinary plastic cup on the bench. It no longer seemed quite so ordinary. The study had shown that polystyrene could use its own light-sensitive behavior to help drive catalyst-free photochemical upcycling, while the surrounding solvent played an active role in creating reactive species. The approach also showed promise for processing mixed plastics and plastic-biomass mixtures, and it even worked in a solvent mixture designed to imitate halogenated organic waste. Yet Yuhan reminded him that this was still a research platform, not a complete solution to the plastic-waste problem. Turning possibility into practice will require further development. “We have learned that waste can contain hidden chemical possibilities,” she said. Wei nodded, watching the last glow fade from the reactor. If sunlight and a piece of discarded plastic can begin such an unexpected chemical journey, what other hidden reactions might scientists discover inside the waste we throw away every day?



REFERENCE

Qin Qin et al. ,Catalyst-free, autoinductive photochemical upcycling of aromatic polymers and mixed plastics via autosensitization.Sci.Adv.12,eaeg9384(2026).DOI:10.1126/sciadv.aeg9384

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| By Dr. Poulami Chakraborty

INSPIRED BY SPIDER WEBS: A SKIN ELECTRODE THAT THRIVES ON HUMIDITY

One quiet morning in Singapore, Li Wei stood beside a laboratory window at Nanyang Technological University and watched a tiny spider web tremble in the humid air. “How does something so thin stay useful when the weather keeps changing?” he wondered. His colleague, Nur Aisyah, looked at the web and then at the electrode they were testing. They were trying to solve a problem in wearable electronics: how could an electrode stay attached to human skin, carry electrical signals clearly, and work reliably for long periods? Dry electrodes could last longer, but their contact with skin created high electrical resistance and noise. Wet electrodes gave better contact, but their water slowly disappeared, weakening both performance and adhesion. The researchers began thinking about the spider web. Its silk contains small charged molecules that attract water from the surrounding air, helping it maintain its properties. Could that idea be copied in a human-made material? The team began designing a new kind of adhesive electrode.

The first challenge was making one material perform several jobs at once. “It must stick to skin, conduct electricity, hold enough water, and still let moisture move through it,” Aisyah said. The researchers built a hygrotrode a hygroscopic, or moisture-loving, conductive adhesive. It used an interpenetrating network made from a gelatin-based material called GelMA, a conducting polymer called PEDOT:PSS, and a biocompatible ionic liquid called BIL. BIL contained positively charged groups that strongly interacted with water molecules. Instead of simply trapping water, the three-dimensional network controlled how water existed inside the material. When removed from a dry environment, the hygrotrode initially showed weak adhesion and noisy signals. After absorbing about 45% water from the surrounding air, however, its adhesion became much stronger and its signal quality improved. This offered an important clue: perhaps surrounding humidity was not the enemy. Perhaps the material could use it.

The investigation then became more detailed. Wei and Aisyah changed the humidity and watched the electrode’s electrical behaviour. As humidity increased, electrical resistance at the interface decreased, while its ability to store charge increased. The scientists focused on two forms of water inside the material. Some was strongly bound to the polymer, while some was “intermediate water,” held more loosely within the network. This intermediate water



| By Dr. Poulami Chakraborty

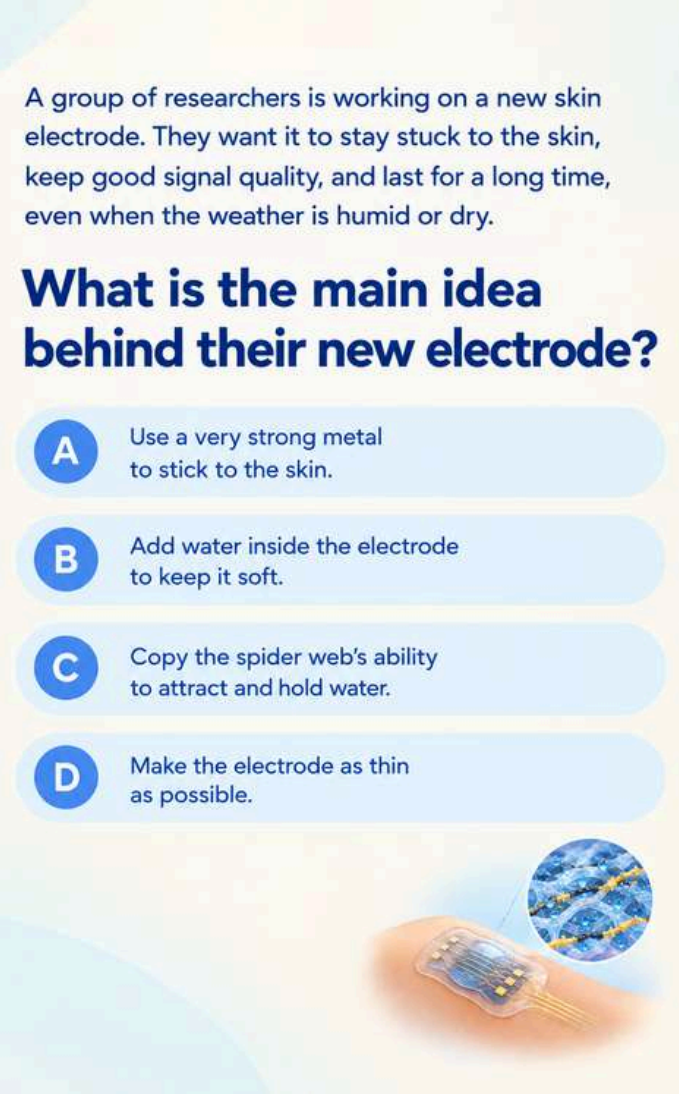
became especially interesting because it could form an electrochemical bridge between the conducting polymer and the skin. The team found that the material could absorb about 70% of its dry mass within three hours outdoors at approximately 70% relative humidity, and it could rapidly rehydrate while being worn. The hygrotrode also allowed water vapour to pass through it, helping it recover after heavy sweating. The secret was not simply having more water. It was controlling how water moved, remained, and interacted inside the material.

But could this spider-web-inspired material survive the test of time? The team compared the hygrotrode with ordinary wet electrodes over several months. After one year in ambient conditions, the hygrotrode's area-specific impedance at 10 hertz was about 82.4 times lower than that of the wet electrode. Its adhesion energy changed by less than 10% during that year, while the wet electrode's adhesion fell by about 96.7% after only two weeks. The researchers placed hygrotrodes on volunteers to record electrical signals from the body. They successfully measured ECG signals from the heart, EOG signals from eye movements, EEG signals from brain activity, and muscle signals for gesture recognition. In one demonstration, a ten-channel patch recorded muscle activity that allowed recognition of 26 different gestures. Even after one year of ageing, the hygrotrode preserved strong signal quality and gesture-recognition performance. These experiments demonstrated long-term laboratory and human-wear performance, although toughness, fatigue resistance, and tear resistance still require improvement.

Late that afternoon, Wei returned to the window where the spider web had first caught his attention. The web had not changed, but he now saw it differently. The researchers had not simply copied spider silk; they had borrowed nature's ability to manage moisture and rebuilt it as a conductive material for the human body. Their hygrotrode combined adhesion, electrical conduction, water absorption, and water-vapour movement in one three-dimensional network, maintaining a stable interface with skin for long periods. It also remained breathable and comfortable during prolonged contact with skin. The study demonstrated promising uses in physiological monitoring, gesture recognition, and electrical stimulation, while future applications in longer-lasting wearable medical devices and human-machine interfaces require further development. A small spider web had led the scientists toward a larger question: could materials work with the body instead of constantly fighting its changing environment? As Aisyah switched off the laboratory lights, she looked once more at the web and wondered: if one tiny creature can inspire a new way to connect technology with the human body, what other secrets are waiting in nature to be discovered?

The next step is to explore how the material performs during everyday movement, repeated use, and changing climates. Researchers will also need to strengthen its durability.

Meeting these challenges could help turn a promising laboratory material into a dependable interface for monitoring the body beyond carefully controlled research settings.



REFERENCE

Lingxuan Kong et al. ,Spiderweb-inspired electronically conductive hygroscopic adhesive for chronic bioelectronic interface.
Sci.Adv.12,eaea3748(2026).DOI:10.1126/sciadv.aea3748

National University of Singapore.

| By Dr. Ipsita Mohanty

SEEDS OF RECOVERY: THE HIDDEN LIFE BENEATH OUR FEET

One quiet morning, Lea stood beside a table covered with maps of the world and asked a strange question: "How much of a forest is still hiding underground?" Her colleague Robin smiled and pointed to a tray of soil. To the eye, it looked like ordinary earth. But inside it could be a soil seed bank a natural store of seeds buried in the ground, waiting for the right conditions to grow. These buried reserves can remain dormant for years, preserving biological possibilities long after visible plants have vanished. At the Swedish University of Agricultural Sciences in Uppsala, Sweden, the research team was part of a much larger international effort. This was not a study from one country or one field. Instead, scientists brought together information from studies across all seven continents to understand what these hidden seed banks were like around the world.

Robin opened a huge database on the computer. "Imagine trying to count every seed sleeping beneath the ground," he said. "We cannot dig up the whole planet, so we need another way." The researchers searched earlier scientific studies and built a global database containing information from 1,442 studies, 3,096 records, 94 countries and all seven continents. Altogether, the studies included observations of more than 35 million seeds. Lea stared at the numbers, surprised by how much information could be hidden in old research papers. Combining many observations allowed the team to compare ecosystems at a scale no single survey could achieve. The team wanted to examine two different things: species richness, meaning how many different plant species were represented, and seed density, meaning how many seeds were found in a certain area of soil. They also wanted to know how these patterns changed between forests, grasslands, wetlands, farms and other ecosystems, and whether habitat degradation changed what remained underground.

As the analysis grew, something unexpected appeared on the screen. "Wait," Lea said. "A place can have lots of seeds without having lots of different species?" That was exactly what the researchers were finding. Species richness and seed density did not always move together. This separation showed why counting seeds alone cannot reveal the full ecological value stored beneath an ecosystem. Tropical ecosystems, for example, generally had high species richness, but their soil seed banks often had relatively low



| By Dr. Ipsita Mohanty

seed density. Wetlands and arable systems, on the other hand, showed some of the highest seed densities. Mediterranean forests, woodlands and shrublands stood out because they combined relatively high richness with relatively high seed density. Even the size of the area studied mattered. The estimated number of species generally increased when the researchers moved from a very small sampling area of 0.01 square metres to a larger 15-square-metre scale. A tiny patch of soil could therefore give a very different picture from a wider piece of ground.

Then Robin showed Lea the result that made the room suddenly feel quiet. Across the ecosystems studied, degraded habitats consistently had lower estimated species richness at the larger 15-square-metre scale, although the strength of the difference varied and the study also reported considerable uncertainty. Seed density behaved differently: sometimes degradation was linked with fewer seeds, while in some forest systems degraded areas actually had higher estimated seed densities. Restoration plans based only on seed abundance might therefore overlook the loss of rare or important species. The researchers suggested that this difference matters because a soil seed bank can help vegetation recover after disturbance. If fewer plant species remain in the hidden seed bank, the ability of an ecosystem to recover naturally may be limited. But the team was careful about what the data could prove. Their global results were affected by uneven sampling, differences among the original studies and the fact that many observations came from only one site.

That afternoon, Lea walked outside and looked at the ground differently. The soil beneath a patch of grass no longer seemed empty. It might contain seeds from plants that had disappeared from the surface, waiting for a disturbance or a change in conditions before appearing again. The study showed that soil seed banks are an important part of plant communities and that their hidden diversity does not always match what we might guess simply by counting seeds. Protecting these underground reserves could strengthen restoration efforts as climate change brings more frequent ecological disturbances worldwide.The researchers also argued that future studies should go beyond simple measures of richness and density by combining seed-bank information with data about the vegetation growing above the soil,while carefully considering the scale at which biodiversity is measured. Lea closed the laptop and looked across the quiet campus. If so many secrets were already buried beneath our feet, what other clues about the future of life might the soil still be waiting to reveal?

Answering that question will require looking more closely at which species persist underground, how long their seeds remain viable, and what allows them to germinate.

For restoration teams, such knowledge could help distinguish places where natural recovery is possible from those needing additional support.

The soil may hold part of an ecosystem's future, but its potential must be carefully assessed.



REFERENCE

Auffret, A.G., Ladouceur, E., Haussmann, N.S. et al. Divergent patterns of richness and density in the global soil seed bank. Nat Commun 17, 8820 (2026). https://doi.org/10.1038/s41467-026-77079-x

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| By Dr. Preeti Sharma

MANGROVE CARBON ON THE MOVE: WHAT THE TIDES CARRY TO SEA

One humid morning in Guangdong Province, China, Lin Xiaoyu stood beside a mangrove creek and watched tidal water creep between tangled roots. The tide seemed ordinary, yet one question would not leave her mind: when this water returned to the sea, what was it carrying away from the forest? Mangroves capture atmospheric carbon and store large amounts in their plants and muddy sediments. But Xiaoyu wondered whether that familiar picture was incomplete. Perhaps tides were also carrying carbon sideways into coastal waters. With colleagues Chen Hao and Li Wen, she investigated three contrasting environments: an estuarine saline mangrove on Qi'ao Island, a coastal mangrove on Hailing Island, and an estuarine freshwater mangrove on Haiou Island. Each site mixed freshwater and seawater differently. The larger study combined measurements from 61 mangrove sites across 14 nations, while the Guangdong sites allowed the team to watch what happened hour by hour as tides entered and left the forest.

The mystery was harder to solve than expected because carbon travels through mangrove water in several forms. Dissolved inorganic carbon, or DIC, includes simple carbon-containing substances dissolved in water. Dissolved organic carbon, or DOC, comes from living or once-living material. Particulate organic carbon, or POC, consists of tiny carbon-rich particles suspended in water. To determine whether these forms were entering or leaving with the tide, the researchers followed complete tidal cycles during wet and dry seasons. Capturing that movement required patience and precision. Instruments anchored in the creeks recorded water movement, temperature, oxygen, pH, chlorophyll and conductivity. For 24 hours at each site, samples were collected near creek mouths, alongside upstream freshwater and offshore seawater. Drones equipped with water-sampling systems also helped. "The tide keeps moving," Hao said as another group of bottles was prepared. "If we want its story, we must move with it."

Back in the laboratory, the bottles began revealing that story. The team measured each carbon form and examined carbon isotopes—different versions of carbon atoms that provide clues about carbon's origin and transformation. They compared their measurements with values expected if freshwater and seawater simply mixed. When actual results departed from that prediction, biological or chemical processes had to be involved. The evidence indic-



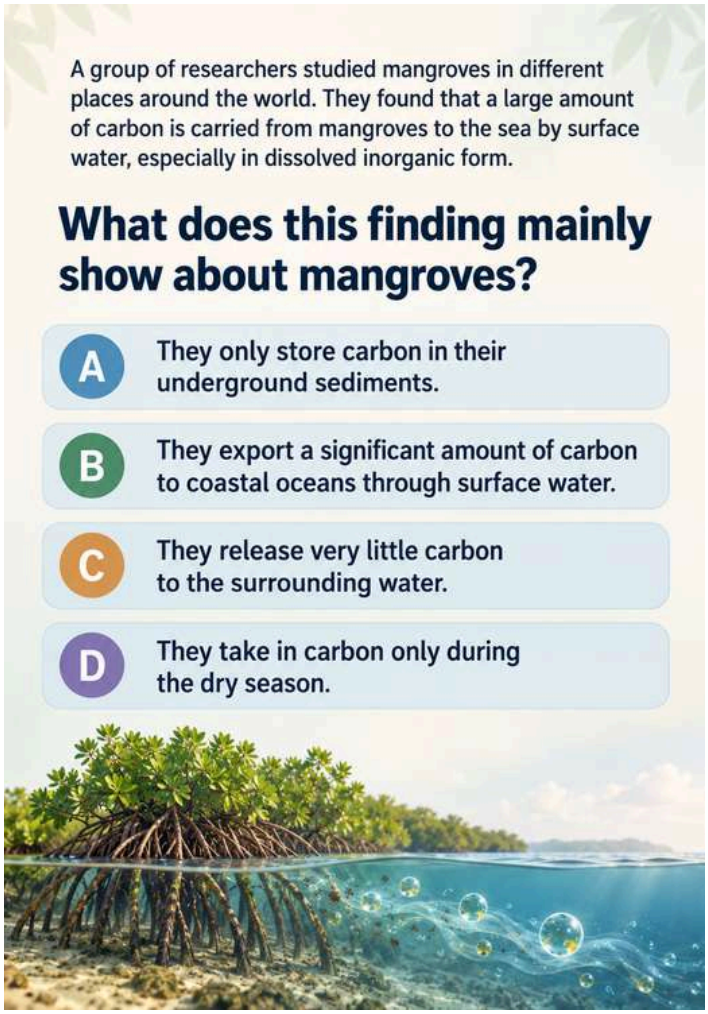
| By Dr. Preeti Sharma

ated that organic carbon degradation—the breakdown of mangrove litter, roots and other material—and carbonate dissolution were the main processes producing additional DIC across the mangrove types. Hidden chemistry unfolded beneath each passing tide. The three environments also behaved differently. DIC and particulate organic carbon export were highest in estuarine freshwater mangroves, whereas dissolved organic carbon export was highest in coastal mangroves. Xiaoyu now saw fallen leaves, muddy water, microbes, minerals, freshwater and seawater not as separate features, but as parts of a changing carbon system connected by every rising and falling tide.

The team then widened its view to mangroves worldwide. Across the global dataset, total lateral surface-water carbon exchange averaged about 101 millimoles per square metre each day, with DIC as the dominant component. Combining the median export rate with global mangrove area produced an estimate of approximately 64.1 million tonnes of carbon exported annually. The scale surprised even experienced mangrove researchers. This suggested that sideways transport into coastal waters is a major, often overlooked part of mangrove carbon sequestration. To explore how warming might alter this pathway, the researchers used interpretable machine-learning models. Water temperature, dissolved oxygen, chlorophyll and salinity were especially influential for DIC and DOC, while season and dissolved oxygen were important for POC. Temperature positively influenced all three components in the models, but the projected response was not unlimited. “Warming does not make everything rise forever,” Wen realized while examining the results. The relationship was more complicated.

Using several warming scenarios, the researchers projected carbon exchange through 2100. Changes were generally smaller under a low-emissions pathway, while intermediate- and high-emissions scenarios produced larger shifts. For China, total lateral carbon export was projected to increase substantially under the intermediate and high scenarios. Yet the models identified a turning point: at about 2.5°C of warming, export reached a threshold and then began declining. These were projections, not observations of the future, and they could not include every influence, including mangrove loss, landward migration or human changes to water flow. Still, the work demonstrated that mangroves do not protect carbon only by locking it beneath their roots. Tides transport substantial carbon from forests into coastal waters, and this lateral pathway should be included in mangrove carbon accounts and climate strategies. Accurate accounting could strengthen future mangrove conservation. As evening returned, Xiaoyu watched the tide move toward the South China Sea. The water looked unchanged, but she now imagined an invisible river of carbon travelling with it. If a tide can conceal such an important part of a forest’s story, what else might scientists discover by following where nature quietly leads?

Following that carbon beyond the creek will be essential to understanding how much remains stored and how much eventually returns to the atmosphere as gases.



REFERENCE

Ouyang, X., Maher, D.T., Lee, S.Y. et al. Surface-water carbon exchange from mangroves and responses to global warming. Nat Commun 17, 9948 (2026). https://doi.org/10.1038/s41467-026-77058-2

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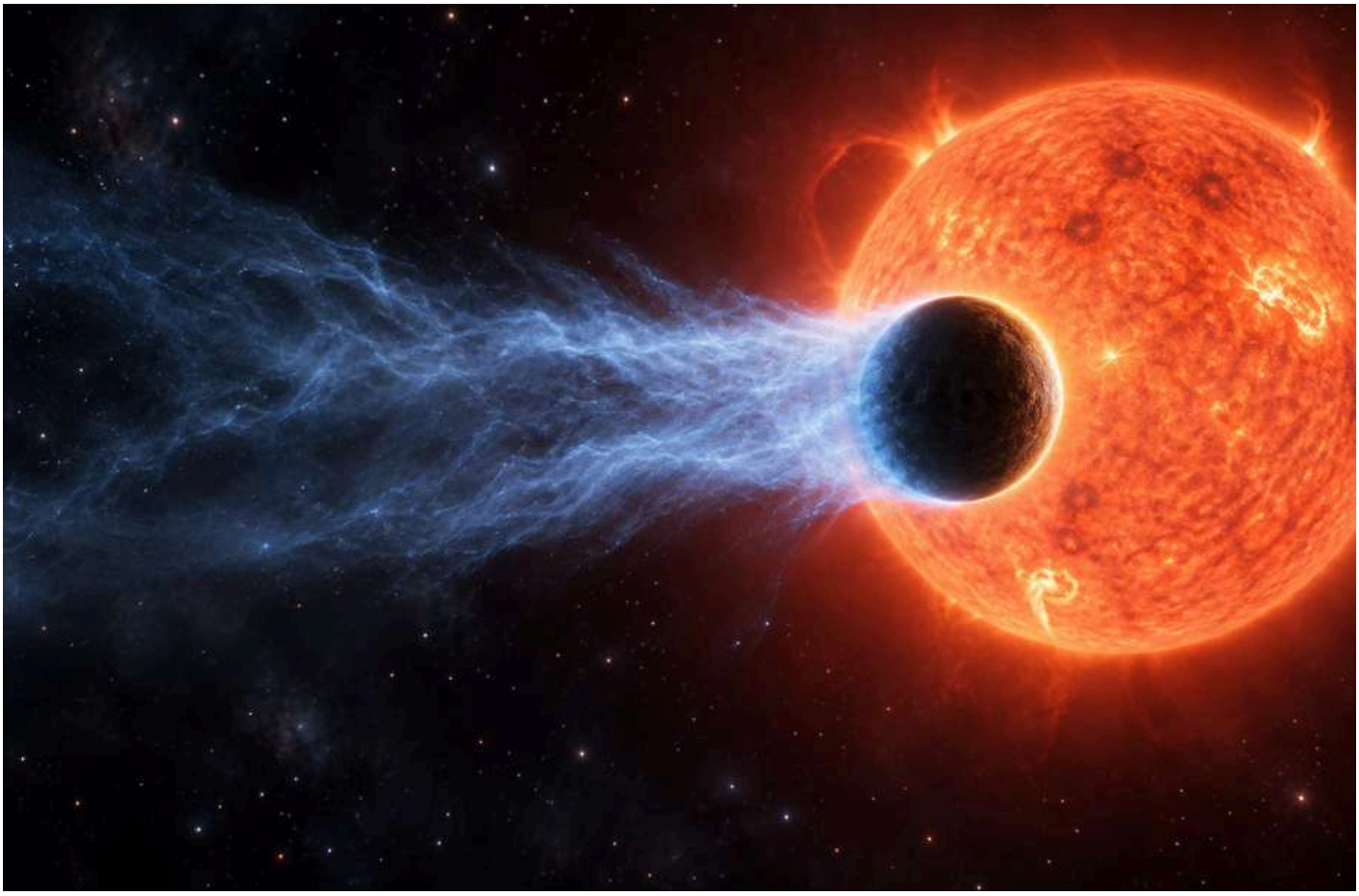
| By Dr. Priyanka

AN ATMOSPHERE IN MOTION: HELIUM ESCAPING FROM A HABITABLE-ZONE WORLD

One cold night at Las Campanas Observatory in Chile, Valentina Rojas looked toward a rocky world invisible to her eyes. Far beyond the Solar System, LHS 1140b crossed its small red star every 24.7 days. The planet receives about 42% as much stellar energy as Earth receives from the Sun, placing it within the habitable zone, where temperatures may permit liquid water under suitable conditions. But Valentina and her fictional colleague Tomás Fuentes were pursuing a more basic mystery: did this distant world possess an atmosphere? Detecting atmospheres around small rocky planets is difficult because their signals are overwhelmed by their stars. On 23 September 2024, the team used the WINERED infrared spectrograph on the 6.5-metre Magellan Clay telescope. During 6.5 hours of observation, they collected 70 spectra measurements that divide starlight into wavelengths and reveal the chemical fingerprints of gases. Each spectrum captured a whisper of the planet's presence.

The clue appeared when LHS 1140b moved across its star. During a transit, some starlight passes through a planet's outer atmosphere before reaching Earth. Different gases absorb particular wavelengths, leaving tiny gaps in the spectrum. Near 10,833 angstroms, the researchers found a pattern matching metastable helium-helium atoms in an excited state that absorb infrared light at characteristic wavelengths. The strongest blended lines produced an absorption depth of about 1.24% during transit. More surprisingly, helium absorption appeared before the transit began. The early signal was consistent with escaping helium extending ahead of the planet in a "leading tail," with tentative evidence of another tail behind it. Its shape offered clues about the planet's atmospheric escape. Instead of merely detecting gas surrounding a rocky world, the observations appeared to capture part of its atmosphere flowing into space. For Valentina, a faint missing piece of starlight had become evidence of a planetary wind.

An exciting signal, however, was not enough. The researchers had to test whether stellar activity or Earth's atmosphere could have produced it. After examining and



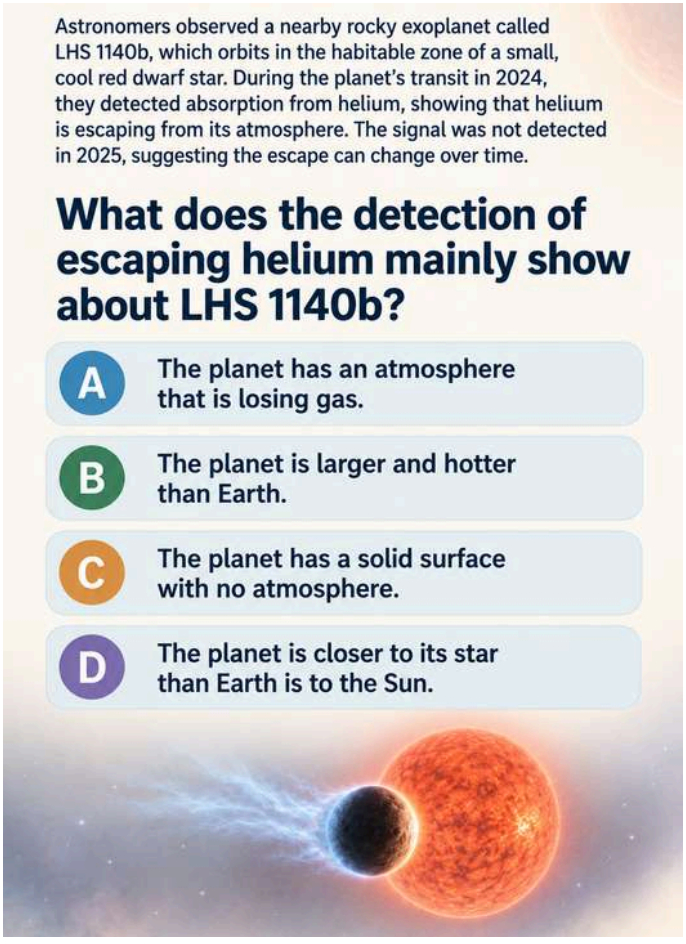
| By Dr. Priyanka

excluding these alternatives, they interpreted the 2024 absorption as an atmospheric outflow from LHS 1140b. The proposed engine was x-ray and extreme-ultraviolet radiation from its red-dwarf star. This high-energy radiation can heat an upper atmosphere until gas escapes as a wind. The team used a computer model called p-winds to simulate the escaping atmosphere and predict its spectrum. Depending on the assumed stellar radiation, the model produced mass-loss rates of roughly 200 million to 420 million grams per second, consistent with escape mainly powered by the star. The model also indicated very little hydrogen relative to helium in the escaping gas. That hydrogen-poor composition suggested that atmospheric loss had already strongly altered the planet's upper atmosphere over time. The wind carried a record of earlier atmospheric loss.

Another mystery emerged when astronomers observed LHS 1140b again in 2025: the helium signal had disappeared. The researchers independently processed both years of observations using another method and recovered the same difference, making a simple analytical error unlikely. Their models showed that realistic changes in stellar radiation or upper-atmosphere temperature could weaken helium absorption below the 2025 detection limit. Atmospheric escape may therefore vary over time; a missing signal did not prove that the outflow had stopped. The neighbouring planet LHS 1140c provided a useful comparison. It is smaller, orbits every 3.78 days and receives about five times Earth's stellar irradiation, yet showed no helium absorption. Earlier studies suggested that it has little or no atmosphere. LHS 1140b, by contrast, lies on the opposite side of a proposed "cosmic shoreline," a possible boundary separating rocky planets that retain atmospheres for billions of years from those that lose them. The two planets illustrate how atmospheric survival can diverge.

As dawn approached, Valentina imagined LHS 1140b nearly fifteen parsecs away, orbiting an old red dwarf while helium streamed from its upper atmosphere. The study did not demonstrate oceans, life or an Earth-like surface. It provided evidence of helium escape in 2024 and showed that the signal changed with time. Repeated observations are essential for separating change from permanence. The observations were consistent with a helium-rich, hydrogen-poor upper atmosphere, while heavier elements such as oxygen, carbon and nitrogen would be harder for the measured wind to remove. If the planet contains substantial water, its cool lower atmosphere might trap water through condensation, limiting how much reaches the escaping upper layers. These possibilities leave the deeper atmosphere and surface mysterious. That uncertainty is scientifically valuable: understanding whether a planet retains heavier gases helps researchers assess its history and future habitability. Valentina watched the sky brighten and considered how a tiny pattern missing from distant starlight had revealed an atmosphere in motion. If one faint helium signal can disclose so much about a distant planet, what hidden story will the next beam of alien starlight reveal?

Each future transit offers another chance to test whether the escaping gas follows predictable patterns or changes unexpectedly, gradually revealing how this distant world responds to its star's restless influence.



REFERENCE

Collin Cherubim et al. ,Helium escaping from the atmosphere of a nearby rocky exoplanet orbiting in a habitable zone.Science393,998-1001(2026).DOI:10.1126/science.aea9708

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| By Dr. Avijit Das

THE SULFUR STONES OF MARS: CURIOSITY CRACKS OPEN AN ANCIENT MYSTERY

One quiet morning on Mars, Curiosity rolled across the dusty floor of Gediz Vallis, a valley cutting through Mount Sharp inside Gale crater. Nearly 225 million kilometres away, planetary scientist Elena Torres examined the rover images with her fictional colleague Marcus Reed. Something on the hillside looked out of place. Among the reddish-brown rocks lay numerous pale stones, some pebble-sized and others much larger, covering part of a roughly 2,100-square-metre area beside a winding canyon. Their unexpected colour immediately distinguished them from the surrounding landscape recorded by Curiosity's cameras. Mars contains abundant sulfur compounds, especially sulfates, in which sulfur is joined with oxygen and other elements. But these stones appeared different. "What happened here?" Elena wondered. Curiosity had come to Gale crater to read Mars's geological history, and now the planet had placed another mystery directly in its path. The team instructed the rover to examine the stones closely.

The first clues came from the Alpha Particle X-ray Spectrometer, or APXS, which identifies elements by studying the x-rays produced by rocks. Curiosity examined five pale stones in ten analyses, and their spectra contained an enormous sulfur signal. Even stranger, elements normally associated with Martian sulfate minerals were mostly absent. The measurements indicated native sulfur—sulfur in its pure elemental form rather than bound inside another mineral. Within the instrument's limits, the stones appeared to contain pure native sulfur beneath coatings of dust and sand. Curiosity then accidentally supplied a better clue when its wheels fractured one stone and exposed its interior. Images revealed translucent, pale-yellow material with a glassy or resin-like shine, matching native sulfur. The broken stone contained sulfur and small holes but no fragments of ordinary rock or sedimentary cement. The accidental fracture transformed a surface observation into compelling mineralogical evidence for the team. Nothing like it had previously been identified in Martian material.

Finding pure sulfur created a larger puzzle: how had it for-

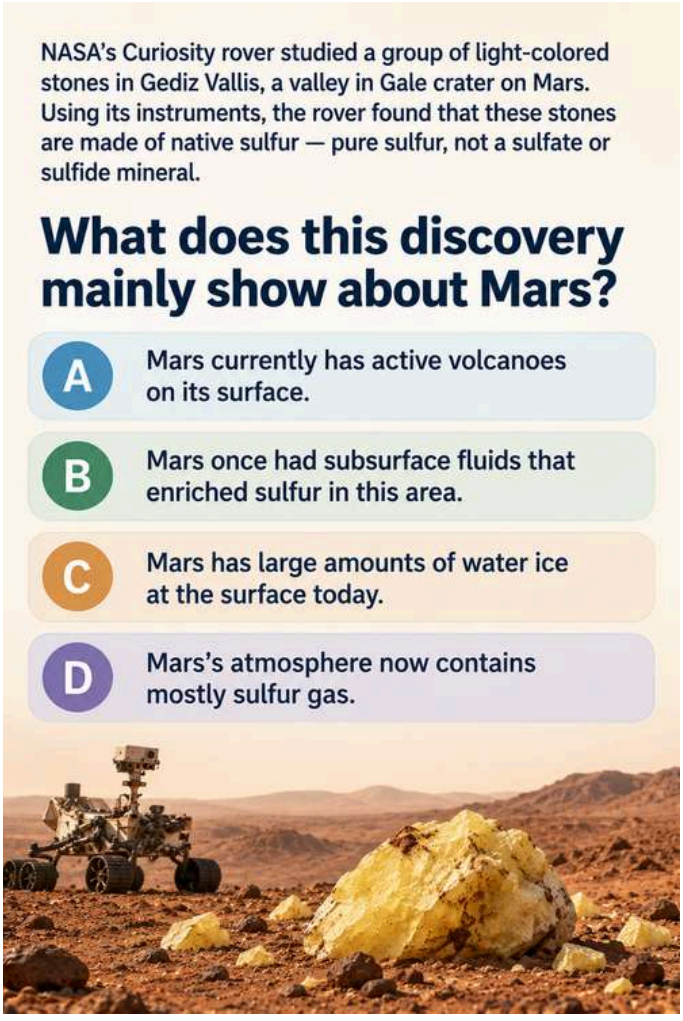


| By Dr. Avijit Das

med there? On Earth, native sulfur commonly occurs near hot volcanic or hydrothermal environments. However, the surface at Gediz Vallis showed no evidence of such intense heating. The stones were concentrated in one area, many contained holes, and their fragility made a long journey from elsewhere unlikely. The researchers considered groundwater or salty brine, but that explanation required chemical conditions and quantities of reducing material unsupported by the evidence. An impact origin also presented difficulties. Another possibility gradually became more convincing. Deep beneath ancient Mars, sulfur-rich gases released by magma may have travelled upward. The researchers considered magmatic degassing—the release of gases from magma—the most plausible primary sulfur source, although the deposit lay far from obvious volcanic features. That conclusion linked the isolated stones to geological activity occurring far below the landscape.

The team proposed an ancient sequence beneath the Martian surface. Sulfur-rich fluids or vapours from magma may have risen, cooled and become trapped within Mars's frozen subsurface, or cryosphere. Sulfur-rich clathrates—ice-like structures capable of trapping gases—might have formed there. Much later, erosion carved the canyon through Gediz Vallis and removed material above the buried reservoir. As pressure decreased, trapped material could have decompressed and released sulfur-rich vapour. Subsequent chemical reactions may have produced native sulfur near the surface, possibly inside an icy trap. This scenario could explain why the deposit was localized, why the sulfur was unusually pure and why holes crossed some stones, as though vapour had passed through them. It united several disconnected clues within one coherent geological history for Gediz Vallis. The researchers stressed that this was a proposed explanation, not a process Curiosity directly observed. Other high-temperature pathways could not be eliminated completely, but surrounding rocks lacked signs of strong heating, and transporting fragile sulfur stones over long distances seemed improbable.

The rocks held one final surprise: their age. From the landscape and the deposit's relationship with surrounding layers, researchers estimated that the native sulfur formed approximately 3.1 to 2.8 billion years ago. Chemically vulnerable material had somehow survived near the Martian surface for billions of years, perhaps protected beneath coarse sediment. A thin coating of oxidized sulfur may also have shielded exposed stones. Its preservation offers a rare window into ancient chemical environments on early Mars. Elena studied the images of pale broken rocks scattered across red dust. The discovery did not prove that volcanoes erupted at Gediz Vallis, nor did it provide evidence of Martian life. Instead, it revealed an unexpected chapter in Mars's sulfur cycle and suggested that sulfur-rich fluids once moved through the ancient subsurface of a planet now cold and quiet. A rover wheel had accidentally cracked one stone, exposing evidence of geological processes hidden across deep time. Marcus smiled: on another world, even a broken rock can become a doorway into the past. What other ancient secrets might be waiting beneath the next ordinary-looking stone?



REFERENCE

Scott J. VanBommel et al. ,A native sulfur deposit in Gale crater, Mars.Science393,820-825(2026).DOI:10.1126/science.adu5501

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DOI: https://doi.org/10.67831/Sci.Factors.2026.1679

SCIENCE DESK

Helping Mothers Breastfeed with Confidence: What Hospitals Can Change



Dr. Inderdeep Singh Kochar
Department of Paediatrics, Dr. S.S. Tantia Medical College, Hospital and Research Centre Sriganganagar, Rajasthan, India

Scientific Profile
Organization Link
Factors Press

AREAS OF EXPERTISE
Pediatrics • Neonatology • Pediatric Critical Care • Breastfeeding Support

OUTLOOK

Breastfeeding is important for both mother and child, yet many mothers stop early despite understanding its benefits. Difficulties such as pain, concerns about milk supply, conflicting family advice, and limited support can gradually reduce a mother's confidence. In this conversation, Dr. Inderdeep Singh Kochar explains why breastfeeding confidence matters and how involving healthcare professionals, experienced mothers, and family members could create practical, low-cost support systems that help mothers continue breastfeeding with greater confidence.

Q *Why do some mothers stop breastfeeding early even when they understand its benefits?*

A Picture a new mother on the postnatal ward. Her baby cries after a feed. A relative suggests that her milk may not be enough; another recommends formula; a nurse gives hurried advice before moving on. By the end of the exchange, the problem is no longer only technique. The mother has begun to doubt whether she can breastfeed at all. (This scenario is a composite of experiences mothers described to us, not a single case.)

That is why knowledge alone does not guarantee continuation. Mothers may understand the benefits of breastfeeding and still face pain, latch difficulties, exhaustion, uncertainty about milk supply, pressure to supplement, or contradictory advice. These experiences accumulate. Once every feed starts to feel like a test, correct information may not be enough to sustain confidence. Our work at Dr. S.S. Tantia Medical College, Hospital and Research Centre in Sriganganagar focused on those moments where confidence begins to unravel.

Q *What made you look beyond breastfeeding knowledge and focus specifically on a mother's confidence in her ability to breastfeed?*

A The shift came from a mismatch we repeatedly saw in clinical practice: mothers often knew what they were supposed to do, yet still felt they were failing. That led us to breastfeeding self-efficacy - a mother's belief that she can breastfeed successfully - rather than knowledge alone.

We measured confidence using the 14-item Breastfeeding Self-Efficacy Scale-Short Form (BSES-SF) . In our survey of 232 women, the mean score was 46.2, and 32% scored below 47, which we classified as low confidence. Earlier breastfeeding difficulties, lower social support, depressive symptoms and first-time motherhood were independently associated with lower scores. The important point was that confidence was not simply an individual personality trait. It was being shaped, positively or negatively, by experiences, relationships and healthcare interactions around the mother.

Q *What were the most common difficulties and concerns shared by mothers in your study, and which had the greatest impact on their confidence?*

A The most common concern was perceived inadequate milk supply, reported by 63% of women. Pain or discomfort was reported by 58%, conflicting family advice by 49%, latch difficulties by 41%, and feeling overwhelmed by 38%. One-third had experienced pressure to use formula, and 28% felt provider support was inadequate.

Milk-supply concerns had one of the strongest independent associations with lower confidence, while pain and latch difficulty also mattered. Psychosocial factors were important too: low social support and depressive symptoms were independent-

ly associated with lower BSES-SF scores. These findings reminded us that breastfeeding difficulties rarely arrive one at a time. A physical problem can quickly become an emotional one when it is reinforced by uncertainty, fatigue, family pressure or inconsistent professional advice.

Q *How do family members, particularly partners and mothers-in-law, influence a mother's breastfeeding experience in the Indian context?*

A Family members can be either a major source of resilience or a source of doubt. In many Indian households, partners, mothers, mothers-in-law and other elders are closely involved in the first weeks after birth. Their advice carries weight, particularly when a new mother is tired, in pain or unsure whether feeding is going well.

Supportive relatives can protect rest, encourage persistence and reinforce professional guidance. But the same influence can undermine confidence when normal newborn crying is interpreted as hunger, milk supply is repeatedly questioned, or prelacteal feeds and formula are recommended because they are familiar practices. Multi-level family influence on infant feeding is well recognised in Indian settings. In our study, conflicting family advice was common enough that counselling only the mother clearly seemed incomplete. The goal is not to cast relatives as barriers; it is to recruit them as allies.

Q *What role can doctors, nurses, and other healthcare professionals play in building confidence rather than simply providing breastfeeding instructions?*

A Healthcare professionals can build confidence by changing the quality of the interaction, not simply by adding more information. A directive such as "feed more frequently" may be technically correct, but it does little for a mother who is worried that her baby is still hungry. She needs consistent troubleshooting, clear explanations of what is normal, and reassurance that an early difficulty can be worked through.

This sits comfortably within the Baby-friendly Hospital Initiative. The revised WHO/UNICEF Ten Steps already call for competent staff, discussion of breastfeeding with women and families, practical support with common difficulties and continuity after discharge . Our confidence-focused approach is not an alternative to BFHI. It is a way of operationalising those standards around locally identified barriers. In our co-design work, providers favoured short communication prompts and confidence-building language that could be used during ordinary ward rounds and discharge counselling rather than creating a separate service.

Q *Your team developed a model combining peer support, improved provider communication, and family counseling. How would this work practically during routine hospital care?*

A Forty-one stakeholders - hospital staff, mothers and family members - took part in the co-design workshops. They prioritised three components. The first was peer support, with experienced breastfeeding mothers offering one-to-one encouragement to new mothers during postnatal rounds. The second was a provider communication toolkit for physicians, nurses and counsellors, using brief prompts for common problems, emotional validation and consistent troubleshooting during rounds and discharge. The third was structured family counselling, bringing in a partner, mother-in-law or other key relative to address common misconceptions such as prelacteal feeding and feeding frequency.

The family session was designed as a 15-minute format; in the micro-pilot, the median recorded time across delivered components was seven minutes per patient, with no additional staff required. Among 26 postpartum women, 88% rated the intervention acceptable or very acceptable. Mean BSES-SF scores increased from 43.8 before the intervention to 52.1 afterwards, but with a small uncontrolled pilot that change is descriptive, not proof of effectiveness.

Q *Could this low-cost approach eventually be expanded to other hospitals and communities across India, and what further research is needed before that can happen?*

A Potentially, yes - but the part worth scaling is the process, not necessarily an identical package. The barriers in Sriganganagar will not be the same as those in a metropolitan private hospital, a rural district facility or a community programme. Staffing, family structures, local beliefs and access to post-discharge support all differ.

A more useful model is to identify where mothers are losing confidence, measure which barriers matter locally, bring mothers, families and healthcare workers together, and design support around clinical

touchpoints that already exist. One setting may need peer support; another may need more consistent bedside counselling, stronger antenatal family engagement or better follow-up after discharge.

The next step is larger, controlled and preferably multi-centre research. We need to know whether these approaches produce sustained improvements in confidence, exclusive breastfeeding and breastfeeding duration, whether benefits persist after discharge, and what adaptation and resources are required in different settings.

If those questions are answered, a low-cost, locally co-designed model could have relevance well beyond a single hospital.

REFERENCE

- Kaur, D., Kumar, R., Kochar, I. S. (2026). Rapid mixed-methods assessment and institutional co-design of breastfeeding support to enhance maternal confidence in a teaching hospital in North India. Journal of Human Lactation. DOI
- Dennis, C. L. (2003). The Breastfeeding Self-Efficacy Scale: Psychometric assessment of the short form. Journal of Obstetric, Gynecologic & Neonatal Nursing, 32(6), 734–744. DOI
- World Health Organization, UNICEF. (2018). Implementation guidance: Protecting, promoting and supporting breastfeeding in facilities providing maternity and newborn services – The revised Baby-friendly Hospital Initiative 2018. Geneva: World Health Organization.

ABOUT THE AUTHORS

Dr. Inderdeep Singh Kochar is Professor of Pediatrics at Dr. S.S. Tantia Medical College, Hospital and Research Centre, Sriganganagar. His work spans pediatric clinical care, maternal-child health, breastfeeding support and pragmatic clinical research. As part of the team that conducted the rapid mixed-methods breastfeeding study, he contributed to investigation, methodology, validation and manuscript development. This article translates those findings into practical lessons for confidence-focused, family-inclusive hospital support.



DOI: https://doi.org/10.67831/Sci.Factors.2026.1688

SCIENCE DESK

Breathing on Their Own Again: A New Approach After Brain Injury



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Scientific Profile | Organization Link | Factors Press

AREAS OF EXPERTISE
Acquired Brain Injury • Neurorehabilitation • Tracheostomy Management • Decannulation

OUTLOOK

Removing a tracheostomy tube can mark an important step in recovery after brain injury, but deciding when a patient is ready requires careful assessment. In this conversation, Dr. Sooraj Mavilakandy explains how a structured bedside approach combines checks of breathing, secretion management, aspiration risk and vocal-cord movement using ultrasound. He discusses its promising early findings, why specialist airway examination remains essential in uncertain cases, and the further research needed to support safer decisions in neurorehabilitation.

Q *Why is deciding when to remove a tracheostomy particularly challenging in patients recovering from brain injury, and what are the risks of removing it too early or keeping it for too long?*

A For someone recovering from an acquired brain injury, removal of a tracheostomy tube can be an important step in rehabilitation. The difficult part is deciding when the person is ready. Breathing comfortably is only one part of the decision. The person also needs to manage secretions, protect the airway during swallowing and have adequate upper-airway and laryngeal function. Brain injury can affect several of these functions at the same time, and recovery does not occur at the same rate in every patient. A person may therefore appear clinically stable but still have difficulty clearing secretions or protecting the airway. Removing the tube too early can lead to respiratory deterioration, airway compromise, aspiration or the need for recannulation. On the other hand, leaving the tube in place longer than necessary can prolong exposure to tracheostomy-related problems and may interfere with communication, swallowing and participation in rehabilitation. The practical question is therefore: is this particular patient ready to breathe, clear secretions and protect the airway safely without the tracheostomy?

Q *Your research explores a structured bedside approach for determining whether a patient is ready for tracheostomy removal. Could you explain how this approach works in simple terms?*

A We wanted to see whether several relatively simple bedside observations could be brought together into a structured assessment. We prospectively studied 36 adults with chronic acquired brain injury undergoing neurorehabilitation. The protocol looked at four areas: how well the patient tolerated tracheostomy capping, how often suctioning was required, whether there was evidence of aspiration on a modified Evans blue dye test, and whether the vocal cords moved symmetrically on laryngeal ultrasound. For capping, participants were observed for at least 48 hours. Significant oxygen desaturation, respiratory distress, marked tachypnoea, or stridor were considered reasons not to pass this part of the assessment. Suction requirements were recorded prospectively, with no more than two suction episodes per 24-hour period required during the observation period. The four findings were considered together. We then compared the bedside classification with a blinded nasopharyngolaryngoscopic examination performed by otolaryngologists. In simple terms, the protocol was designed to provide a consistent bedside way of assessing whether a patient appeared suitable for further consideration of decannulation, rather than relying on a single sign or test. It was intended to support clinical decision-making, not replace specialist airway assessment when this was clinically indicated.

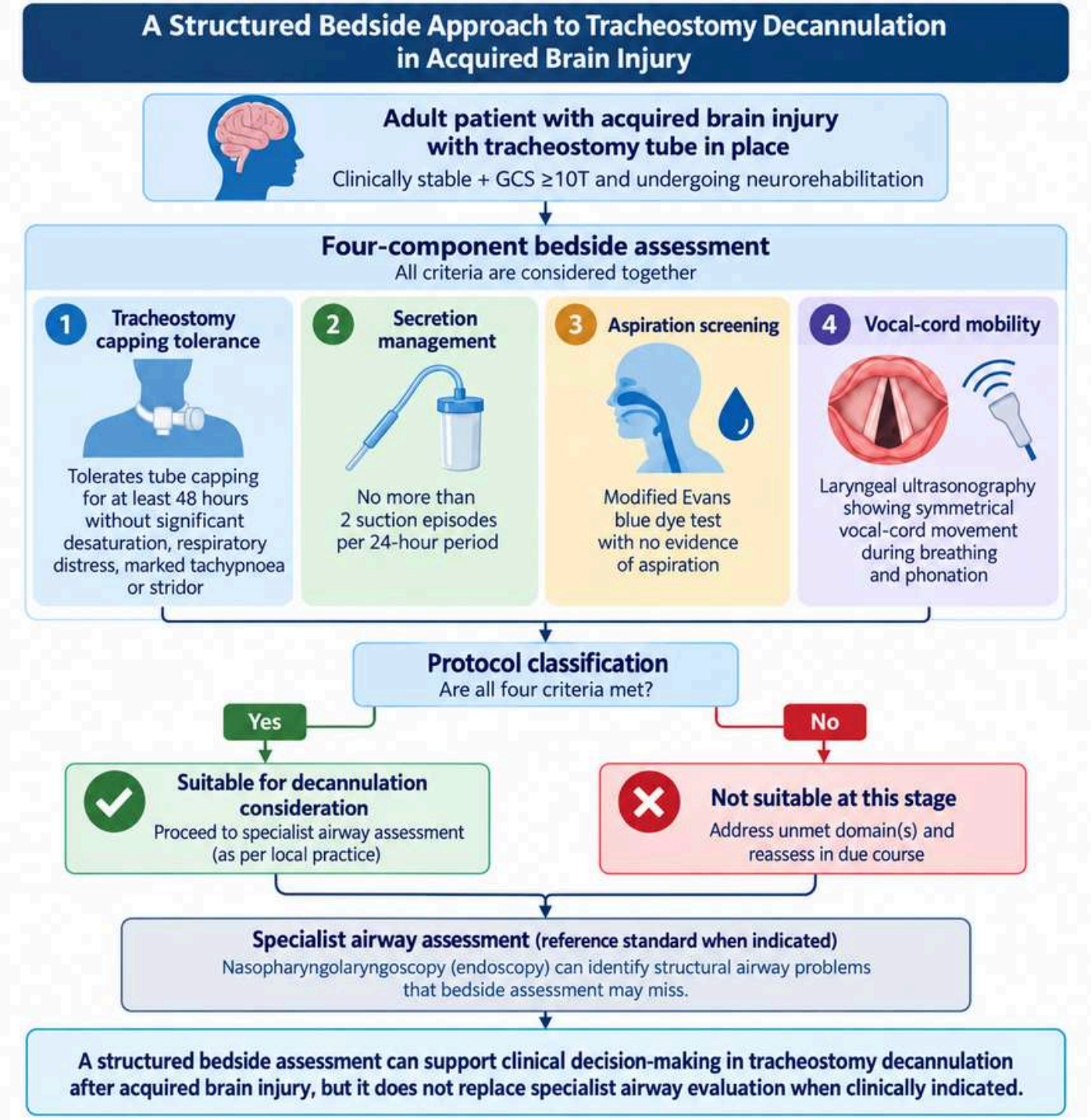


Figure 1. Conceptual representation of the four components evaluated in the prospective bedside protocol. The protocol is intended to support clinical decision-making and does not replace specialist airway evaluation when clinically indicated.

Q *Laryngeal ultrasound is an important part of this approach. What can it reveal about a patient's vocal cords and airway, and what advantages does it offer as a non-invasive bedside tool?*

A Laryngeal ultrasound allows the movement of the vocal cords to be observed through the skin of the neck. In our study, a trained radiologist used a high frequency linear probe to assess whether the vocal cords opened and closed symmetrically during breathing and phonation. The main practical advantage is that it is non-invasive and can be performed at the bedside. It does not require an endoscope to be passed through the nose or throat, and the assessment can potentially be repeated when

needed. This may be particularly useful in rehabilitation settings where specialist endoscopic assessment is not immediately available. There are also limitations. Ultrasound does not provide the same direct view of the airway that endoscopic examination provides. Image quality and interpretation can also depend on the patient and the operator's experience. For this reason, we used ultrasound as one component of a four-part protocol. Our study does not show that laryngeal ultrasound alone can determine whether a patient is ready for decannulation.

Q *The bedside protocol showed 96% sensitivity and about 92% overall accuracy compared with specialist airway examination. What do these findings mean from a clinical perspective?*

A Of the 36 participants, 25 were considered suitable for decannulation according to the reference nasopharyngolaryngoscopic assessment. The bedside protocol identified 24 of these 25 participants, corresponding to a sensitivity of 96%. Overall, the bedside classification agreed with the specialist assessment in 33 of the 36 participants, giving an accuracy of 91.7%. Specificity was 81.8%, and the Cohen's kappa value was 0.80, indicating substantial agreement in this cohort. In clinical terms, these findings suggest that the protocol was able to identify most of the participants who were considered suitable for decannulation by the reference assessment. At the same time, these findings come from a relatively small, single-center study involving 36 patients. The confidence intervals around some of the estimates were wide. The results should therefore be viewed as evidence of potential usefulness rather than proof that the bedside protocol is equivalent to endoscopic assessment.

Q *Could this type of bedside assessment be particularly useful in hospitals and rehabilitation centres where access to specialists or endoscopic examinations is limited?*

A There is a potential practical role for this type of assessment in these settings. A structured approach can help clinicians consider the same important factors in a consistent way, even when an otolaryngology service or endoscopic examination is not immediately available. This could be particularly relevant in neurorehabilitation, where patients may remain in rehabilitation facilities for prolonged periods and decisions about tracheostomy management are made as neurological recovery progresses. However, our study did not measure costs, specialist referral rates, procedure utilisation, or health-system outcomes. We therefore cannot conclude from this study that the protocol reduces resource use or replaces specialist services. A reasonable way to view the protocol is as a bedside assessment and decision-support approach. It may help clinicians identify patients who appear suitable to proceed to the next stage of assessment, while patients with concerning or uncertain findings can be referred for specialist evaluation.

Q *Your study also identified situations where bedside assessment could miss structural airway problems. What does this tell us about the continued role of endoscopy and specialist evaluation?*

A This was one of the clearest lessons from the study.Two participants passed the bedside protocol but were found on nasopharyngolaryngoscopy to have suprastomal granulation tissue causing approximately 50% narrowing of the airway. These structural abnormalities were not detected by the bedside assessment. This illustrates the difference between assessing whether a patient appears physiologically ready for decannulation and directly examining the airway. A bedside assessment can provide useful information about breathing, secretion management, aspiration risk, and vocal-cord movement, but it cannot identify every structural abnormality. The findings therefore support a complementary approach. Endoscopy remains important when structural airway disease is suspected, when bedside findings do not fit the clinical picture, or when there is uncertainty about whether decannulation is appropriate. In our study, the bedside protocol was intended to support clinical decision-making, not to replace specialist airway examination when it is clinically indicated.

Q *Looking ahead, how do you see this approach influencing tracheostomy care and neurorehabilitation, and what further research is needed before it can be adopted more widely?*

A The main potential value of this approach is not a new single test, but a more structured way of bringing several bedside observations together. In

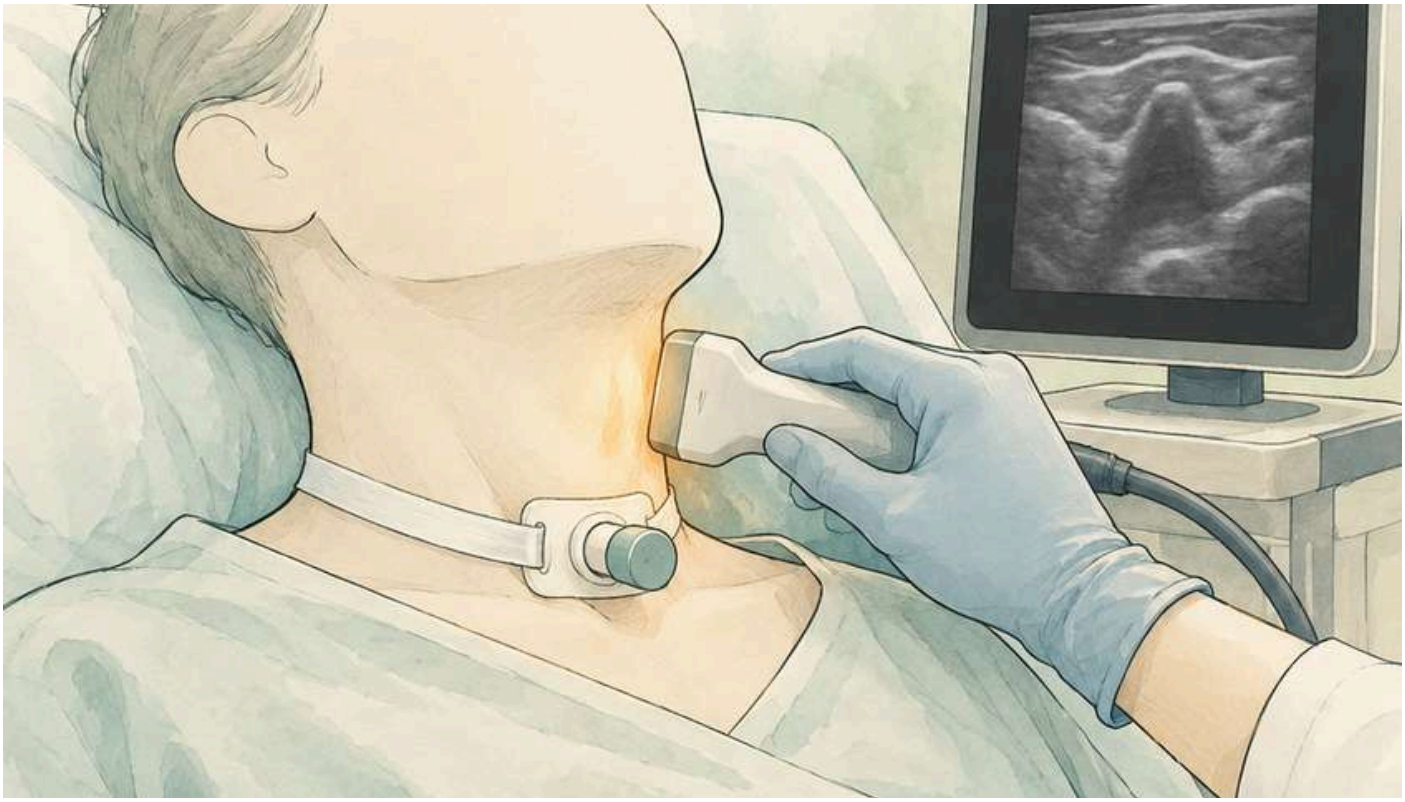
neurorehabilitation, decannulation is part of a wider process of recovery involving breathing, airway protection, swallowing, communication, and participation. Our study provides an initial prospective evaluation of the composite protocol against blinded specialist airway assessment. It does not establish whether using the protocol improves long-term rehabilitation outcomes or reduces healthcare utilisation. Before the approach can be used more widely, it needs to be tested in larger and more diverse patient populations and across multiple centers. Future studies should also examine how consistently different clinicians can perform and interpret the ultrasound assessment, how much each component contributes to the overall result, and how the protocol performs in different rehabilitation and acute-care settings. The message from our study is therefore fairly simple: a structured bedside assessment may help clinicians identify patients who are ready for consideration of decannulation, but it should complement clinical judgement and specialist airway assessment when clinically indicated.

REFERENCE

- Mavilakandy, S., George, J., Chinniah, P. K., et al. Prospective validation of a non-invasive bedside protocol for tracheostomy decannulation in acquired brain injury with otolaryngologic concordance. Brain Injury 40(12), 1115–1124 (2026). DOI
- Enrichi, C., Battel, I., Zanetti, C., et al. Clinical criteria for tracheostomy decannulation in subjects with acquired brain injury. Respiratory Care 62(10), 1255–1263 (2017). DOI
- Gallice, T., Cugy, E., Branchard, O., et al. Predictive factors for successful decannulation in patients with tracheostomies and brain injuries: A systematic review. Dysphagia 39(4), 552–572 (2024). DOI

ABOUT THE AUTHORS

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DOI: https://doi.org/10.67831/Sci.Factors.2026.1688

SCIENCE DESK

When 'Stay Positive' Goes Too Far: The Hidden Psychology of Toxic Positivity

OUTLOOK

As awareness of mental health grows, understanding the difference between genuine optimism and toxic positivity is becoming increasingly important. In this article, Dr. Alphonsa Jose K and Deepika Premlal highlight how the pressure to remain positive can sometimes invalidate genuine emotions and negatively affect psychological well-being. Drawing on their recent research, the authors emphasize the need for reliable tools to measure toxic positivity and further studies exploring its effects on individuals, relationships and social environments. Their work also encourages a shift towards more compassionate approaches to mental health, particularly in families, workplaces, educational institutions and healthcare settings. Ultimately, the message is clear: emotional well-being is not about staying positive at all times, but about acknowledging difficult emotions, expressing them openly and receiving meaningful support.



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AREAS OF EXPERTISE
Toxic Positivity • Positive Mental Health • Mental Health Literacy • Community Mental Health

Q *What exactly is "toxic positivity," and how is it different from having a genuinely positive or hopeful outlook on life?*

A Toxic positivity is different from authentic positivity, as positivity is mandated without considering the experiences and circumstances of the person. For example, an employee who has contributed significantly to an organisation receives a low performance rating from their boss. When the employee raises concerns about this rating, instead of addressing the issue, the boss may force the employee to look at the brighter side, saying that others have received even lower ratings, their marks are average, and they should be happy about it. The employee's negative emotional response is considered inappropriate, and they are encouraged to focus only on the positive aspects. In such situations, this pressure to remain positive can become a source of harm, burnout, and other negative outcomes rather than promoting well-being.

A positive mindset is indeed a powerful coping mechanism. Differentiating toxic positivity from authentic positivity is essential: toxic positivity compels people to minimise and suppress negative feelings, whereas authentic positivity recognises negative emotions as adaptive, informational signals and encourages constructive efforts to address them. Although maintaining a hopeful mindset during adversity serves as a valuable coping mechanism, applying positivity in an insincere, blanket manner that ignores complex feelings can be damaging. It reinforces unrealistic expectations, hinders genuine emotional expression, and discourages people from seeking help.

Q *Your research identifies four important dimensions: emotional suppression, emotional invalidation, unrealistic optimism, and disingenuous happiness. Could you explain these in simple terms with some everyday examples?*

A Emotional suppression involves hiding or masking one's true feelings rather than expressing them openly. For example, someone feeling anxious before a presentation may say, “Totally fine, no stress!” despite feeling otherwise. Research suggests that repeatedly suppressing emotions can worsen mood and reduce positive feelings. Emotional invalidation occurs when someone's feelings are dismissed or considered unimportant. For instance, telling a friend experiencing heartbreak, “It's good for you; there are so many others to choose from,” may unintentionally make them feel guilty or ashamed of their emotions. Unrealistic optimism involves expecting positive outcomes regardless of circumstances, often overlooking genuine difficulties. When someone loses a job, saying “Everything happens for a reason; something better will come” without offering practical support is one example. Disingenuous happiness refers to displaying happiness despite feeling otherwise, often due to social expectations. For example, someone experiencing stress and burnout may still post “blessed and grateful” on social media to maintain a positive image. These four dimensions often overlap.

Even a simple statement such as “Leave it, it's fine, it will be better soon” can simultaneously dismiss genuine emotions, encourage unrealistic optimism, and create pressure to appear happy.

Q *Why can phrases such as “just stay positive” or “look on the bright side,” although usually well-intentioned, sometimes make a person experiencing distress feel worse rather than better?*

A Phrases like these frame negative emotions as something to be corrected or dealt with, rather than something that should be understood. The phrase is aimed at reducing the suffering , but the listener is given the onus of fixing the negative emotions, and lead to judgements along the lines of they are choosing negativity or misfortune by dwelling on it. The oversimplification of complex situations using these, can trivialize the distress of the person, and may lead to self blame. Imagine, somebody got a serious medical diagnosis, but the partner or a friend says, ‘ Think positive! Everything will be fine!, you may feel like you are wrong for being afraid in the setting. The pressure to ‘stay positive’ can create secondary emotions of shame and guilt. Other famous phrases like happiness is a choice, good vibes only etc transfers the onus of emotional experience to the person struggling already, which can further trigger stigma and minimizes the person’s struggles, than validating them.

The toxic positivity or positivity mandate did not appear out of nowhere, the social-cultural antecedents are societal expectations, social media influence, cultural and historical influence, and misinterpretation of positive psychology movement . The ideas like New thought movement, and American Dream, promoted positive thinking as a route to success. While it is inspirational, when we dwell on the idea that positive thinking will alone determine the outcomes, irrespective of the contextual realities are problematic as we have seen already . Best sellers like Rhonda Byrne’s ‘The Secret’ promoted the same idea ,. This belief is not harmful in itself, however, it can contribute to harmful norms like if positive thinking makes things work, then things that don’t work must be your fault, which place the responsibility for wellbeing on the individual, while overlooking the structural issues such as inequality, economic insecurity, and unequal access to opportunity and healthcare, to name a few.

Social media today functions largely as a curated highlights reel, where people showcase their success and achievements while hiding setbacks and doubts. For a person on the viewing side, this can create a reassurance to be positive at all times. Constant exposure to highly curated and idealised content may contribute to the normalisation of a perpetual state of happiness and to an overestimation of positive outcomes, leading to unrealistic optimism . People compare their unfiltered private lives with others’ public curated presentations and conclude their struggles are abnormal and shameful. This results in ordinary negative emotions such as sadness, anxiety, and frustration feeling like evidence of personal inadequacy. Taken together these factors produce a culture that fosters inauthentic self-representation where people learn to suppress, hide or reframe negative feelings to fit what is socially acceptable. This leads to a productivity focused environment where individuals are expected to stay upbeat and resilient regardless of workload, stress or life circumstances.

Q *Can constantly suppressing sadness, fear, anger, or disappointment affect a person’s emotional well-being and relationships over time?*

A Constant suppression of negative emotions can lead to increased distress and worsening mental health

outcomes such as anxiety and depression. Studies have shown that emotional suppression is specifically linked to worsening mood, sympathetic activation, negative feelings about social interactions and continued or worsened emotions alongside a decrease in positive emotions.

It can also undermine the authenticity of relationships. When their distress is invalidated, individuals may feel lonely and isolated, and they may stop sharing how they truly feel. It can also create a mismatch between a person's emotional needs and the support they receive. Someone who genuinely needs their feelings validated and a chance to vent may instead be met with forced optimism, such as being told to "look for the silver lining. "The feeling of being alone, not understood/ even invalidated, even when surrounded by multiple others. Constant emotional suppression can result in sympathetic activation- flight or fight response resulting in physical symptoms as well.

Q *Toxic positivity can also appear in workplaces, schools, and healthcare settings. How can we encourage optimism and resilience without dismissing genuine difficulties or negative emotions?*

A In workplaces, toxic positivity often turns structural concerns like excessive workload, job insecurity, poor leadership or burnout into an employee's responsibility to "stay positive," or practice self-care. As a solution to issues like understaffing or u reasonable performance expectation, organizations create appreciation events, mindfulness sessions or motivational messaging.

In schools, toxic positivity can affect both students and staff alike. Asking teachers to prioritize students and school over their wellbeing, treating poor academic performance solely as student's lack of persistence rather than addressing their actual needs and framing emotional wellness as an individual attitude are examples of that.

In health care settings, overemphasis on courage or "fighting spirit" imply that recovery and survival depend on a patient's attitude rather than disease characteristics, and care provided. These narratives are never against authentic positive attitudes or never push one to abandon hope or positive attitude, rather, positivity should not be overgeneralized or applied to every situation. Additionally, it is important not to dismiss negative emotions, without understanding the root cause or not acknowledging the difficulty or structural concerns. Additionally, ensuring support that matches the distress is also imperative. If a teacher is overwhelmed by their workload, offer practical assistance.

If a patient is distressed by a diagnosis, ask what specifically is troubling them and provide targeted support. Ultimately, an empathetic and authentic approach to emotional well-being, one that embraces the full range of emotions, is warranted, rather than blanketing with mandated positive thinking.

Q *Research on toxic positivity is still developing. What are the most important questions scientists need to investigate next, and could better ways of measuring toxic positivity help us understand its impact on mental health?*

A The Scoping review calls for the need of psychometrically valid measures to operationalize the concept- toxic positivity, which comprehensively address the four major clusters. The most urgent gap is measurement. Imagine trying to study fever without a thermometer. Currently, the only tool available, the IDRlabs 3-Minute Toxic Positivity Test, whose psychometric properties "have not been documented" (p. 3).

As the research in the area is in its nascent stage a good measure will be a game changer. Considering this need, a second-order-construct based tool to measure toxic positivity is patented by the researchers and will be made available for future researchers. Additionally, the evidence available is primarily descriptive or opinion based, hence more valid empirical research on the causes, and consequences are highly recommended. The immediate tools of the cultural translation of toxic positivity, through family, parenting etc need to be addressed.

Note: The page numbers mentioned are corresponding to the original publication's page numbers.

REFERENCE

- Premlal D. and Jose K. A., "Conceptualising toxic positivity: Definition, dimensions, antecedents and consequences: A scoping review of the literature," *Cognition and Emotion*, 2026. DOI

ABOUT THE AUTHORS

Dr Alphonsa Jose K and Ms Deepika Premlal contribute to positive psychology and emotion research by clarifying how well-intentioned positivity can become psychologically harmful. Their scoping review, "Conceptualising toxic positivity," published in Cognition & Emotion (2026), systematically synthesises scattered literature to propose a coherent definition, dimensions, antecedents and consequences. This work establishes conceptual foundations for measurement, intervention and future empirical research on toxic positivity, directly advancing the article's central topic. This work is part of the doctoral thesis of Ms Deepika Premlal, which addresses the dynamic relationship between positive mental health literacy, stigma, toxic positivity, and psychological wellbeing among Indian Youth.



DOI: https://doi.org/10.67831/Sci.Factors.2026.1691

SCIENCE DESK

Natural Defenses in Meghalaya's Traditional Potatoes Against the Tuber Moth Insect Pest

OUTLOOK

Traditional potato varieties may hold valuable clues to protecting crops from pests. In this Science Desk conversation, Dr. Kennedy Ningthoujam and Mr. Shashikumar E. Shivannanavara explore how Meghalaya's local potatoes resist the potato tuber moth, which damages crops in both fields and storage. They explain how tiny leaf hairs and natural defensive chemicals help discourage egg laying and feeding, and why conserving these varieties matters. Their findings could guide breeding efforts to combine natural pest resistance with higher yields and reduce reliance on chemical pesticides.



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AREAS OF EXPERTISE
Arthropod Diversity and Pest Management (Biorational approaches)



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AREAS OF EXPERTISE
Pest Management (Biorational approaches)

Q *Potato tuber moth is a destructive insect pest of potato crops. What makes this pest particularly challenging for potato growers, both in the field and during storage?*

A The potato tuber moth is especially destructive because it is a field-cum-storage pest. It can damage potato crops before harvest and continue causing losses during storage. Its larvae remain concealed inside plant tissues and tubers, making the pest difficult to detect and control.

Adult moths lay eggs on leaves, stems, and exposed tubers. The larvae burrow into leaves and stems, forming mines, and may also tunnel directly into tubers. This reduces plant vigor and damages marketable potatoes. Larvae inside the tubers are difficult to detect and are protected from insecticides. Infested tubers may rot and eventually become unmarketable.

The pest can also continue developing in stored potatoes, particularly when tubers are exposed and storage conditions are warm. Therefore, even a small infestation entering the store can multiply rapidly and spread, leading to significant post-harvest losses.

Q *What motivated you to investigate Meghalaya's traditional potato varieties as potential sources of natural resistance to the potato tuber moth?*

A The main motivation for investigating Meghalaya's traditional potato varieties was their unique genetic diversity and long history of cultivation under local environmental conditions. These varieties have been conserved and cultivated by farmers over generations and may possess naturally occurring traits that confer tolerance or resistance to important insect pests, including the potato tuber moth. Such locally adapted genetic resources therefore represent a valuable source of potential pest resistance.

Another important motivation was the growing concern over the dependence on chemical pesticides for managing potato tuber moth. Excessive or repeated pesticide application can increase production costs and may adversely affect beneficial organisms, the environment, and food safety.

Identifying naturally resistant potato varieties could therefore provide an alternative, environmentally safer, and more sustainable approach to pest management.

The study was also motivated by the possibility of combining resistance traits from Meghalaya's traditional varieties with the high-yielding characteristics of commercial cultivars. Although some traditional varieties may have comparatively lower yields, their natural resistance and biochemical defense mechanisms could serve as valuable sources of resistance in future breeding programs. Thus, the investigation aimed not only to identify traditional potato varieties with resistance to potato tuber moth but also to assess their potential as genetic resources for developing high-yielding, pest-resistant potato cultivars with reduced dependence on chemical pesticides.

Q *Phan San Minit and Lah Ksain showed particularly strong resistance in your study. What characteristics distinguished these varieties from the more susceptible commercial potatoes?*

A The local potato varieties Phan San Minit and Lah Ksain showed comparatively higher densities of both glandular and non-glandular trichomes than the susceptible varieties. These local varieties were found to be comparatively more resistant to potato tuber moth than the commercial varieties Kufri Jyoti and Kufri Megha.

The lower preference of potato tuber moth for Phan San Minit and Lah Ksain was observed in terms of both oviposition and feeding. The expression of resistance was positively associated with higher glandular and non-glandular trichome density on the leaves, greater trichome length, and higher concentrations of defensive biochemical compounds.

Among the biochemical factors, higher levels of the glycoalkaloids α-solanine and α-chaconine, along with phenolic compounds such as chlorogenic acid, caffeic acid, and flavonoids, were associated with greater resistance compared with the susceptible varieties Kufri Jyoti and Kufri Megha.

Thus, the resistance observed in Phan San Minit and Lah Ksain appears to be associated with a combination of physical defenses (trichomes) and biochemical defenses (glycoalkaloids and phenolic compounds), which may reduce potato tuber moth oviposition and feeding.

Q *Your findings highlight glandular and non-glandular trichomes as important physical defenses. How do these structures help reduce egg laying and feeding by the potato tuber moth?*

A Trichomes are often the first plant structures encountered by arthropods when they land on or move across plant surfaces. Therefore, they play an important role in antixenosis resistance, a type of resistance that deters insect feeding and oviposition. In many crops, particularly solanaceous plants, resistance is associated with the presence, type, density, and morphology of trichomes.

Trichomes are broadly classified into two major types: glandular and non-glandular. Glandular trichomes possess a glandular head and can contribute to plant defense by producing and releasing toxic or deterrent compounds. They may also trap insects through sticky secretions and release defensive chemicals that reduce herbivore activity. In addition, glandular trichomes can interact with herbivores and attract their natural enemies, thereby contributing to indirect plant defense. The size and structure of the glandular head may therefore provide an indication of its potential defensive or toxic activity.

In contrast, non-glandular trichomes generally do not produce defensive chemicals but provide physical protection. Their rigid and often pointed structures can interfere with insect movement, feeding, and oviposition. In Solanum species, non-glandular trichomes are commonly spike-like and can act as physical barriers against herbivores. Differences in their size, density, and structure may influence their effectiveness in protecting plants from insect pests as well as from certain abiotic stresses.

Thus, both glandular and non-glandular trichomes can contribute to insect resistance through chemical and physical mechanisms, respectively. Their density, length, and morphology may therefore be important factors in determining the resistance of potato varieties to potato tuber moth.

Q *Resistant varieties also contained higher levels of glycoalkaloids and phenolic compounds. How do these natural chemicals contribute to defense against the insect pest?*

A Glycoalkaloids play an important role in the chemical defense of potato plants against insect pests. They have been reported to interfere with the insect nervous system by inhibiting the enzyme

acetylcholinesterase (AChE) and by damaging gastrointestinal cell membranes. These effects can disrupt digestion and impair other physiological functions, thereby reducing insect growth and survival. Phenolic compounds, particularly chlorogenic acid, caffeic acid and various flavonoids, also contribute to plant defense. Besides their antioxidant properties, these compounds can exert insecticidal or deterrent effects by interfering with insect metabolism and development. Phenolic compounds can participate in redox reactions and generate reactive compounds that may cause cellular damage in insects.

However, resistance to potato tuber moth cannot be attributed to glycoalkaloids or phenolic compounds alone. Their defensive effects depend on several factors, including compound concentration, tissue distribution, cultivar, insect developmental stage, and interactions with other plant defense mechanisms. Therefore, the resistance of a potato variety is likely to result from the combined effects of multiple physical and biochemical defense traits rather than from a single compound.

Q *What do these findings tell us about the importance of conserving Meghalaya's traditional potato varieties, especially as high-yielding commercial varieties increasingly replace local germplasm?*

A The traditional potato varieties of Meghalaya were comparatively richer in nutrients than the commercial varieties and contained substantial levels of biochemical compounds associated with resistance to insect pests. These naturally occurring compounds may contribute to plant defense while remaining within levels considered safe for human consumption. However, the traditional varieties generally produced lower yields than the commercial cultivars.

The inherent resistance of these traditional varieties to insect pests suggests that their cultivation may require fewer applications of chemical pesticides for effective pest management. The presence of naturally occurring defensive compounds can reduce plant and tuber susceptibility to insect infestation, particularly by potato tuber moth. Consequently, the use of resistant traditional varieties could help reduce dependence on chemical pesticides, lower production costs, and minimize the environmental and food-safety risks associated with excessive pesticide use.

Therefore, these traditional potato varieties represent valuable genetic resources for future potato breeding programs. Their resistance traits could be incorporated into high-yielding commercial cultivars through suitable breeding approaches. Combining the natural pest resistance and nutritional characteristics of traditional varieties with the high-yielding potential of commercial cultivars could contribute to the development of high-yielding, nutritionally improved, and potato tuber moth-resistant varieties, thereby promoting more sustainable potato production.

Q *Looking ahead, how could these resistant traditional varieties and their defensive traits be incorporated into breeding programs to develop high-yielding, pest-resistant potatoes with reduced reliance on chemical pesticides?*

A Looking ahead, the resistant traditional potato varieties of Meghalaya could serve as valuable genetic resources for the development of high-yielding and potato tuber moth-resistant cultivars. Their inherent resistance and naturally occurring defensive biochemical compounds could be incorporated into breeding programs through hybridization with high-yielding commercial varieties. The resulting progenies can then be evaluated and selected for desirable combinations of pest resistance, nutritional quality, agronomic performance, and yield.

Further characterization of the morphological and biochemical traits associated with resistance would help in understanding the specific mechanisms responsible for tolerance to potato tuber moth. Once validated, these traits could be used as selection criteria in breeding programs. Where appropriate molecular markers are identified, marker-assisted selection could further accelerate the development of resistant cultivars.

Combining the resistance traits of traditional Meghalaya varieties with the high-yielding and agronomically desirable characteristics of commercial cultivars could result in improved potato varieties that maintain high productivity while showing greater resistance to potato tuber moth.

The development and adoption of such resistant cultivars could also reduce dependence on chemical pesticides. Since resistance is inherently expressed by the plant, fewer pesticide applications may be required to manage pest populations, potentially reducing production costs, pesticide residues, and adverse effects on beneficial organisms and the environment. Resistant cultivars can further be integrated with other components of integrated pest

management (IPM) to develop more sustainable and environmentally friendly potato production systems.

Thus, Meghalaya's traditional potato varieties represent an important reservoir of genetic diversity and resistance traits. Their effective utilization in future breeding programs could contribute to the development of potato cultivars that combine high yield, improved nutritional quality, and resistance to potato tuber moth, while reducing reliance on chemical pesticides and promoting sustainable potato production.

REFERENCE

- Shivannanavara, S. E., Ningthoujam, K., Sorokhaibam, M., et al. Morpho-physical and biochemical traits associated with potato (Solanum tuberosum L.) genotypes conferring resistance to potato tuber moth, Phthorimaea operculella (Zeller). Scientific Reports 16, 23848 (2026). DOI

ABOUT THE AUTHORS

Dr. Kennedy Ningthoujam and Mr. Shashikumar E. Shivannanavara work on sustainable approaches to crop pest management. Dr. Ningthoujam is affiliated with the College of Postgraduate Studies in Agricultural Sciences, Central Agricultural University, Umiam, Meghalaya. His research focuses on insect diversity, beneficial organisms and natural pest resistance in crops. Their article explores how leaf hairs and natural defensive chemicals contribute to potato tuber moth resistance in Meghalaya's traditional potato varieties, highlighting their potential for breeding pest-resistant potatoes.



DOI: https://doi.org/10.67831/Sci.Factors.2026.1694

SCIENCE DESK

A Clearer View of Acid Reflux: Improving Assessment During Endoscopy



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Scientific Profile
Organization Link
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AREAS OF EXPERTISE
Advanced Therapeutic Endoscopy • ERCP • Endoscopic Ultrasound

OUTLOOK

Acid reflux is common, but understanding why it occurs requires looking beyond symptoms to the natural barrier between the esophagus and stomach. When this barrier becomes structurally disrupted, stomach contents can more easily flow upward and cause reflux. In this conversation, Dr. K.G. Sabu explains how a more structured approach during endoscopy can assess these anatomical changes consistently, helping doctors better understand the severity of reflux disease and potentially paving the way for more informed treatment decisions.

Q *What causes acid reflux, and why is the barrier between the stomach and esophagus important?*

A Gastroesophageal reflux disease (GERD) is one of the most common gastrointestinal disorders worldwide. Although symptoms such as heartburn and regurgitation are familiar to many people, the reason stomach contents flow back into the esophagus is more complex. A key factor is the anti-reflux barrier at the junction between the esophagus and stomach, known as the esophagogastric junction (EGJ). This barrier is formed by several structures working together, including the lower esophageal sphincter, crural diaphragm, and gastroesophageal flap valve. Normally, these structures help prevent stomach contents from flowing back into the esophagus. When this junction becomes anatomically disrupted for example, through widening of the hiatal opening, upward movement of the stomach, or loss of the flap-valve mechanism the barrier becomes less effective and reflux can occur more easily. Upper gastrointestinal endoscopy allows doctors to directly examine this junction, but the findings need to be assessed in a consistent and clinically meaningful way. In our prospective study of 458 patients, we evaluated the American Foregut Society (AFS) classification of EGJ integrity to determine whether this structured approach could provide a more reliable assessment than conventional methods.

Q *Why was a new classification needed?*

A For many years, endoscopists have used the Hill classification to describe the gastroesophageal flap valve. It grades the appearance of the valve from a relatively normal configuration to severe disruption. The Hill system has been useful but focuses primarily on the visual appearance of the flap valve while other barrier components particularly hiatal diameter and hernia extent are less precisely incorporated.

The AFS classification was developed to make the evaluation more comprehensive and structured. Instead of asking the endoscopist to make a predominantly visual judgement about one component, it combines several anatomical measurements and provides a standardized framework for examining the junction.

Q *What do the "L, D and F" components of the AFS classification mean?*

A One useful feature of the AFS system is that it breaks EGJ anatomy into three readily understandable components: length, diameter and flap valve—the LDF components.

Length (L) refers to the axial length of hiatal herniation. In practical terms, it evaluates whether part of the stomach has migrated upward through the diaphragm and, if so, by how much. Greater axial separation indicates increasing anatomical disruption.

Diameter (D) describes the width of the diaphragmatic or hiatal opening. The diaphragm normally surrounds the lower esophagus relatively

closely. As the crura separate and the opening becomes wider, the external component of the anti-reflux barrier becomes progressively weaker.

Flap valve (F) assesses whether the gastroesophageal flap valve is preserved or lost. A well-formed flap valve provides an additional mechanical barrier to reflux. Flattening or disappearance of this valve is an early sign that normal EGJ anatomy has been disturbed.

The strength of the AFS approach is therefore not simply that it produces another grade. It encourages the endoscopist to examine the individual anatomical components that contribute to the anti-reflux barrier and then integrate them into an overall assessment.

Q *How reproducible was the AFS classification in our study?*

A For any classification to be clinically useful, different physicians should be able to apply it consistently. We therefore made reproducibility an important part of our study.

We prospectively included 458 patients, and endoscopic recordings were evaluated independently by four experienced endoscopists who were blinded to one another's assessments. The recordings were also reassessed to evaluate whether the same endoscopist would give a similar grade on a separate occasion.

The AFS classification demonstrated substantial reproducibility. Quadratic weighted kappa values for interobserver agreement ranged approximately from 0.65 to 0.79, with an average of about 0.72. Intraobserver agreement was similarly strong, indicating that individual endoscopists generally reproduced their own assessments when the recordings were reviewed again.

Importantly, the structured AFS approach showed better overall consistency than the conventional Hill classification. This is clinically relevant because a grading system becomes much more useful when a Grade II or Grade III assessment has approximately the same meaning regardless of which trained endoscopist performs the examination.

Q *Why is the relationship with symptoms and esophagitis important?*

A One of the strongest findings was the relationship between AFS grade and GERD severity. The Spearman correlation with the validated GERD Health-Related Quality of Life score was approximately 0.88, exceeding the corresponding value for the Hill classification.

We also observed a striking stepwise increase in erosive esophagitis as EGJ disruption became more severe. Esophagitis was present in only about 8% of patients in the lowest AFS category, increasing progressively across grades and reaching approximately 84% in Grade IV.

This biological gradient is important. It suggests that the AFS classification is not merely describing anatomical differences that look interesting during endoscopy. Increasing structural disruption appears to parallel increasing clinical expression of reflux disease.

Q *Could AFS grading eventually help guide treatment?*

A Most patients with GERD are managed initially with lifestyle measures and acid-suppressive therapy; more complex cases may require endoscopy, reflux monitoring, and manometry. A standardized EGJ description could help integrate these findings, distinguishing patients with severe structural disruption and pathological reflux from those with intact anatomy and normal reflux testing.

AFS grade should not yet be used in isolation for intervention decisions. Prospective evidence linking grades to objective reflux measurements and treatment response will be essential.

Q *What are the next steps for AFS classification, and how could it improve GERD assessment in the future?*

A Our study provides prospective evidence supporting the clinical relevance and reproducibility of the AFS classification, but broader validation is still needed before it can be widely incorporated into routine clinical practice. The first step will be multicentre studies involving endoscopists with different levels of experience. This will help determine whether the reproducibility we observed can be achieved across different clinical settings, particularly when supported by standardized training. AFS grades should also be systematically compared with objective physiological measurements, including prolonged pH or impedance-pH monitoring and high-resolution esophageal manometry. Such studies could clarify how the anatomical changes seen during endoscopy relate to the actual burden of reflux and the function of the anti-reflux barrier. Longer-term studies will also be important to determine whether AFS classification can predict clinically meaningful

outcomes, such as response to proton-pump inhibitors, progression of reflux disease, and outcomes following endoscopic or surgical anti-reflux procedures. Emerging technologies may further improve the consistency of this assessment. High-quality video documentation, automated measurements, and eventually artificial-intelligence-assisted interpretation could reduce observer dependence and make EGJ assessment more standardized across centres. Traditionally, endoscopy in GERD has focused largely on its consequences, such as esophagitis or Barrett's esophagus.

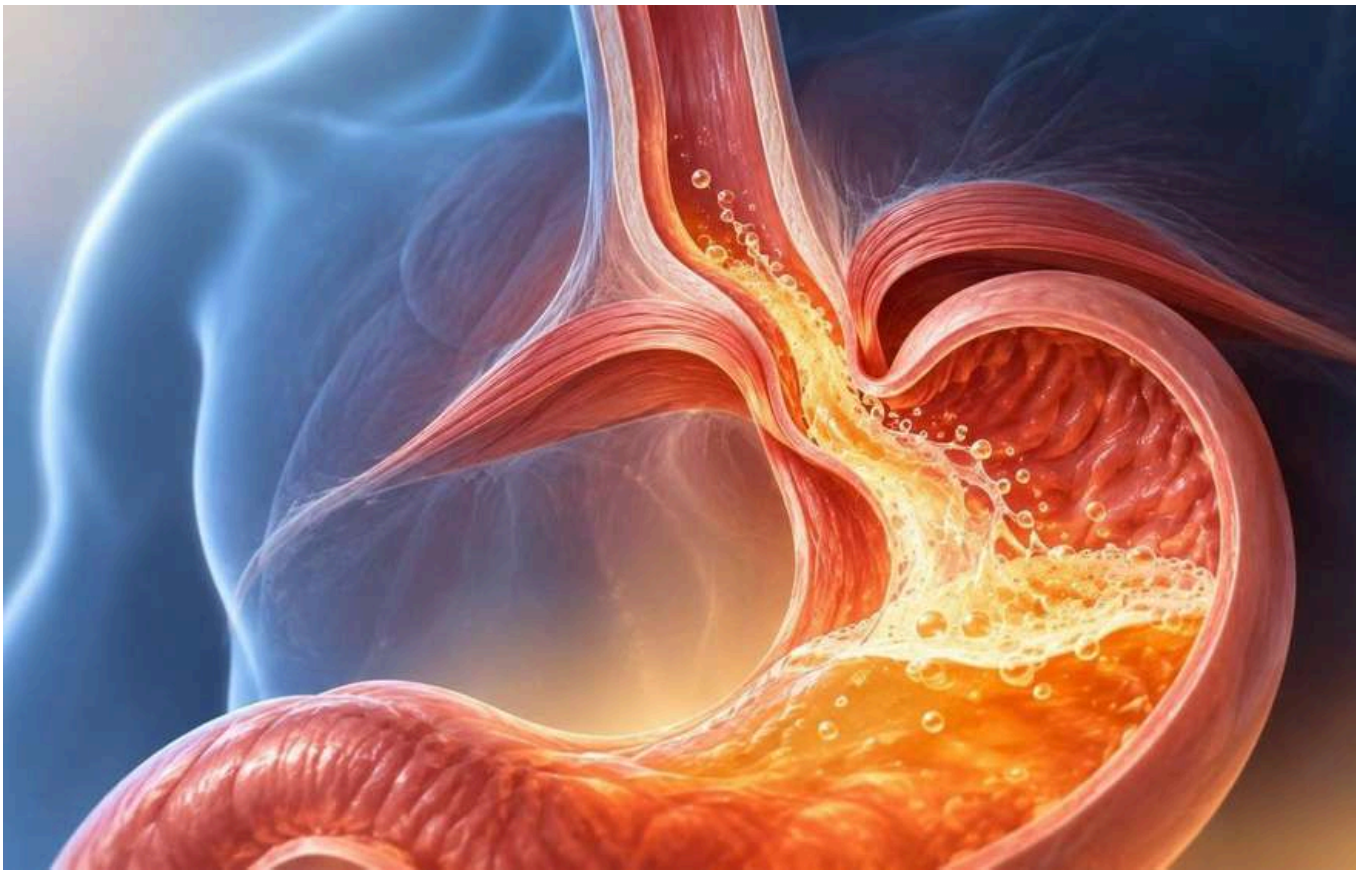
A structured assessment of EGJ integrity shifts some of this attention toward the underlying anatomy that contributes to reflux. The AFS classification brings measurable anatomical features together with flap-valve assessment, and our findings show that it can be applied reproducibly, with increasing grades paralleling increasing disease severity. The next challenge is to integrate this anatomical information with symptoms, reflux monitoring, and esophageal physiology to support clinical decision-making. With further validation, standardized assessment of EGJ integrity could become an important part of how we understand, evaluate, and ultimately manage GERD.

ABOUT THE AUTHORS

Dr. K.G. Sabu and colleagues prospectively evaluated the American Foregut Society classification of esophagogastric junction integrity in 458 patients with assessment by four independent endoscopists. Their work demonstrated strong reproducibility and a close relationship between increasing anatomical disruption, GERD symptom severity and erosive esophagitis, supporting a more structured approach to endoscopic evaluation of the anti-reflux barrier.

REFERENCE

- Sabu KG, Kumar VV, Kumar KVV, et al. Prospective Validation of the American Foregut Society Classification of Gastroesophageal Junction Integrity. Clinical Gastroenterology and Hepatology. 2026. DOI
- Nguyen NT, Thosani N, Canto MI, et al. The American Foregut Society White Paper on the Endoscopic Classification of Esophagogastric Junction Integrity. Foregut. 2022. DOI
- American Society for Gastrointestinal Endoscopy. Guideline on the diagnosis and management of gastroesophageal reflux disease. Gastrointestinal Endoscopy. 2025.



DOI: https://doi.org/10.67831/Sci.Factors.2026.1698

SCIENCE DESK

Rare Hemoglobin Variants: Improving Diagnosis Through Integrated Laboratory Testing using Chromatography, Electrophoresis and Mass Spectrometry Techniques



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Scientific Profile | Organization Link | Factors Press

AREAS OF EXPERTISE
Clinical Mass Spectrometry • 'OMICS' technology • Protein sequencing



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AREAS OF EXPERTISE
Hematopathology • Immunology

OUTLOOK

Rare changes in hemoglobin, the protein that carries oxygen in blood, can escape routine testing or be mistaken for more familiar variants. In this conversation, Dr. Deepalakshmi D. Putchen and Dr. Swathi Kulkarni explain how combining electrophoresis, chromatography and mass spectrometry helps uncover these hidden differences. They explore why accurate identification matters for patient care, family screening and genetic counselling, and how better reference libraries and selective confirmatory testing could make the diagnosis of rare hemoglobin variants more reliable.

Q *What are hemoglobin variants, and why is it important to correctly identify even rare variants that may not initially cause obvious symptoms?*

A Hemoglobin is the protein in red blood cells that carries oxygen around the body. In healthy adults it exists mainly as three normal types: HbA, which makes up the vast majority, together with a smaller amount of HbA2 and a trace amount of HbF (fetal hemoglobin). Changes in the genetic makeup of these globin chains lead to hemoglobin variants and thalassemia. Variants usually result from small genetic changes that alter the structure of a globin chain, whereas thalassaemia results from reduced production of one or more globin chains. Sickle cell disease is the best-known example, but hundreds of rarer variants have also been described.

Importantly, carrying a haemoglobin variant does not necessarily mean being ill. Many carriers remain completely healthy, particularly when the variant is inherited from only one parent. Identifying these variants is nevertheless important. A healthy carrier can pass the variant to their children, and if both parents carry certain variants, their child may inherit a serious disorder. Some variants may also cause problems during physiological stress, such as illness, surgery, low oxygen levels or pregnancy. Finally, certain variants can interfere with laboratory tests such as HbA1c, potentially producing misleading results and inappropriate clinical decisions.

Q *Why can rare or compound hemoglobin variants be difficult to identify using routine laboratory tests?*

A Rare or compound hemoglobin variants pose significant diagnostic challenges because routine

laboratory tests like cation-exchange HPLC (CX-HPLC) and capillary electrophoresis (CE) rely fundamentally on physical properties such as charge and hydrophobicity to separate hemoglobin fractions. Consequently, if a rare variant involves an amino acid substitution that does not alter the net charge of the hemoglobin molecule, it will not produce a distinct peak or band, effectively rendering it invisible to these screening methods. Furthermore, rare variants often exhibit retention times or migration patterns that overlap significantly with wild-type hemoglobins like HbA or HbA2. This co-migration can lead to the misclassification of a rare variant as a common one or cause it to be masked entirely by the dominant normal hemoglobin peak. In compound heterozygotes, where more than one variant is present, the complexity increases as peaks may merge, or shift making it difficult to distinguish individual components.

Q *Your research combines techniques such as capillary electrophoresis, HPLC, and mass spectrometry. What does each technique contribute, and why is combining them more effective than relying on a single test?*

A Each technique probes a different physical property of hemoglobin and combining them compensates for the limitations inherent to any single method. Capillary electrophoresis separates hemoglobin variants by their charge-to-size ratio in a liquid-filled capillary, providing high-resolution separation and accurate quantification of common variants and hemoglobin fractions such as HbA, HbA2, HbF etc. CX-HPLC separates hemoglobins by charge and retention time, offering rapid, reproducible screening with reliable quantification. Mass spectrometry determines the precise molecular mass and, when combined with peptide mapping, identifies the exact amino-acid substitution information neither CE nor CX-HPLC can provide.

Relying on one method risks missed or misidentified variants: two different variants can co-migrate on CE or CX-HPLC and appear identical, while MS resolves ambiguous or novel variants that don't match known reference patterns. Together, they give resolution, quantification, and definitive structural identification —necessary for confident diagnosis.

Q *Your studies have identified unusual combinations of hemoglobin variants, including Q-India/D-Punjab and G-Coushatta/D-Punjab. What makes such cases particularly challenging and scientifically interesting?*

A These are compound heterozygous states two different variant hemoglobins inherited together, rather than a single variant paired with normal hemoglobin. That makes them challenging on several fronts.

First, both variants can co-migrate or overlap on CE or CX-HPLC; without confirmatory testing, one variant can mask the other, or the combination can be misread as a single abnormal peak. Second, the challenge lies partly in rarity: each of these variants is uncommon individually, so their co-occurrence is exceptionally rare, with very limited reference data on how they interact analytically or clinically.

Scientifically, these combinations are valuable precisely because they're rare: each confirmed case adds to a very limited body of data on genotype-phenotype correlation, informs accurate carrier counselling, and helps refine diagnostic algorithms for labs encountering similar unusual patterns.

Q *How can more accurate identification of rare hemoglobin variants influence patient care, genetic counselling, and family screening?*

A More accurate identification of rare hemoglobin variants has direct implications across three interconnected areas of care.

For patient management, correct identification prevents misdiagnosis and inappropriate treatment. A variant misread as a common disorder, or one that distorts a routine test like HbA1c, can lead to unnecessary interventions or missed management of an unrelated condition such as diabetes. Precise identification flags variants that behave differently under stress surgery, hypoxia, or pregnancy allowing clinicians to anticipate complications rather than react to them.

For genetic counselling, knowing the precise variant (rather than simply "abnormal hemoglobin") allows accurate risk assessment. Different variants carry different inheritance patterns and clinical severity when paired with other variants, so precise characterization is essential for counselling couples, on the likelihood and severity of disease in their children.

For family screening, identifying a variant in one individual opens the door to testing relatives who may be silent carriers. This is particularly important for rare or novel variants, where a single index case can

reveal that the variant is present within a family or community.

Collectively, accurate variant identification shifts hemoglobinopathy care from reactive to proactive improving individual outcomes while building the reference data needed to guide future diagnoses.

Q *Can an integrated laboratory approach help reduce unnecessary genetic testing while still ensuring that difficult cases receive molecular confirmation when needed?*

A Yes. An integrated approach using CE or CX-HPLC as first-line screening, reserved for cases where results are clear and consistent handles the majority of samples without ever needing molecular testing, since most common variants are readily identified by their characteristic separation patterns.

Molecular or mass spectrometry-based confirmation is then applied selectively, only when results are ambiguous: overlapping peaks, unexpected quantification, discordance between CE and CX-HPLC, or a pattern that doesn't match known reference variants. This tiered strategy avoids blanket use of expensive, time-consuming molecular testing on every sample, while still ensuring that genuinely difficult or novel cases—like unusual double-variant combinations get the definitive characterization they require.

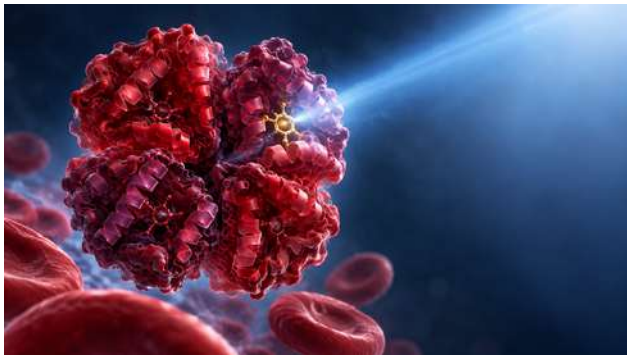
The result is a system that's both cost-effective and diagnostically reliable: routine cases are resolved quickly and cheaply, and laboratory resources are concentrated where they add real value.

ABOUT THE AUTHORS

Dr. Deepalakshmi D. Putchen and Dr. Swathi Kulkarni work in laboratory medicine in Bengaluru, Karnataka. Dr. Putchen heads Research and Development at Neuberg Anand Academy of Laboratory Medicine, specialising in clinical mass spectrometry and protein analysis. Dr. Kulkarni heads Hematology at Neuberg Anand Reference Laboratories, with expertise in hematopathology and immunology. Their research combines established blood tests with mass spectrometry to identify rare hemoglobin variants that routine testing may miss or leave unresolved, supporting more accurate diagnosis, patient care and genetic counselling.

Q *Looking ahead, how do you see advances in mass spectrometry and other diagnostic technologies changing the way rare hemoglobin disorders are detected and characterized?*

A Looking ahead, the greatest advances may come not simply from newer instruments, but from how we combine and interpret different technologies. CE, CX-HPLC and low-resolution mass spectrometry can identify many haemoglobin variants, while molecular testing and high-resolution mass spectrometry can help resolve particularly unusual cases. However, identification by any technology ultimately depends on the quality and breadth of its reference library. Expanding these libraries to include more rare variants, their molecular characteristics and, where available, associated clinical information could substantially improve recognition and confidence in identification. In the future, integrating laboratory findings, molecular data and clinical information may allow rare haemoglobin variants to be identified more accurately and meaningfully.



REFERENCE

- Puthiyaveettil, A. K., Kulkarni, S., Golwilkar, V. A., et al. An integrated approach to identify rare hemoglobin variants using capillary electrophoresis, liquid chromatography and mass spectrometry. Journal of Chromatography B 1280, 125132 (2026). DOI
- Putchen, D. D., Kulkarni, S., Puthiyaveettil, A. K., et al. Discovery of a rare hemoglobin variant Q-India/D-Punjab in whole blood from an Indian patient using capillary electrophoresis and mass spectrometry. Separation Science Plus 8(4), e70036 (2025). DOI
- Kulkarni, S., Putchen, D. D., Venkatachala, P. K., et al. Rare variant hemoglobin Köln in Southern India an underdiagnosed entity? Journal of Hematopathology 18, 56 (2025). DOI

SCIENCE DESK

Rice, Wheat, and the Evolution of Diabetes Risk. How Long-Term Dietary Traditions May Have Influenced Human Genetics



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Scientific Profile | Organization Link | Factors Press

AREAS OF EXPERTISE
Statistical Genetics • Population and Quantitative Genetics • Evolutionary Genetics • Genetic Epidemiology

OUTLOOK

For thousands of years, staple foods such as rice and wheat have shaped not only human diets but possibly our biology as well. Could these long-standing food traditions be connected to differences in inherited risk for type 2 diabetes? In this Science Desk conversation, Dr. Ranajit Das explores the fascinating idea of gene–diet co-evolution, explains how polygenic risk scores reveal patterns across populations, and discusses why understanding our genetic and dietary history could contribute to more personalized and culturally relevant approaches to disease prevention.

Q *Rice and wheat are the two most widely consumed staple foods in the world. What inspired your team to investigate whether these long-standing dietary patterns might be linked to genetic susceptibility to type 2 diabetes?*

A Type 2 diabetes has traditionally been viewed as a disease influenced by two major factors: our genes and our lifestyle. While scientists have spent decades studying these separately, much less attention has been given to how the two may have influenced each other over thousands of years.

Rice and wheat are more than just staple foods they have shaped human civilizations for thousands of years. Across much of East, Southeast, and South Asia, rice became the dominant staple, while wheat has long been central to diets across Europe, West Asia, and many other regions. These long-standing dietary traditions created very different nutritional environments over hundreds of generations.

We were interested in a simple but fascinating question: could these long-term dietary environments have influenced the distribution of genetic variants associated with type 2 diabetes? Rather than asking whether rice or wheat is "better," we wanted to explore whether populations with different historical staple diets show differences in their inherited genetic susceptibility to diabetes. This allowed us to combine population genomics with nutritional science to investigate a possible example of gene–diet co-evolution. This question also brought together two exciting fields population genomics and nutritional science to explore whether our evolutionary history may have left detectable signatures in our genomes.

Q *Many readers may not be familiar with polygenic risk scores (PRS). Could you explain, in simple terms, what they are and how they help scientists understand inherited risk for diseases like type 2 diabetes?*

A To understand polygenic risk scores, it helps to first understand our genome. Every cell in our body contains a copy of our genome the complete set of DNA instructions inherited from our parents. If we think of the genome as an instruction manual written using just four chemical "letters" (A, T, G, and C), then every individual carries a slightly different version of that manual. These tiny differences make each of us unique and influence everything from our eye colour and height to how our bodies process food, respond to medicines, fight infections, and become susceptible to diseases.

Most common diseases, however, are not caused by a single gene. Conditions such as type 2 diabetes, heart disease, cancer, obesity, and many neuropsychiatric disorders arise through the combined effects of

thousands of genetic variants interacting with each other and with environmental factors such as diet, physical activity, pollution, and lifestyle. Each individual genetic variant contributes only a very small amount to disease risk, but when considered together, they can provide valuable insights into inherited susceptibility.

A polygenic risk score (PRS) combines the effects of thousands, sometimes even millions, of these genetic variants into a single numerical score that estimates an individual's inherited predisposition to a particular disease. Rather than searching for a single "diabetes gene", PRS captures the cumulative influence of many genes spread across the entire genome. It is a powerful research tool because it allows scientists to study how genetic susceptibility varies between individuals and populations.

Importantly, a PRS is not a diagnosis, nor does it predict a person's future with certainty. A high polygenic risk does not mean someone will inevitably develop a disease, just as a low score does not guarantee lifelong protection. Our health is shaped by a continuous interaction between genetics and the environment. Diet, exercise, sleep, stress, medications, socioeconomic conditions, and many other factors can either increase or reduce disease risk throughout life.

In our study, we used PRS not to predict diabetes in individuals, but to compare patterns of inherited genetic susceptibility across populations with different long-term dietary traditions. More broadly, polygenic risk scores are becoming an important tool in precision medicine, helping researchers understand why some populations are more vulnerable to certain diseases and paving the way for more personalized approaches to disease prevention and healthcare.

Q *Your study found differences in genetic risk between populations with historically rice-based and wheat-based diets. What were the key findings, and what do they suggest about the relationship between our diet and our genes?*

A Our analysis revealed a striking pattern at the global level. Populations with long histories of rice-based diets generally showed higher average polygenic risk scores for type 2 diabetes than populations traditionally dependent on wheat-based diets. The difference was statistically very strong and remained consistent across thousands of individuals from diverse populations.

However, when we focused only on South Asia, the picture became much more nuanced. The differences between rice- and wheat-consuming populations became much smaller, with considerable overlap between groups.

These findings suggest that the relationship between diet and genetics is not simple or These findings suggest that the relationship between diet and genetics is not simple or deterministic. Instead, they support the idea that long-term dietary environments may have contributed to shaping how genetic susceptibility is distributed across human populations. South Asia, however, tells a more complex story. For much of its history, many populations have consumed both rice and wheat (often in the form of roti or chapati), with the balance varying across regions, cultures, and communities. Because the dietary environment has not been consistently dominated by a single staple, any evolutionary adaptation associated with one grain is likely to have been weaker or more difficult to detect. In addition, South Asia harbours extraordinary genetic diversity, shaped by thousands of years of migration, admixture, and population structure. This remarkable genetic heterogeneity, combined with mixed dietary traditions, makes it much more challenging to identify clear gene diet evolutionary patterns than in broader global comparisons.

Q *One of the most interesting concepts in your study is gene–diet co-evolution. Could you explain what this means and why it is important for understanding human health and disease?*

A Gene–diet co-evolution is the idea that our biology has not evolved independently of our food. Throughout human history, the diets consumed by different populations have acted as part of the environment in which natural selection operated. Over thousands of generations, genetic variants that improved survival or reproductive success under local dietary conditions may have become more common, while others became less frequent. In this way, our genomes carry traces of the nutritional environments experienced by our ancestors.

Evolutionary biology teaches us that the human genome is not a static blueprint but a historical record of adaptation. Different populations evolved under different ecological conditions, climates, infectious

diseases, and food resources. As agriculture emerged around 10,000 years ago, it fundamentally changed the human diet, introducing new selective pressures that varied across regions depending on the crops that became staple foods. These long-term dietary environments may have subtly influenced the distribution of genetic variants involved in metabolism, energy regulation, and glucose homeostasis.

One of the best-known examples of gene–diet co-evolution is lactase persistence. In populations with a long history of dairy farming, genetic variants allowing adults to digest lactose became common because they provided a nutritional advantage. Our study asks whether a similar evolutionary principle might also apply to staple carbohydrates such as rice and wheat. While our findings do not prove that historical diets directly caused differences in genetic susceptibility to type 2 diabetes, they are consistent with the hypothesis that long-term dietary traditions may have contributed to shaping population-level patterns of metabolic risk.

This evolutionary perspective has important implications for medicine. Many common diseases including type 2 diabetes, obesity, cardiovascular disease, and even some autoimmune disorders arise because our biology evolved under environmental conditions that differ markedly from those we experience today. By understanding how human populations adapted to different nutritional environments, we gain valuable insight into why disease risk varies across populations and why a single dietary recommendation may not be equally effective for everyone. Evolutionary biology therefore provides an important framework for precision medicine, helping us develop prevention strategies that are not only genetically informed but also culturally and historically relevant.

Q *Your analysis also showed that these differences were much less pronounced within South Asia. Why do you think this region tells a more complex story about diet, genetics, and diabetes risk?*

A South Asia is one of the most genetically and culturally diverse regions on Earth. Unlike many parts of the world where one staple grain dominates, people across South Asia often consume varying combinations of rice, wheat, millets, pulses, and other cereals. Dietary habits differ between states, communities, religions, and even neighboring villages. The region has also experienced thousands of years of migration, admixture, and population mixing. As a result, today's genetic landscape reflects a long and complex demographic history rather than a single dietary tradition.

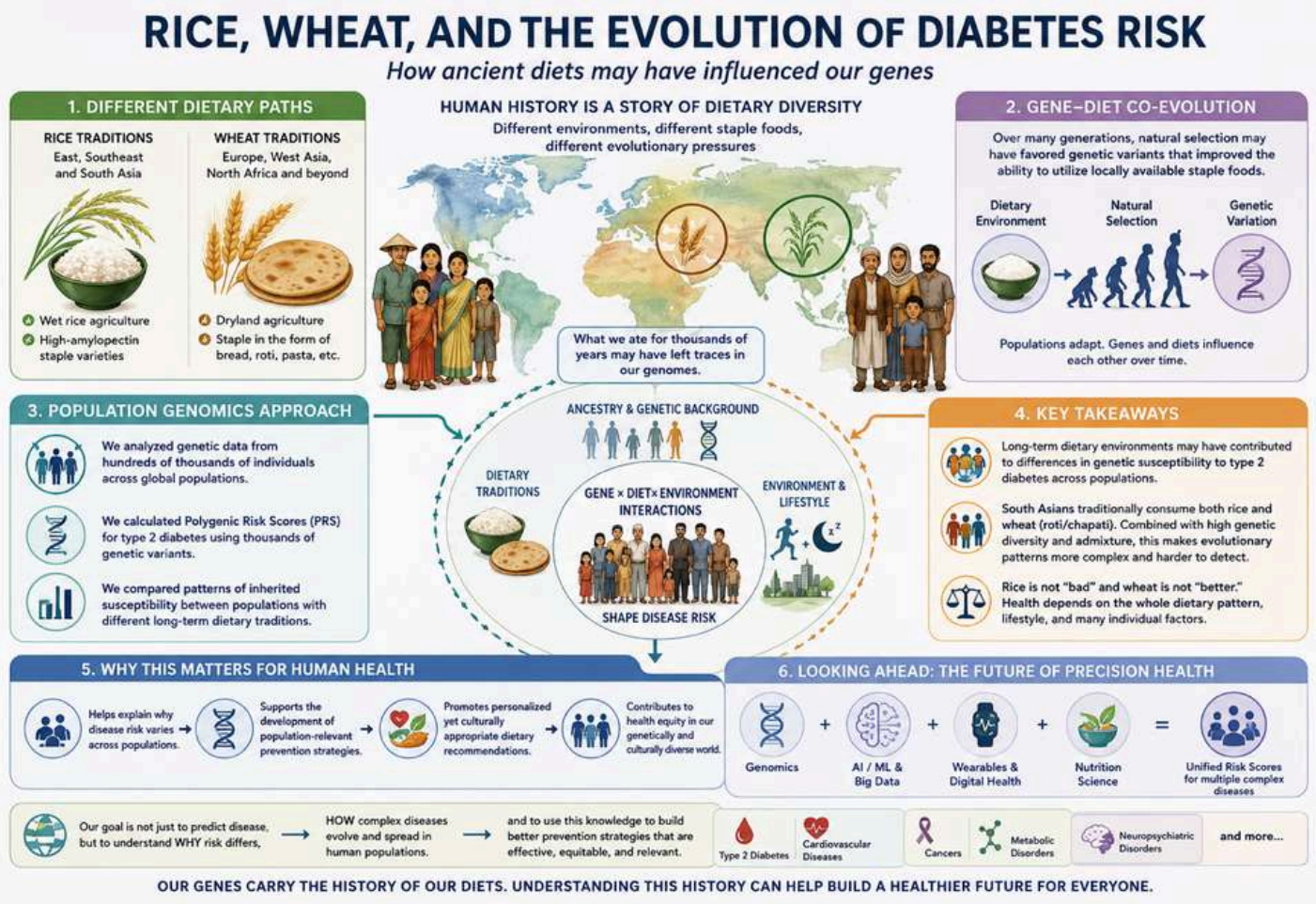
Because of this complexity, it is not surprising that the differences between rice- and wheat-based populations are less distinct within South Asia than they are at the global level. In many ways, South Asia reminds us that human biology cannot be understood through simple categories. Genetics, culture, environment, and lifestyle are deeply interconnected.

Q *Some readers may wonder whether this means rice is "bad" or wheat is "better." Based on your findings, how should people interpret these results, and what message would you like the public to take away?*

A This is perhaps the most important question, and the answer is no. Our study does not suggest that rice is harmful or that wheat is inherently healthier. In fact, billions of people around the world have consumed rice as a staple food for generations while maintaining healthy lives, just as many populations have thrived on wheat-based diets.

One of the most common misconceptions is that simply replacing rice with roti or chapati will reduce the risk of diabetes. Scientific evidence does not support such a blanket conclusion. The health effects of both rice- and wheat-based foods depend on many factors, including the variety of grain, the degree of processing and refinement, cooking methods, portion size, accompanying foods, and an individual's overall dietary pattern and lifestyle. Whole grains whether rice or wheat are generally more beneficial than their highly refined counterparts because they retain more fibre and nutrients.

Our findings are not about declaring one staple food superior to another. Rather, they highlight that populations have evolved under different dietary environments and that inherited genetic susceptibility may vary across populations. This reinforces an important principle: nutrition is not "one size fits all." The most effective dietary advice should be based on the totality of the diet, regular physical activity, healthy body weight, adequate sleep, and other lifestyle factors, while also recognising the biological and cultural diversity of different populations.



The broader message is that traditional diets should not be judged by a single ingredient. Instead of asking whether rice is better than wheat or vice versa, we should focus on building balanced, minimally processed diets that are nutritionally adequate, culturally acceptable, and sustainable. As genomics continues to advance, future dietary recommendations may become increasingly personalized, helping people make food choices that are appropriate not only for their lifestyle but also for their unique genetic background.

Q *Looking ahead, how could advances in genomics and nutrition research help develop more personalized and culturally appropriate strategies for preventing type 2 diabetes?*

A We are entering an exciting era in which genomics, artificial intelligence (AI), machine learning (ML), wearable technologies, and digital health are beginning to transform our understanding of complex diseases. Together, these technologies allow us to move beyond studying single genes or single risk factors and instead understand health as the result of dynamic interactions between genetics, lifestyle, diet, environment, and behaviour.

As genomic databases become more representative of the world's diverse populations, we will gain a much clearer understanding of how different genetic backgrounds influence responses to diet, medications, and environmental exposures. This will enable healthcare strategies that are not only scientifically robust but also culturally appropriate, recognising that the best dietary recommendations may differ across populations because of differences in ancestry, traditional food practices, and local environments.

Importantly, personalized nutrition does not mean abandoning traditional diets or replacing them with universal prescriptions. Instead, it aims to optimise existing dietary habits in ways that preserve cultural heritage while improving health outcomes. The goal is to provide recommendations that people can realistically adopt within their own communities and lifestyles.

More broadly, our research extends far beyond type 2 diabetes. At our laboratory, we are interested in understanding how complex multifactorial diseases

including metabolic disorders, cancers, neuropsychiatric conditions, and other common chronic diseases have evolved and become distributed across human populations. By integrating genomic information with clinical, environmental, and lifestyle data, we are developing AI- and machine learning-based approaches to generate unified risk scores that capture an individual's overall susceptibility to multiple diseases rather than focusing on a single condition.

Ultimately, our vision is not simply to predict disease risk, but to understand why diseases arise, how they evolve within populations, and which biological and environmental factors shape their distribution. By combining evolutionary biology, genomics, and artificial intelligence, we hope to build predictive models that support earlier prevention, more precise interventions, and equitable healthcare strategies tailored to the genetic and cultural diversity of human populations.

ABOUT THE AUTHORS

Dr. Ranajit Das is an Associate Professor at the Yenepoya Research Centre, Yenepoya University, Mangalore, India. His research focuses on human genetics, population genetics, evolutionary genetics, and genetic epidemiology. He studies how genetic differences among individuals and populations can influence their risk of developing diseases. His work also explores how diet, lifestyle, environment, and human evolutionary history interact with our genes, helping researchers better understand why disease risks can vary across different populations.

REFERENCE

- Chirakkal, S.N., Indu, A.A. & Das, R. Diet-genetic interactions in type 2 diabetes: Comparing polygenic risk in rice- and wheat-consuming populations. Nutr Metab Insights 19, 11786388261457983 (2026). DOI



SCIENCE DESK

Beyond Wheelchair Provision: Building Real Independence and Inclusion in India



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AREAS OF EXPERTISE
Interior Design • Ergonomics • Assistive Devices • Rehabilitation

OUTLOOK

Wheelchair can open new possibilities, but genuine independence depends on much more than receiving a device. In this Science Desk conversation, Ms. Christy Thomas George explores how suitable wheelchairs, practical training, accessible surroundings and continued rehabilitation support shape everyday life for wheelchair users in India. Drawing on her study in Coimbatore, she explains how physical barriers and social attitudes can restrict participation, and why services and policies should focus on helping people move confidently, make their own choices and participate fully in community life.

Q *Your study found that only 49% of wheelchair users were independently mobile. What does "independent wheelchair mobility" mean in everyday life, and why is achieving it still challenging for many users?*

A Independent wheelchair mobility means being able to move safely and effectively without another person having to push, guide, or physically assist. In everyday life, it involves more than moving around a room. It includes getting out of bed and into the wheelchair, moving around the home, leaving the house, travelling along nearby streets, visiting shops or health facilities, attending education or work, and participating in family and social activities.

Achieving this is challenging because mobility depends on several connected factors. A person may have enough upper-limb strength to propel a wheelchair but be unable to leave the home because of steps, narrow doorways, uneven paths, or inaccessible toilets. Another person may manage smooth indoor floors but find rough roads, potholes, steep slopes, rain, traffic, or crowded public spaces difficult or unsafe.

Independent mobility is therefore not simply an individual ability. It is the outcome of an interaction between the user, the wheelchair, available support services, and the physical and social environment. The finding that only 49% of participants were independently mobile shows that access to a wheelchair alone does not necessarily mean access to independent movement.

Q *Many people may assume that providing someone with a wheelchair automatically improves independence. Why is wheelchair provision alone often not enough?*

A A wheelchair is an important starting point, but it is only one part of an effective mobility solution. A wheelchair may not improve independence if it is uncomfortable, poorly fitted, difficult to propel, unstable, unsuitable for the terrain, or in need of repair. Users may also require guidance on transfers, propulsion, braking, negotiating slopes, avoiding falls, pressure relief, and basic maintenance.

Wheelchair provision should therefore be understood as a service pathway rather than a one-time distribution event. This pathway should include assessment, prescription, fitting, training, maintenance, repair, and follow-up. Without these components, a person may own a wheelchair but remain dependent on others for mobility and daily activities.

The central policy priority must shift from counting wheelchairs distributed to ensuring that every wheelchair user has the practical opportunity to live independently, participate in community life, and exercise choice and dignity. This means measuring success not only by the number of devices delivered, but also by whether users can move safely, manage



daily life, and take part in the roles that matter to them.

Q *Your findings suggest that wheelchair type can influence mobility. What makes a wheelchair truly suitable for an individual, particularly in Indian environments and communities?*

A A suitable wheelchair is not defined by whether it is manual, powered, customised, or technologically advanced. It is defined by whether it matches the individual user and the environment in which that person lives. Important considerations include body size, posture, upper-limb strength, medical condition, pain, fatigue, daily activities, home layout, work or educational demands, and access to repair services.

The wheelchair should provide appropriate seating support, comfort, stability, manoeuvrability, and efficient propulsion. It should also be durable and affordable to maintain. In many Indian communities, users may need to travel over uneven roads, damaged pavements, narrow pathways, household thresholds, or poorly designed ramps. They may also encounter crowded public spaces, inaccessible transport, limited shelter from rain, and toilets that cannot accommodate a wheelchair.

Our study found an association between wheelchair type and independent mobility. However, this should not be interpreted as evidence that one type of wheelchair is universally superior. The multivariable analysis did not identify a single independent predictor of mobility, indicating that independence is influenced by several factors working together. The most appropriate approach is therefore individual assessment and user-centred prescription, rather than a one-size-fits-all model of wheelchair provision.

Q *Only 18% of participants were independent in activities of daily living. What are some major barriers that can limit everyday independence for wheelchair users?*

A Activities of daily living include tasks such as personal care, bathing, dressing, toileting, transferring, preparing food, moving around the home, and managing routine household activities. The finding that only 18% of participants were independent in these activities shows that a wheelchair user may be mobile in some situations but still face major limitations in everyday life.

Physical barriers can include reduced upper-limb strength, pain, fatigue, poor balance, difficulty transferring, pressure-related discomfort, or secondary health complications. Environmental barriers may include steps at home entrances, narrow doorways, inaccessible bathrooms, inadequate space

to turn a wheelchair, uneven surfaces, and lack of accessible transport. Social and economic barriers can include dependence on family members, low income, limited access to rehabilitation, lack of repair services, unemployment, and insufficient information about available support.

These barriers often occur together. For example, an accessible wheelchair may still be difficult to use independently if the home bathroom has no space for turning or transferring. Similarly, a person may develop skills but have limited opportunities to use them if family members, schools, workplaces, and public spaces continue to assume dependence.

Q *Awareness of government or NGO support programmes was associated with greater independence in daily activities. How important are information, financial support, training, and follow-up services after someone receives a wheelchair?*

A They are essential because they help convert a wheelchair from a device into a practical tool for independent living. In our study, awareness of government or non-governmental organisation support programmes was associated with greater independence in activities of daily living. Among participants aware of these programmes, 31.7% were independent in daily activities, compared with 8.5% among participants who were unaware.

Because the study was cross-sectional, this association does not establish that awareness itself causes independence. Nevertheless, it suggests that informed users may be better able to access financial support, rehabilitation services, repairs, training, or other resources that support daily functioning.

Information should be clear, local, and easy to access. Healthcare providers, rehabilitation centres, community health workers, disability organisations, and local authorities all have a role in explaining available schemes and helping users navigate application processes. Financial support can make appropriate wheelchairs, cushions, repairs, transport, and home modifications more affordable. Training can improve safety and confidence. Follow-up can identify problems with fit, posture, pain, damage, or changing functional needs before they lead to reduced mobility or wheelchair abandonment.

Q *Your study also highlights psychosocial issues such as embarrassment and avoiding going out. How can social attitudes, inaccessible public spaces, and stigma affect confidence and participation?*

A Independence is not only physical. A person may have the ability to propel a wheelchair but still avoid going out because of embarrassment, fear of being judged, inaccessible public spaces, or previous experiences of exclusion. In our study, improved psychosocial self-esteem was associated with less avoidance of going out and lower public embarrassment.

Negative attitudes can reduce confidence by making wheelchair users feel that they are unwelcome, dependent, or burdensome. Overprotection by families, pity, low expectations, and discrimination can also limit opportunities to make decisions, learn skills, work, study, travel, and participate in social life. These attitudes may be as restrictive as a flight of steps or an inaccessible toilet.

Public infrastructure communicates whether people are expected to belong. When schools, workplaces, clinics, transport systems, sidewalks, toilets, and recreation spaces are inaccessible, wheelchair users receive a message that their participation was not considered. Inclusion requires both accessible design and respectful attitudes. Communities must recognise wheelchair users as active citizens with aspirations, expertise, and the right to take part in ordinary life.

Q *Looking ahead, what changes in wheelchair design, rehabilitation services, public infrastructure, policy, and assistive technology could help more wheelchair users achieve genuine independence and social inclusion?*

A The most important change is to build an integrated system that supports mobility, independence, and social participation together. Wheelchair services should include individual assessment, appropriate prescription, fitting, skills training, maintenance, repair, and follow-up. Users and families should receive practical guidance, while peer support may help users build confidence and share effective strategies for daily life.

Wheelchair design should be user-centred, durable, comfortable, stable, and appropriate for local terrain and living conditions. Technological innovation can be valuable when it is affordable, repairable, reliable, and matched to the user's functional needs. Lightweight designs, improved seating and cushions, terrain-adapted wheels, powered mobility, and digital systems for service access may all help when

introduced thoughtfully.

Policy and infrastructure must address the wider environment. Homes, public buildings, toilets, footpaths, roads, transport, workplaces, schools, and health facilities should be accessible from the planning stage. Government and NGO schemes should be visible, easy to understand, and linked to rehabilitation and community support. Most importantly, wheelchair users should be involved directly in designing products, evaluating services, planning accessibility, and shaping policy.

A wheelchair can be life-changing, but it cannot change a person's life alone. Genuine independence becomes possible when appropriate technology is combined with skilled services, accessible environments, informed support, and communities that respect the rights and contributions of wheelchair users.

REFERENCE

- Thomas George, C., & V., S. (2026). Independent Wheelchair Mobility and Associated Factors Among Wheelchair Users in Coimbatore, India: A Cross-Sectional Study. Disability and Rehabilitation: Assistive Technology, 1–13. DOI

ABOUT THE AUTHORS

Ms. Christy Thomas George is a Research Scholar specialising in assistive technology, rehabilitation sciences, ergonomics, and quality of life. Her research focuses on mobility assistive devices, particularly their accessibility, usability, user experiences, and role in promoting independent living. Her work brings together interdisciplinary perspectives to understand how assistive technologies can better respond to the needs of end-users and contribute to greater independence, meaningful participation, and enhanced quality of life.



SCIENCE DESK

A Blood Protein That Could Reveal Diabetes Before It's Too Late



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Scientific Profile
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AREAS OF EXPERTISE
Endocrinology • Molecular Biochemistry • Immunology

OUTLOOK

Type 2 diabetes develops gradually, often beginning with insulin resistance and metabolic changes long before the disease is diagnosed. Scientists are therefore searching for biological markers that could provide an earlier picture of these changes. In this Science Desk conversation, Dr. Surbhi Tyagi discusses Sestrin-2, a protein produced in response to cellular stress, and explains why its increasing levels from healthy individuals to prediabetes and diabetes could offer new insights into metabolic health and the early identification of diabetes risk.

Q *What is Sestrin-2, and what inspired you to investigate its connection with insulin resistance and type 2 diabetes?*

A Sestrin-2 is a stress-responsive protein that helps cells adapt to metabolic and oxidative stress. It is involved in several important cellular pathways related to energy balance, antioxidant defense, inflammation, and metabolism. Because these processes are closely connected with insulin resistance and type 2 diabetes, Sestrin-2 has attracted increasing interest as a potential biomarker of metabolic health. My interest in Sestrin-2 developed from the need to better understand what happens biologically before and during the development of type 2 diabetes. Conventional markers such as fasting glucose and HbA1c are extremely valuable for diagnosis and monitoring, but diabetes develops through a gradual process. Insulin resistance and metabolic disturbances can begin years before diabetes becomes clinically established. In our research, we therefore investigated circulating Sestrin-2 in individuals with normal glucose regulation, prediabetes, and type 2 diabetes, and examined its relationship with insulin resistance and other metabolic parameters. The objective was not simply to identify another laboratory marker, but to understand whether Sestrin-2 could provide additional information about the biological changes accompanying metabolic deterioration.

Q *Your study found that Sestrin-2 levels progressively increased from healthy individuals to people with prediabetes and then type 2 diabetes. What does this tell us about the progression of the disease?*

A The progressive increase in circulating Sestrin-2 across the three groups was one of the important findings of our study. Individuals with prediabetes had higher Sestrin-2 concentrations than healthy controls, while the highest levels were observed among individuals with type 2 diabetes. This pattern suggests that Sestrin-2 may be associated with the metabolic stress that accompanies the transition from normal glucose regulation toward diabetes. Importantly, this does not mean that Sestrin-2 itself causes diabetes or that an elevated level automatically predicts that an individual will develop diabetes. One possible interpretation is that increasing Sestrin-2 reflects a compensatory response to increasing cellular stress. As insulin resistance, hyperglycaemia, oxidative stress, and metabolic disturbances become more pronounced, cells may increase the expression or release of stress-responsive proteins such as Sestrin-2. Our findings therefore add to the concept that type 2 diabetes should be viewed as a progressive metabolic disorder rather than a condition that suddenly appears when blood glucose crosses a diagnostic threshold.

Q *How is Sestrin-2 associated with insulin resistance, and why is this relationship important?*

A In our study, Sestrin-2 showed a positive association

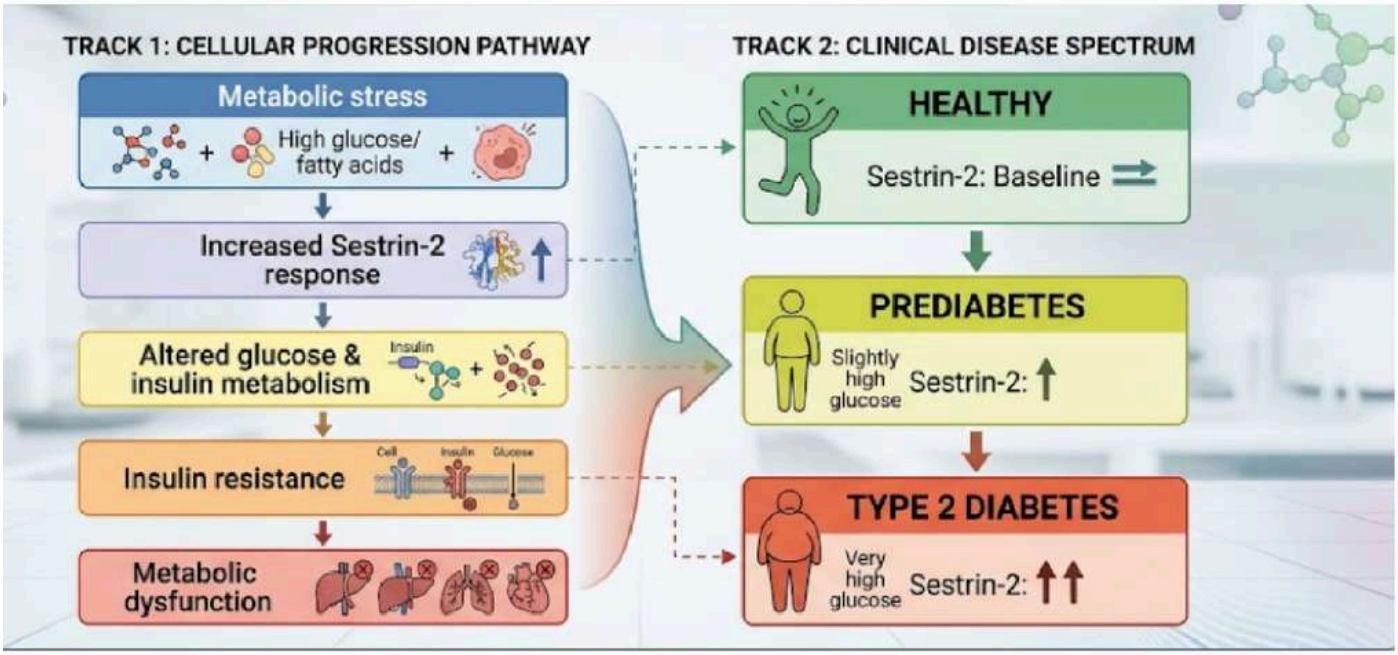


Figure 2. Schematic representation of the potential role of Sestrin-2 in the progression of metabolic dysfunction. Increasing metabolic stress across the spectrum from healthy glucose regulation to prediabetes and type 2 diabetes may be associated with an enhanced Sestrin-2 response. Sestrin-2 is a stress-responsive protein involved in cellular adaptation, metabolic regulation, and maintenance of cellular homeostasis.

with markers of impaired glucose metabolism and insulin resistance, including fasting glucose, HbA1c, fasting insulin, and HOMA-IR. Insulin resistance occurs when tissues such as muscle, liver, and adipose tissue become less responsive to insulin. Initially, the pancreas may compensate by producing more insulin. Over time, however, this compensation may become insufficient, contributing to persistent hyperglycaemia and eventually type 2 diabetes. The relationship with Sestrin-2 is interesting because Sestrin-2 participates in cellular responses to metabolic and oxidative stress. It is connected with pathways involved in energy sensing and regulation of cellular metabolism. Therefore, elevated Sestrin-2 may reflect the biological stress associated with worsening insulin sensitivity. Understanding this relationship could help researchers identify biomarkers that capture aspects of metabolic dysfunction beyond blood glucose alone. However, associations do not establish causation, and the precise biological mechanisms linking circulating Sestrin-2 with insulin resistance require further investigation.

Q *Your study found promising diagnostic performance for Sestrin-2, particularly in distinguishing people with type 2 diabetes from healthy individuals. How significant is this finding?*

A The diagnostic performance observed in our study is encouraging because it suggests that circulating Sestrin-2 may have the ability to distinguish metabolic states, particularly healthy individuals from those with established type 2 diabetes. Receiver operating characteristic, or ROC, analysis is commonly used to evaluate how well a biomarker differentiates between groups. The promising performance observed for Sestrin-2 supports the need for further research. However, diagnostic performance in a single cross-sectional study should be interpreted carefully. A promising area under the ROC curve does not by itself establish that a biomarker is ready for routine clinical use. A clinically useful biomarker must perform consistently across different populations, age groups, ethnic backgrounds, disease stages, and laboratory settings. Future studies should therefore determine whether Sestrin-2 provides information beyond conventional risk factors and whether combining Sestrin-2 with established markers improves prediction of future diabetes.

Q *Why might Sestrin-2 levels increase as metabolic health worsens? Could this be part of the body's response to oxidative and metabolic stress?*

A One plausible explanation is that the increase in

Sestrin-2 represents a protective or compensatory cellular response.

Metabolic dysfunction can increase oxidative stress, inflammation, nutrient overload, and disturbances in cellular energy metabolism. Sestrin-2 is a stress-responsive protein involved in cellular defense mechanisms and metabolic regulation. Its increase may therefore reflect the body's attempt to adapt to an increasingly stressful metabolic environment.

In simple terms, Sestrin-2 may be viewed as part of the cell's response system rather than simply a marker of disease itself.

Nevertheless, the biology is complex. An increase in circulating Sestrin-2 could reflect several interacting processes, and the relationship may differ depending on disease stage and tissue. More experimental and clinical research is needed to determine whether Sestrin-2 is primarily a protective response, a marker of metabolic stress, or potentially involved in disease mechanisms.

Q *What further research is needed before Sestrin-2 could potentially be considered for clinical use in diabetes risk assessment or monitoring?*

A Several important steps are required.

First, longitudinal studies are needed to determine whether elevated Sestrin-2 can predict who will progress from normal glucose regulation or prediabetes to type 2 diabetes. Cross-sectional studies can demonstrate associations but cannot establish temporal relationships. Second, larger multicentre studies involving diverse populations are necessary to establish reliable reference ranges and clinically meaningful cut-off values. Third, researchers need to

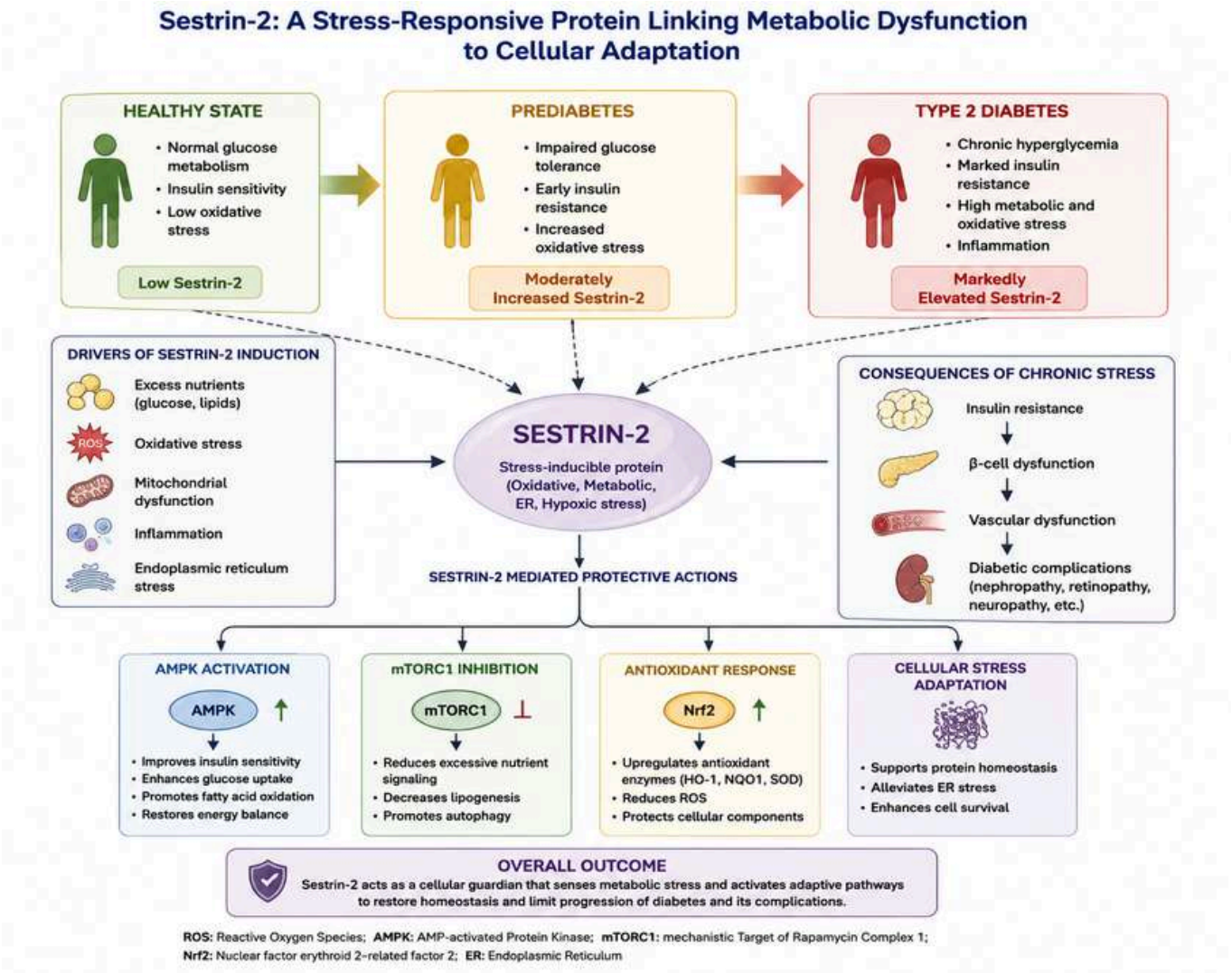


Figure 2. Schematic representation of the potential role of Sestrin-2 in metabolic dysfunction. Increasing metabolic and oxidative stress associated with insulin resistance and type 2 diabetes may stimulate Sestrin-2, which is involved in cellular stress responses, AMPK–mTOR signalling, antioxidant defence, and metabolic adaptation.

determine whether Sestrin-2 adds predictive value beyond established measures such as fasting glucose, HbA1c, BMI, blood pressure, lipid profile, and other recognized risk factors.

Fourth, laboratory methods need to be standardized. Differences between assay platforms and commercial ELISA kits could affect measured concentrations, making standardization essential before routine clinical implementation.

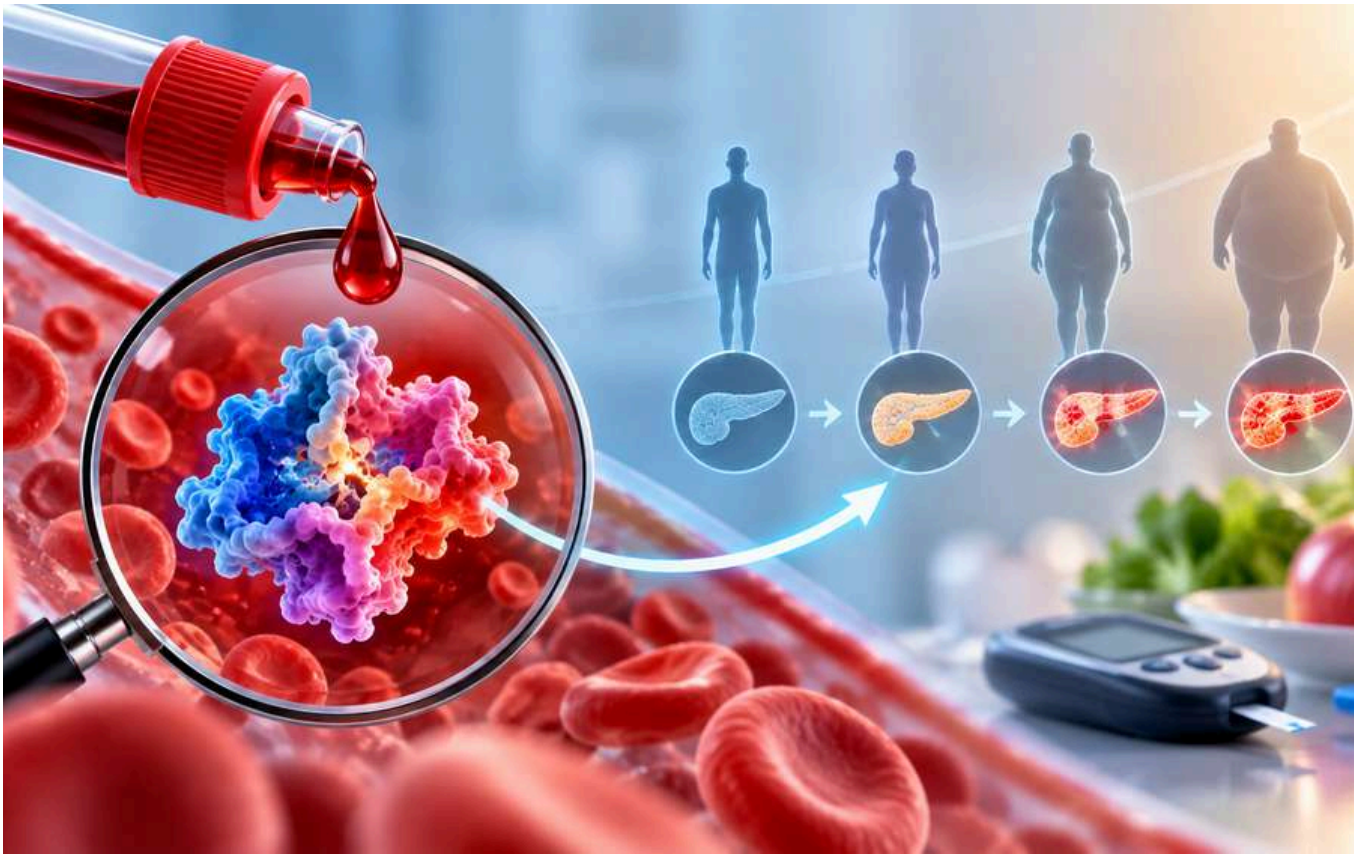
Finally, we need to understand how Sestrin-2 changes with lifestyle modification, weight loss, exercise, pharmacological treatment, and progression or improvement of insulin resistance. The ultimate goal is not to replace established diabetes tests, but to determine whether Sestrin-2 can provide complementary information that improves early risk identification and our understanding of metabolic disease. Overall, our findings support Sestrin-2 as a promising research biomarker associated with insulin resistance and type 2 diabetes. They also highlight an important principle in diabetes research: metabolic deterioration develops gradually, and understanding the biological signals that accompany this process may help us identify new opportunities for earlier intervention.

REFERENCE

- Lee, J.H. et al. Sestrin as a feedback inhibitor of TOR that prevents age-related pathologies. Science 327, 1223–1228 (2010). DOI
- Wolfson, R.L. et al. Sestrin2 is a leucine sensor for the mTORC1 pathway. Science 351, 43–48 (2016). DOI
- Tyagi, S., Nagtilak, S. & Parashar, P. Sestrin-2: A new biomarker for type 2 diabetes mellitus and insulin resistance. J Diabetes Metab Disord 25, 187 (2026). DOI

ABOUT THE AUTHORS

Surbhi Tyagi is a researcher in Medical Biochemistry investigating biomarkers associated with insulin resistance and type 2 diabetes. Her research focuses particularly on Sestrin-2 and C-peptide and their relationships with metabolic dysfunction. Through clinical and biochemical research, her work aims to improve understanding of the biological changes accompanying the progression from normal glucose regulation to prediabetes and type 2 diabetes and explore potential biomarkers for earlier risk assessment.



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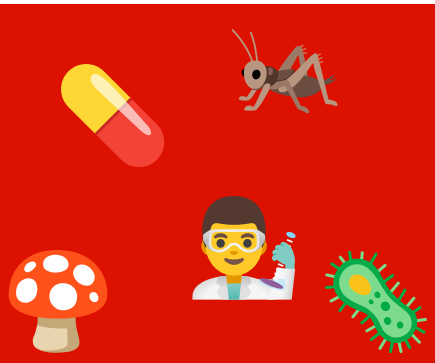
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Answers here – don't peek!





Q1

What can Raman spectroscopy help scientists identify in living microbial cultures?

A. The colour of the culture container
B. Chemical molecules produced by microbes
C. The age of the laboratory
D. The weight of the microscope

Q2

How can light help activate certain experimental cancer treatments?

A. By changing the patient's blood group
B. By stimulating specially designed nanoparticles
C. By replacing all medicines
D. By stopping all cell division

Q3

What can kidney stone crystals trigger in surrounding kidney cells?

A. Photosynthesis
B. Inflammation and cell damage
C. Faster bone growth
D. Increased oxygen production

Q4

Why are millets considered important for sustainable agriculture?

A. They grow only in flooded fields
B. Some varieties tolerate relatively dry conditions
C. They require no sunlight
D. They are produced without farming

Q5

What should someone do if they suddenly experience significant vision loss?

A. Wait several weeks
B. Seek urgent medical attention
C. Rub their eyes repeatedly
D. Avoid telling anyone

Q6

How do biomolecular condensates help organise activities inside cells?

A. By forming compartments without surrounding membranes
B. By replacing all DNA
C. By turning proteins into minerals
D. By stopping all chemical reactions

Q7

Why is analysing biomedical research funding important?

A. To guarantee every project succeeds
B. To identify research priorities and funding gaps
C. To eliminate the need for scientists
D. To predict the exact date of discoveries

Q8

What does stereotactic body radiotherapy (SBRT) allow doctors to do?

A. Deliver highly focused radiation to selected targets
B. Treat cancer without any imaging
C. Replace every type of surgery
D. Prevent all cancers permanently

DISCOVERY HIGHLIGHTS

PHYSICS & ASTRONOMY



A SMALL ATOMIC CHANGE TRANSFORMS HOW MAGNETIC MATERIALS VIBRATE

Researchers have discovered that replacing some manganese atoms with nickel can dramatically change how magnetism interacts with atomic vibrations in a honeycomb-shaped crystal. The team studied a material called $Mn_3NiTa_2O_9$ using Raman spectroscopy at temperatures ranging from 8 to 300 kelvin. They found that cooling the material below its magnetic transition temperature of approximately 97 kelvin caused its atomic vibrations to soften, with stronger changes below 46 kelvin. Surprisingly, a closely related material without nickel showed the opposite behavior, with vibrations becoming harder. This difference reveals that nickel substitution reverses the interaction between magnetic order and lattice vibrations, known as spin–phonon coupling. The findings demonstrate how small changes in chemical composition can fundamentally alter magnetic materials, offering insights for designing future magnetoelectric and spin-based technologies.

Singh H. et al., Journal of Physics: Condensed Matter, 2026.

QUANTUM STUDY REVEALS HOW ELECTRONS MOVE THROUGH TINY ATOMIC CHAINS

Researchers have used theoretical models to investigate how electrons travel through tiny atomic chains and how their movement changes when the surrounding environment interferes. The study examined a specially arranged quantum chain in which the connections between neighboring sites follow a repeating pattern. Computer calculations revealed that the chain's structure, length and arrangement of its ends strongly influence electron transmission. Interestingly, chains containing an odd number of sites supported stable pathways that allowed electrons to pass at zero energy. When environmental disturbances were introduced, quantum interference weakened and electron transmission decreased, although important patterns linked to chain size remained detectable. These findings improve understanding of quantum transport in nanoscale systems and could help guide the design of future electronic devices that rely on precise control of electron movement.

Koley A., Journal of Physics: Condensed Matter, 2026.

CHEMISTRY & CHEMICAL SCIENCES



LIGHT AND ELECTRICITY OFFER CLEANER WAYS TO MAKE COMPLEX MOLECULES

Researchers have developed two environmentally friendly methods for producing sulfur-containing molecules that are useful building blocks in chemical research. The study focused on synthesizing benzimidazothiazoles, a class of compounds containing nitrogen and sulfur atoms. In the first approach, visible light activates the starting materials, allowing oxygen from the air to drive the formation of new chemical bonds. The second method uses electricity to trigger the same transformation without requiring metal catalysts, chemical additives or large amounts of oxidizing agents. Both approaches produced the desired compounds in high yields, worked with a wide range of starting materials and required relatively short reaction times. The reactions could also be scaled up, demonstrating their practical potential. These findings offer simpler and potentially more sustainable alternatives to conventional chemical synthesis, highlighting how light and electricity can reduce the need for additional chemical reagents.

Balaraman V. et al., Organic & Biomolecular Chemistry, 2026.

DISCOVERY HIGHLIGHTS

A NEW THEORY EXPLAINS HOW SINGLE MOLECULES RELEASE ENERGY IN LIVING CELLS

Researchers have developed a theoretical framework to explain how individual molecules release and use energy during chemical reactions. Traditional thermodynamics generally describes the behavior of large collections of molecules, but many biological processes occur one molecule at a time. The study extends thermodynamic principles to single-molecule reactions, focusing on ATP hydrolysis, the process by which cells release usable chemical energy. Using mathematical equations, the researcher calculated how the energy released from ATP changes with acidity, magnesium availability and other conditions found inside living cells. The analysis also established a theoretical upper limit on the work that a single molecule can perform during ATP hydrolysis. These findings offer a new perspective on how enzymes and molecular motors operate, helping connect fundamental thermodynamic laws with the microscopic processes that power life.

Nath S., BioSystems, 2026.

BIOLOGY AND LIFE SCIENCE

MITOCHONDRIA REVEAL A HIDDEN DEFENSE AGAINST VIRAL INFECTIONS

Researchers have discovered that mitochondria, the energy-producing structures inside cells, play a crucial role in fighting viruses independently of the body's well-known interferon defense system. The study identified a new function of MAVS, a protein involved in antiviral immunity, in maintaining mitochondrial health a-



nd supporting the transport of essential proteins into mitochondria. When MAVS was absent, mitochondria became damaged, lost energy-producing capacity and were increasingly removed by cells, weakening their ability to restrict viral replication. Restoring MAVS reversed these defects and strengthened antiviral protection.

Remarkably, this defense mechanism restricted SARS-CoV-2 replication even when interferon signaling was impaired and also contributed to protection against Japanese encephalitis virus.

The findings reveal an additional layer of cellular immunity and suggest that preserving mitochondrial function could offer new directions for antiviral research.

Sah V. et al., mBio, 2026.

DISCOVERY OF A NEW PROTEIN VARIANT REVEALS HIDDEN ROLES IN CELL SURVIVAL

Researchers have discovered a previously unknown form of maspin, a protein involved in controlling cell tgrowth, inflammation and programmed cell death. The newly identified variant, called B5N, contains an additional protein segment and was confirmed in human skin and esophageal tissues. Laboratory experiments revealed that this structural difference changes how the protein behaves and influences genes involved in inflammation, antiviral responses and cell survival. Compared with conventional maspin, the new variant caused less overall cell death and showed weaker effects on cell proliferation. Both forms also enhanced the activity of an enzyme involved in breaking down blood clots. Interestingly, several genes affected by the variant were also activated in SARS-CoV-2-infected cells. These findings reveal how alternative gene splicing can create proteins with distinct biological functions, offering new insights into cellular regulation and disease-related pathways.

Gupta S. et al., Gene, 2026.

AGRICULTURE & FOOD SCIENCE

GENE EDITING OFFERS NEW HOPE FOR GROWING RICE IN SALTY SOILS

Researchers have used CRISPR/Cas9 gene editing to improve rice tolerance to salt stress, a major challenge threatening agricultural productivity worldwide. The study focused on a gene called OsPLDβ1, which plays a role in plant stress signaling. By disrupting this gene, scientists developed rice plants that performed better under saline conditions than unmodified plants.The edited plants showed stronger antioxidant defenses, helping them neutralize harmful molecules produced during salt stress. They also demonstrated improved regulation of ion transport, maintained photosynthetic efficiency and preserved important growth and productivity traits. These findings reveal that OsPLDβ1 acts as a negative regulator of

DISCOVERY HIGHLIGHTS



salt tolerance in rice. The research identifies a promising genetic target for developing salt-tolerant rice varieties, potentially helping farmers maintain crop production in salt-affected agricultural regions.

Karippadakam S. et al., Frontiers in Genome Editing, 2026.

ANCIENT INDIAN WHEAT HOLDS THE KEY TO MORE NUTRITIOUS GRAINS

Researchers have uncovered valuable genetic diversity in an ancient Indian dwarf wheat, Triticum sphaerococcum, that could help improve the nutritional quality of modern wheat. The study evaluated 116 accessions under normal, heat-stress and water-deficit conditions, examining grain quality, protein content and essential minerals. Ancient wheat consistently showed superior nutritional potential compared with modern bread wheat varieties.Two promising accessions, PAUTS10 and Sonamoti, stood out for their high protein, gluten and zinc content. Using genome-wide association analysis, researchers identified 30 stable genetic markers associated with important grain quality and nutritional traits. These findings provide valuable targets for wheat breeding and biofortification programs. By combining ancient genetic resources with modern genomic technologies, scientists could develop wheat varieties with improved nutritional value and greater agricultural resilience.

Gaikwad K. B. et al., Journal of the Science of Food and Agriculture, 2026.

ENVIRONMENT & CLIMATE SCIENCE

HIDDEN MICROPLASTICS IN SOIL COULD THREATEN GROUNDWATER

Researchers have discovered how changing water flow conditions influence the movement and accumulation of microplastics beneath the ground, raising concerns about groundwater contamination. Using large experimental columns filled with gravel, scientists tracked how polyethylene and polystyrene particles moved through sediments under different water infiltration patterns.

Continuous water flow allowed microplastics to travel downward earlier, while intermittent flow triggered sudden releases of trapped particles. Interestingly, more than half of the recovered particles were retained within the upper sediment layer, showing that underground sediments can temporarily store plastic pollution. Smaller particles generally moved faster, while larger particles were released later. The findings reveal that subsurface sediments can act as both reservoirs



and sources of microplastics, depending on changing water conditions. Understanding these processes improve groundwater pollution assessments and environmental protection strategies.

Singh J. et al., Water Research, 2026.

HIDDEN AIR POLLUTANTS IN THE HIMALAYAS MAY WORSEN WARMING AND HEALTH RISKS

Researchers have identified a group of atmospheric pollutants that may contribute to both regional warming and harmful oxidative stress in the northwestern Himalayas. The study focused on humic-like substances (HULIS), complex organic compounds present in airborne particles that absorb sunlight and generate reactive oxygen species. Scientists found that these substances contributed substantially to the warming effects of brown carbon aerosols and accounted for more than half of the measured oxidative potential of airborne particles. Neutral HULIS showed particularly strong effects, with their ability to generate harmful reactive

DISCOVERY HIGHLIGHTS

molecules increasing during summer. The findings suggest that sunlight-driven atmospheric reactions can influence both the climate and potential health impacts of air pollution. Understanding these overlooked pollutants could improve air quality monitoring, climate assessments and pollution control strategies in sensitive Himalayan environments.

Yadav R. K. et al., Environmental Pollution, 2026.

BIODIVERSITY & CONSERVATION

CHASING ELEPHANTS AWAY MAY WORSEN HUMAN–WILDLIFE CONFLICT

Researchers have found that chasing elephants away from villages and farmland may provide temporary relief but could worsen human–wildlife conflict in the long term. The study monitored Asian elephant movements across 223 days in South Bengal, India, comparing natural movement with local chasing and organized hula drives. Elephants subjected to hula drives travelled considerably longer distances, averaging 9.43 kilometres daily, compared with 5.20 kilometres during local drives. Human attacks peaked on drive days, while crop damage increased afterward. Researchers also observed mixed community responses, with local interference frequently disrupting operations. The findings suggest that repeatedly driving elephants away is stressful, resource-intensive and unlikely to provide lasting solutions. The study highlights the need for more sustainable, community-supported strategies that protect bo-



th elephants and people.

Singh A. and Kumara H. N., iScience, 2026.

HIMALAYAN FROGS REVEAL HIDDEN GENETIC RISKS TO THEIR SURVIVAL

Researchers have uncovered important genetic differences in Amolops marmoratus, a hillstream frog traditionally harvested for food in India's Darjeeling region. By analysing DNA sequences from populations across Asia, scientists discovered that Darjeeling frogs possess considerably lower genetic diversity than populations in Southeast Asia, China and Myanmar. The findings suggest that historical geographic isolation and population changes have shaped their distinctive genetic makeup. Genetic analysis also revealed evidence of past population expansion following the establishment of a small founding population. However, limited genetic diversity may reduce the population's ability to adapt to environmental changes. Traditional frog harvesting could place additional pressure on these vulnerable populations. The study highlights the importance of protecting Himalayan freshwater habitats, monitoring frog populations and promoting community awareness to support the long-term conservation of this ecologically important species.

Mandal K. et al., BMC Genomics, 2026.

EARTH & GEOLOGICAL SCIENCES

HIDDEN URANIUM IN GROUNDWATER MAY ESCAPE RADIATION DETECTION

Researchers have discovered that measuring environmental radiation alone may not reliably reveal uranium contamination in groundwater.

The study examined 96 groundwater samples from the Chittorgarh region of Rajasthan, India, comparing dissolved uranium concentrations with surrounding gamma radiation levels. Scientists found that uranium concentrations varied nearly 100-fold, while radiation measurements showed relatively small differences. Surprisingly, areas containing higher uranium concentrations did not necessarily exhibit elevated gamma radiation.

Further analysis revealed that uranium movement through groundwater was influenced by local geological formations and water chemistry rather than directly reflecting surface radiation patterns.

These findings demonstrate that conventional gamma radiation measurements cannot substitute for direct testing of dissolved uranium under the investigated conditions. The research highlights the importance of comprehensive groundwater monitoring to identify hidden contamination risks and protect drinking-water quality in regions affected by naturally occurring uranium.

Rani A. et al., Journal of Hazardous Materials, 2026.

DISCOVERY HIGHLIGHTS



OCEAN & MARINE SCIENCE

HOW TINY OCEAN ORGANISMS PROTECT THEMSELVES FROM HARMFUL SUNLIGHT

Researchers have discovered that phytoplankton, microscopic organisms responsible for much of the ocean's food production, use different strategies to protect themselves from intense sunlight and ultraviolet radiation. The study compared phytoplankton communities from the Arabian Sea and the South Tropical Indian Ocean through controlled experiments aboard a research vessel. Arabian Sea phytoplankton recovered rapidly from light-induced damage, while communities in the South Tropical Indian Ocean relied more heavily on protective pigments and mechanisms that safely dissipate excess light energy. These differences were linked to regional environmental conditions and the types of phytoplankton present. The findings suggest that changing ocean temperatures, sunlight exposure and water mixing could alter how these organisms survive and function.

Understanding their protective mechanisms could improve predictions of marine productivity, carbon cycling and ecosystem responses to climate change.

Paul P. and Patil J. S., Marine Environmental Research, 2026.

FOREST BACTERIA REVEAL HIDDEN SECRETS OF CARBON STORAGE

Researchers have uncovered important differences in how bacteria from mangrove and terrestrial forests process carbon, offering new insights into their role in climate regulation. The study examined microbial communities from forest soils, sediments and leaf litter in Goa, India, using advanced DNA sequencing to reconstruct 15 bacterial genomes. Scientists discovered that even closely related bacteria possessed different genetic abilities to break down plant materials, process carbon compounds and participate in nutrient cycling.

Some mangrove-associated bacteria carried distinctive genes linked to carbon metabolism and sulfur processing, while others showed specialized abilities to degrade complex carbohydrates.

Interestingly, these differences were more closely associated with bacterial lineages than forest habitat alone.

The findings identify promising genetic markers for investigating microbial contributions to carbon cycling and could support improved monitoring of carbon storage in forest ecosystems.

Ghose M. et al., Microbiological Research, 2026.



ENGINEERING & MANUFACTURING

OLIVE OIL-BASED 4D PRINTING OFFERS NEW HOPE FOR BONE AND CARTILAGE REPAIR

Researchers have developed an innovative 4D printing material derived from olive oil that could support the repair of damaged bones and cartilage. Unlike conventional 3D-printed materials, these specially designed polymers can recover their original shape when exposed to temperatures close to that of the human body. Scientists demonstrated that the material possesses mechanical properties resembling natural tissues, including cartilage and ligaments, while achieving nearly 99% shape recovery. The printed structures also showed antibacterial activity against different types of bacteria, potentially reducing infection risks. Importantly, laboratory experiments revealed that the material supported human stem cell survival and encouraged their development into bone- and cartilage-forming cells without added growth factors. This sustainable, low-cost

DISCOVERY HIGHLIGHTS

technology could pave the way for personalized implants that improve tissue regeneration and orthopedic treatments.

Ghosal K. et al., Bioactive Materials, 2026.

TURNING TEXTILE WASTE INTO STRONGER, SUSTAINABLE BUILDING MATERIALS

Researchers have developed an innovative method to transform discarded cotton fibers from textile mills into strong, low-cost composite materials suitable for construction applications. The study combined waste cotton fibers with polypropylene, a commonly used plastic, using a specialized blending and heat-pressing process. This approach improved the bonding between cotton fibers and plastic, producing materials with high mechanical strength and durability. The resulting composites achieved a tensile strength of 54.5 MPa and a flexural strength of 66.5 MPa, demonstrating their potential for practical applications. Microscopic examination revealed strong connections between the recycled fibers and surrounding plastic, helping explain their improved performance. By converting industrial textile waste into valuable products, this technology could reduce landfill disposal, support resource-efficient manufacturing and advance the circular economy through sustainable material development.

Pankaj et al., Waste Management, 2026.

COMPUTER SCIENCE & ARTIFICIAL INTELLIGENCE



AI AND LASER TECHNOLOGY OFFER NEW POSSIBILITIES FOR ORAL CANCER DETECTION

Researchers have developed a promising approach that combines artificial intelligence with Raman spectroscopy to identify oral cancer using tissue, blood serum and urine samples. Raman spectroscopy uses laser light to detect subtle biochemical differences between healthy and cancerous samples without requiring chemical labels. Scientists trained machine learning models to recognize cancer-associated patterns across these different biological materials. Among the tested methods, a support vector machine achieved the highest classification performance, with an average area under the curve of 0.964, indicating strong ability to distinguish cancer from non-cancer samples. The study also identified changes in proteins, lipids and metabolites associated with oral cancer. These findings provide early evidence that combining spectroscopy with artificial intelligence could support flexible, potentially non-invasive cancer screening methods, although further clinical validation is necessary.

Sharma M. et al., Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 2026.

UAI REVEALS HOW TINY PORES COULD HELP CAPTURE CARBON DIOXIDE FROM AIR

Researchers have used artificial intelligence to identify key structural features that could make materials more effective at capturing carbon dioxide directly from the atmosphere. The study examined 2,523 metal–organic frameworks, highly porous materials capable of trapping gas molecules within microscopic spaces. By combining molecular simulations with machine learning, scientists developed models to predict carbon dioxide uptake under atmospheric conditions. Surprisingly, the size and arrangement of pores proved far more important than chemical composition, accounting for over 90% of the models' predictions. Materials with specific pore dimensions and large internal surface areas showed greater potential for carbon capture. This approach could help researchers narrow a large pool of candidates before undertaking laboratory experiments. Saving time during this screening stage would allow greater attention to practical questions, including material stability, production costs and performance during repeated carbon capture cycles. These findings provide practical design guidelines for developing more efficient carbon-capturing materials. The research could accelerate the discovery of promising technologies for removing atmospheric carbon dioxide and addressing climate change. However, promising predictions still require experimental validation. Future studies must assess how humidity, competing gases and regeneration energy affect performance before these materials can be considered suitable for widespread deployment.

Nath D. et al., Journal of Molecular Graphics and Modelling, 2026.

DISCOVERY HIGHLIGHTS



SOCIAL & BEHAVIORAL SCIENCES

HIDDEN MENTAL HEALTH CHALLENGES AMONG INDIA'S SMALLHOLDER FARMERS

Researchers have highlighted the mental health challenges faced by smallholder farmers in Central India and the importance of coping strategies in managing psychological distress. The study surveyed 176 farmers across four districts of Madhya Pradesh, assessing symptoms of depression, anxiety and stress alongside their approaches to handling difficulties. Results revealed that 23.3% of participants experienced some level of depression, 23.3% reported anxiety and 20.5% experienced stress. Farmers who relied more heavily on avoidance and disengagement strategies tended to report poorer mental health outcomes. However, many participants demonstrated adaptive coping patterns, with relatively low levels of severe psychological distress. The findings suggest that promoting healthier coping strategies and integrating mental health support into agricultural and social welfare programs could improve farmers' psychological well-being and strengthen rural community resilience.
Kaushik D. and Bhat R., Journal of Agromedicine, 2026.

CONFIDENCE IN USING AI MAY HELP STUDENTS ACHIEVE BETTER ACADEMIC RESULTS

Researchers have found that students' confidence in using artificial intelligence could play an important role in academic success. The study surveyed 345 university students across three public universities in Saudi Arabia to examine how social influence, AI skills, learning approaches, academic stress and mental wellbeing relate to academic performance. Results showed that encouragement and influence from others were associated with better academic outcomes, both directly and through several psychological and learning-related factors. Interestingly, students' confidence in their ability to use AI effectively emerged as the strongest predictor of academic performance among the factors examined. Smart learning practices and mental wellbeing also contributed to these relationships. The findings suggest that universities could improve learning outcomes by strengthening students' AI confidence, encouraging responsible technology use and supporting psychological wellbeing alongside academic development.
Bhunia A. K. and Alzahrani S., Frontiers in Psychology, 2026.

FAMILY CONNECTIONS AND GIVING SUPPORT MAY HELP OLDER INDIANS FEEL LESS LONELY

Researchers have found that family connections and opportunities to support others may be important for understanding loneliness among older urban Indians.
The study surveyed 378 older adults in Kalyani, West Bengal, examining how different social networks and exchanges of support were associated with loneliness.

The researchers identified five network types, including networks centred on friends, children living elsewhere, spouses and children living together, distant family, and other connections. After accounting for additional factors, networks involving spouses and children living together, or children living away, were associated with lower loneliness compared with the "other" category. Social support partly explained these relationships.

Interestingly, giving support showed a more favourable relationship with loneliness than receiving support, highlighting the potential importance of older people feeling useful and involved. Because the study measured participants at one point in time, it cannot establish that family connections or giving support directly reduce loneliness. Nevertheless, the findings suggest that efforts to support healthy ageing should consider meaningful participation alongside care provision.

Community spaces and opportunities for intergenerational interaction could help older adults maintain valued social roles and connections.
Hasan M. S. and Ghosal S., Humanities and Social Sciences Communications, 2026.

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SCIENCE IN FOCUS



AI-DRIVEN DRUG DEVELOPMENT

₹86 Crore Boost for India's AI-Driven Drug Development

Finding a promising drug molecule is only the beginning of developing a medicine. Researchers must then test how it works, assess safety and establish whether it is suitable for studies involving people. India's Technology Development Board, under the Department of Science and Technology, has signed an agreement to provide ₹86 crore to Bengaluru-based Peptris Technologies for a programme advancing four drug candidates identified using artificial intelligence. Called VIGOR, the project has a total cost of ₹172 crore. It aims to move the candidates through preclinical development, validation and preparation for clinical trials. This means the immediate focus is on strengthening the evidence needed before human testing, rather than introducing medicines for public use. AI can help researchers identify useful molecules, but computer predictions require experimental confirmation. The programme addresses this gap between discovery and clinical readiness. The funding agreement has been signed, while the proposed development work and progression towards trials remain the programme's objectives. The announcement does not establish that the candidates are safe or effective in patients. If successful, the project could strengthen India's capacity to translate computational research into potential treatments. Its progress will depend on experimental results, safety assessments and the requirements governing further drug development.



CHALLENGES IN THE HIMALAYAS

New Research Centre to Address Health Challenges in the Himalayas

People living or working at high altitude face health challenges. Low oxygen, extreme cold and difficult terrain can affect the body and make medical care harder to access. The Indian Council of Medical Research is establishing a dedicated Centre for High Altitude Medicine and Public Health Research at Keylong in Himachal Pradesh. Union Health Minister Jagat Prakash Nadda laid its foundation stone on 12 October 2026. The proposed centre will build on an existing ICMR field station, developing it into a permanent, year-round research institution with specialised laboratories and staff. The foundation ceremony marks a step towards establishing the facility; it does not mean the completed centre is already operating. Researchers plan to study altitude-related illness, adaptation to low oxygen, maternal and newborn health, child nutrition and disease patterns in Himalayan communities. Collaboration with the Armed Forces Medical Services and other institutions will connect biomedical research with experience gained in demanding mountain environments. The programme will also examine whether drone delivery, digital health services and artificial intelligence can improve healthcare access in remote areas. These are planned investigations, rather than proven services announced through this development. The resulting evidence could guide prevention, diagnosis and care for Himalayan residents and personnel.

SCIENCE IN FOCUS



CANCER DRUG PRICE

Wider Cancer Drug Price Controls Aim to Ease Treatment Costs

Cancer treatment can place a heavy financial burden on families, particularly when medicines must be purchased over long periods. Prices can rise considerably as drugs move through the supply chain, leaving patients facing substantial ongoing costs. The government has approved wider controls on trade margins for cancer medicines that are outside the scheduled list of drugs with regulated ceiling prices. According to the Department of Pharmaceuticals, the margins will be limited to 30% of the maximum retail price.The government estimates that the measure could reduce prices by up to 70% and generate annual savings of ₹2,500 crore for patients. These figures are projections, not savings already recorded.Implementation still requires further steps. An expert committee under the Directorate General of Health Services will finalise the medicines covered, after which the National Pharmaceutical Pricing Authority will issue the relevant notification.The decision builds on a 2019 intervention covering 42 selected cancer drugs. The expanded approach is intended to include branded and generic medicines, domestic and imported products, and patented and non-patented treatments.Manufacturers will also be required to maintain current production levels to support continued availability.The policy could improve affordability without changing the medicines themselves. Its actual impact will depend on the final coverage, implementation and whether lower prices reach patients consistently across pharmacies and hospitals throughout the country.



SAFER FOR WILDLIFE

Making India's Highways Safer for Wildlife

Highways connect communities and support economic activity, but they can also divide wildlife habitats. Animals crossing roads risk collisions, while barriers can restrict access to food, water and breeding areas.The National Highways Authority of India has released a document describing how wildlife protection can be incorporated into highway planning, design and construction. Titled "Wildlife Mitigation Measures & Structures," it brings together engineering approaches intended to maintain movement between habitats.The document reports more than 2,150 wildlife mitigation structures constructed or proposed across national highways. This combined figure includes planned structures and should not be read as the number already completed.Measures include animal underpasses, overpasses, adapted culverts and canopy crossings. Fencing, speed regulation and noise barriers complement these structures. Camera traps are used to monitor animal movement and help assess mitigation measures.NHAI reports approximately ₹19,700 crore invested over five years in wildlife mitigation infrastructure and related environmental safeguards. This represents past investment, rather than a newly announced funding allocation.The document provides a reference for integrating ecological needs with transport engineering. Designs are intended to reflect wildlife movement, local habitat conditions and technical feasibility.

Its importance extends beyond building crossings: protecting connectivity requires structures that animals actually use. Continued monitoring will be necessary to assess performance, identify collision hotspots and improve measures where road development affects wildlife habitats.

SCIENCE IN FOCUS



NATURE WITH ECONOMIC

India's New Roadmap Links Nature with Economic Planning

Economic growth depends on natural resources, yet conventional economic figures do not fully describe changes in forests, water, soils or biodiversity. Environmental accounting helps connect these changes with economic activity, providing a clearer picture of development.India's Ministry of Statistics and Programme Implementation has released its Strategy for Environmental-Economic Accounts for 2026–2030. The document sets a roadmap for expanding environmental accounts and addressing gaps in the information available to policymakers.The planned work covers forests, minerals, soil, land, water, carbon stocks and biodiversity, among other subjects. It builds on earlier efforts involving wetlands, oceans, energy, agricultural land and the services that ecosystems provide. The approach follows the United Nations System of Environmental-Economic Accounting, which provides a framework for organising environmental and economic information together. The strategy has been published, but the expanded accounts and improvements in data coverage remain objectives for the coming years. It also offers guidance to states and union territories seeking to develop their own environmental accounts. Better information could help governments assess resource use, understand environmental pressures and compare development choices. However, the document itself does not demonstrate improved environmental outcomes. Its value will depend on translating the roadmap into reliable statistics that support informed decisions



INDIA AND GHANA

India and Ghana Join Forces on Crop Research and Food Losses

Improving crop production requires more than better seeds. Farmers also need suitable technologies, effective storage and ways to process and market their harvests. India and Ghana have signed a five-year agreement connecting the Indian Council of Agricultural Research with Ghana's Crops Research Institute. The partnership provides a framework for joint research, scientific exchanges, training and agricultural technology transfer. The first phase will focus on vegetable crops, particularly tomatoes. ICAR plans to support the introduction of suitable high-yielding tomato lines and varieties, alongside the scaling up of proven agricultural technologies in Ghana. Further cooperation will address processing and value addition for cassava, yam and other tuber crops. Planned activities also include technical support for cold storage, refrigerated transport, sorting, grading and processing to help tackle post-harvest losses. The agreement allows exchanges of scientists, breeding materials, germplasm and research methods. A joint working group will oversee cooperation and review progress. The agreement has been signed, while the research projects, technology deployment and expected improvements in production remain future work. It does not establish that farmers have already achieved higher yields or reduced losses. If implemented effectively, the partnership could strengthen food production and agricultural value chains while supporting sustained cooperation between researchers.

SCIENCE IN FOCUS



AIRSHIP PLATFORM

India's Experimental Airship Platform Reaches 21 Kilometres

The stratosphere offers a vantage point for observing large areas of Earth. Developing platforms that can operate there requires systems capable of functioning in thin air while maintaining control and communication. India's Defence Research and Development Organisation has completed a successful experimental flight of an indigenous High-Altitude Platform. The lighter-than-air system reached 21 kilometres above sea level and remained around 20 kilometres for more than 30 minutes before being commanded to descend. The platform was recovered, and researchers analysed its flight data. Throughout the trial, the ground control station received real-time video and information about the vehicle's operating conditions. The experimental system carried navigation, sensing and control equipment, including an inertial measurement unit, a GPS receiver, onboard cameras and an altitude-control mechanism. Developed by the Aerial Delivery Research and Development Establishment in Agra, the project aims to create a long-endurance stratospheric surveillance platform. The trial involved coordination with aviation regulators, the Indian Air Force and other authorities. The completed flight demonstrates progress in operating and controlling the experimental platform at high altitude. However, maintaining altitude for half an hour does not establish the prolonged endurance envisaged for the eventual system. Further development and testing will be needed to assess reliability and sustained operation. If those goals are achieved, the technology could support aerial surveillance from a persistent high-altitude vantage point.



INDIA AND JAPAN

India and Japan Set Out a Path for Joint Climate Projects

Reducing greenhouse gas emissions requires cleaner technologies, reliable measurements and financing. International partnerships can help bring these together, especially where promising projects need support before they can operate at scale. Clear procedures help participants understand their responsibilities. India and Japan have launched an operational manual for their Joint Crediting Mechanism, establishing procedures for climate projects under their partnership. The manual was launched in New Delhi on September 30, 2026. The mechanism aims to encourage low-carbon technologies, attract climate finance and support measurable emission reductions and removals in India. It also seeks to strengthen cooperation between the two countries. The manual explains the project process, beginning with submission of a project idea and extending to the issuance and authorisation of credits. These credits represent recognised climate outcomes from eligible activities. The development follows a cooperation agreement signed in August 2025 and implementation rules adopted in June 2026. It supports cooperation under Article 6.2 of the Paris Agreement, which allows countries to work together towards climate commitments.

For project developers, the manual provides a clearer route through the requirements of the mechanism. However, its launch does not mean that projects have already delivered verified reductions or received credits. The next stage is implementation. The partnership's value will depend on the projects undertaken, the technologies deployed and the credibility of their measured outcomes.

SCIENCE IN FOCUS



3D CONCRETE PRINTING

Andhra Pradesh Tests 3D Concrete Printing for Rural Homes

Building a house usually involves assembling walls through manual work. Concrete printing offers another approach: a computer-controlled machine deposits a concrete mixture in layers to form walls, following a digital design. Andhra Pradesh has launched a pilot project to explore this technology for rural housing. The foundation stone was laid on October 4, 2026, in Guntur district, beginning a trial of an approach to building homes for rural communities. The ₹14 crore project plans to build 177 houses at Burripalem and Obulnayudupalem. According to the government announcement, construction is expected to be completed within six months. The proposed approach uses specialised machinery to print concrete structures. Other parts of a home, including roofing, doors, electrical wiring and plumbing, still require construction and installation. Officials expect the technology to reduce construction time, costs and labour requirements. They also say the houses are designed for greater durability and a longer lifespan than conventional alternatives. These are projected benefits; the announcement does not provide completed-project results demonstrating them. The foundation ceremony marks the start of the pilot, rather than the delivery of finished printed homes. The project could provide useful experience in applying automated construction to affordable housing. Its wider significance will depend on actual costs, construction quality, maintenance needs and whether the method can be expanded successfully to serve more rural families.



QUANTUM SECURITY TESTED

Quantum Security Tested Across a 5.56-Kilometre Open-Air Link

Secure communication depends on encryption keys that allow messages to be read only by authorised users. Quantum key distribution uses the behaviour of light particles to share keys and detect signs of interception. It differs from sending ordinary data through an internet connection.QNu Labs, working with the Bhaskaracharya National Institute for Space Applications and Geo-informatics and IIT Gandhinagar, has demonstrated a 5.56-kilometre quantum key distribution link through open air.The field trial took place on the night of September 27–28, 2026, between the institute and IIT Gandhinagar. A tracking system kept the optical equipment aligned across the distance.The link generated secure keys at 230–260 bits per second, with a quantum bit error rate below 5%. This rate describes errors in the quantum signals used to establish the keys, rather than the speed of ordinary message transmission.Researchers combined the hardware with the institute's Vedic Kavach platform, which uses cryptographic methods designed to resist attacks from quantum computers. The integrated system successfully encrypted and decrypted test messages.The demonstration provides practical experience in combining quantum hardware with complementary software security. It could inform efforts to develop secure communication networks.However, this was a ground-based trial, not a satellite link or a nationwide service. Longer distances, changing atmospheric conditions and reliable operation will require development and testing before wider deployment.

SCIENCE IN FOCUS



ORGANIC WASTE INTO FUEL

India Launches ₹23,731 Crore Plan to Turn Organic Waste into Fuel

Organic waste can become a useful energy resource. Microorganisms break down materials such as cattle dung and crop residues to produce biogas. After purification and compression, this gas can serve as fuel, while processed residues can provide manure. India has launched an integrated GOBARdhan scheme to expand its compressed biogas sector. Announced on October 1, 2026, the scheme has an approved outlay of ₹23,731 crore and covers ten years, from 2026–27 to 2035–36. The framework brings together purchase assurance, predictable pricing, capital assistance, pipeline development, credit guarantees and support for the wider production ecosystem. A handbook and unified digital portal have also been launched to guide applicants and simplify implementation.

The scheme aims to increase domestic compressed biogas production nearly ten-fold. It seeks to give developers clearer routes to customers and financing, addressing obstacles that can prevent promising projects from becoming operating plants. India already had more than 217 commissioned plants by August 2026, according to the announcement. The new scheme builds on this existing base. Its potential importance extends beyond fuel production. Collecting and processing organic waste could create rural employment, supply manure and reduce dependence on imported gas. However, the production expansion, jobs and environmental benefits are projections. Results will depend on plants being built, dependable feedstock supplies, effective operations and sustained demand for gas and manure products.



RESEARCH PROGRAMME

New Research Programme Targets Pests in India's Stored Grain

Insects can damage wheat and rice long after harvesting, making safe storage essential for food security. Repeated use of pest-control chemicals can encourage resistance, while fumigation requires careful handling to protect workers and limit exposure. The Indian Council of Agricultural Research and the Food Corporation of India have signed an agreement to investigate alternative fumigation methods for stored foodgrains. The agreement was signed on September 30, 2026.

The initial two-year research phase will be conducted by ICAR's Central Institute of Post-Harvest Engineering and Technology in Ludhiana, with support from the Department of Food and Public Distribution. Researchers plan three types of trials. One will use nitrogen gas exceeding 99% purity to control pests in wheat stored in metal silos. Another will combine carbon dioxide with phosphine for wheat and rice stored in warehouse bags. The third will test carbon dioxide treatment of bagged grain enclosed within airtight covers. These approaches aim to address pest resistance, occupational exposure, environmental impacts and fumigant residues. The combined treatment still uses phosphine, so the programme should not be described as entirely chemical-free.

The trials will help determine whether these methods offer reliable pest control while remaining practical for large storage facilities and protecting the quality of grain.

INNOVATIONS & PATENTS

Every great invention begins with a bold idea—and a patent to protect it. Innovations drive progress, and patents turn breakthroughs into lasting impact. From lab benches to the marketplace, this is where creativity meets protection.

| By Dr. Avijit Das

ROBOTS THAT WALK AND FLY: A NEW APPROACH TO HYBRID ROBOTICS

Robots are increasingly being developed to explore dangerous environments, inspect damaged infrastructure, and assist in disaster response. However, most robots are designed either to move on the ground or to fly. Walking robots can navigate uneven surfaces but may struggle to cross large gaps, while flying robots can bypass obstacles but are less suited to sustained ground movement. A new invention proposes a robotic system that combines both capabilities, allowing a four-legged robot to walk on the ground and transform into a flying machine when needed.

The system uses four motorised legs for ground movement, with each leg carrying an electric ducted fan. A fifth fan is positioned centrally on the robot's body to provide additional thrust during flight. When switching to aerial operation, the robot deploys its landing gear for support, folds its legs into a flight-ready position, and activates its five fans. Once airborne, the landing gear can retract to reduce interference. A central control system coordinates the leg movements, propulsion units, and landing gear, enabling controlled transitions between walking and flying modes.

The invention's main advantage is its ability to combine two different forms of movement within a single robotic platform. Such technology could potentially support search-and-rescue missions, industrial inspections, and exploration of difficult terrain where conventional robots face limitations. By integrating flexible mechanical design with coordinated electronic control, the invention offers a promising approach to developing more adaptable robots capable of operating across challenging environments.

INNOVATION

Raturi P, Mohan S. Multimodal Robotic System for Ground Locomotion and Aerial Operation. Indian Patent Application No. 202641030841.
Indian Institute of Technology Palakkad, Kerala, India.



| By Dr. Priyanka

SMART SAFETY WEAR THAT DETECTS DANGER AND SENDS EMERGENCY ALERTS

Personal safety is a growing concern, particularly for children, older adults and individuals who may be unable to call for help during an emergency. Most existing safety devices, such as panic buttons and mobile applications, require users to activate them manually. However, during an assault or other dangerous situation, a person may not have the opportunity to seek assistance. A new invention proposes an intelligent wearable safety system that can automatically detect signs of forced interference and initiate protective responses without requiring the wearer to press a button. The technology uses insulated copper wires embedded within clothing to create an electrical circuit that continuously monitors the garment's condition. If the clothing is forcibly torn, cut or tampered with, changes in electrical continuity are detected by sensors and analysed by a small electronic control unit.

The proposed system can then activate audible alarms, flashing lights and emergency notifications containing the wearer's location. Additional features include automatic audio or video recording, an electronically controlled locking mechanism and optional deterrent devices intended to discourage an attacker. The invention's significance lies in combining automatic threat detection, emergency communication and protective mechanisms within a single wearable system. Unlike conventional panic buttons, it is designed to respond even when the wearer cannot manually request help. Such technology could potentially support personal safety in everyday environments, although its effectiveness, reliability and the safety of its deterrent mechanisms would require practical testing. The invention illustrates how smart textiles and electronic sensing could contribute to the development of more responsive personal protection technologies.

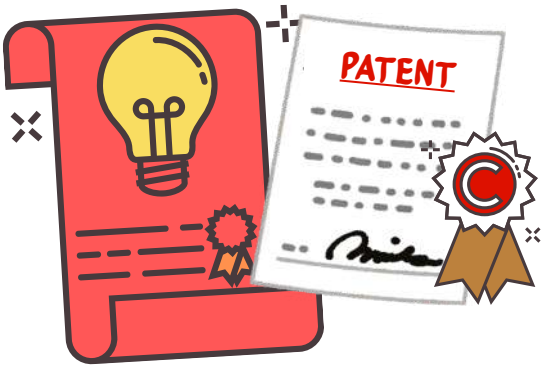
INNOVATION

Nagaraj N. An Automatic Personal Mishap Detection, Prevention and Safety Wear. Indian Patent Application No. 202641029032. Published 20 March 2026.

ESOMEIN Manufacturing Private Limited, Vellore, Tamil Nadu, India.



Dark by Design, Cool by Function: Defect-Engineered Spinel Pigments for Solar Heat Management





Dr. Sheik Muhammadhu Aboobakar Shibli
University of Kerala, India
| Scientific Profile |
| Organization Link |
| Factors Press |

AREAS OF EXPERTISE
Protective coatings • Electrocatalysts • Electrodes • Photocatalytic Hydrogen Generation



Dr. Saithathul Fathima Sameera
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| Organization Link |
| Factors Press |

AREAS OF EXPERTISE
Sustainable and Functional coatings • Advanced material characterization • Surface and Interface Engineering • Hydrogen Generation

THE INNOVATION EDGE

Can dark-coloured buildings and vehicles stay cool under the sun? Prof. Sheik Muhammadhu Aboobakar Shibli and Dr. Saithathul Fathima Sameera of the University of Kerala have developed a patented technology challenging the idea that dark surfaces must absorb more heat. Their specially engineered pigments retain dark colours while reflecting significant solar infrared radiation. By precisely modifying crystal structures, these pigments offer a promising solution for cooler roofs, buildings, and vehicles, potentially reducing cooling energy demand and supporting sustainable, heat-resilient cities without compromising appearance.

Have you observed that wearing a black shirt on a hot summer day makes you feel hotter, whereas a white shirt helps keep you cooler? We've all learned the simple rule that dark colours absorb sunlight and trap heat, while light colours reflect it. But what if a surface appears pitch black or deep brown to our eyes, yet behaves like a shiny mirror reflecting the sun's heat away?

Looking Beyond What the Eye Can See

Let's look at sunlight. The light hitting a surface isn't just the visible colours we that see; but a major part of the sun's energy arrives as invisible near-infrared (NIR) radiation, which carries pure heat, particularly around 1100 nm. Pigments are coloured substances that give paints, inks, and other materials their colour by selectiv-



Figure 1. Comparative Analysis of Conventional and Advanced Near-Infrared (NIR) Reflective Cool Roof Performance. Comparison of performance of conventional and advanced roofs under solar radiation. Left: A Conventional low-reflectance roof (R% 10-20, high heat absorption, high building temperature). Right: A High-reflectance IR cool roof (R% 61 using a new dark-colored pigment; reflects heat, lowering building temperature).

DOI: https://doi.org/10.67831/Sci.Factors.2026.1674

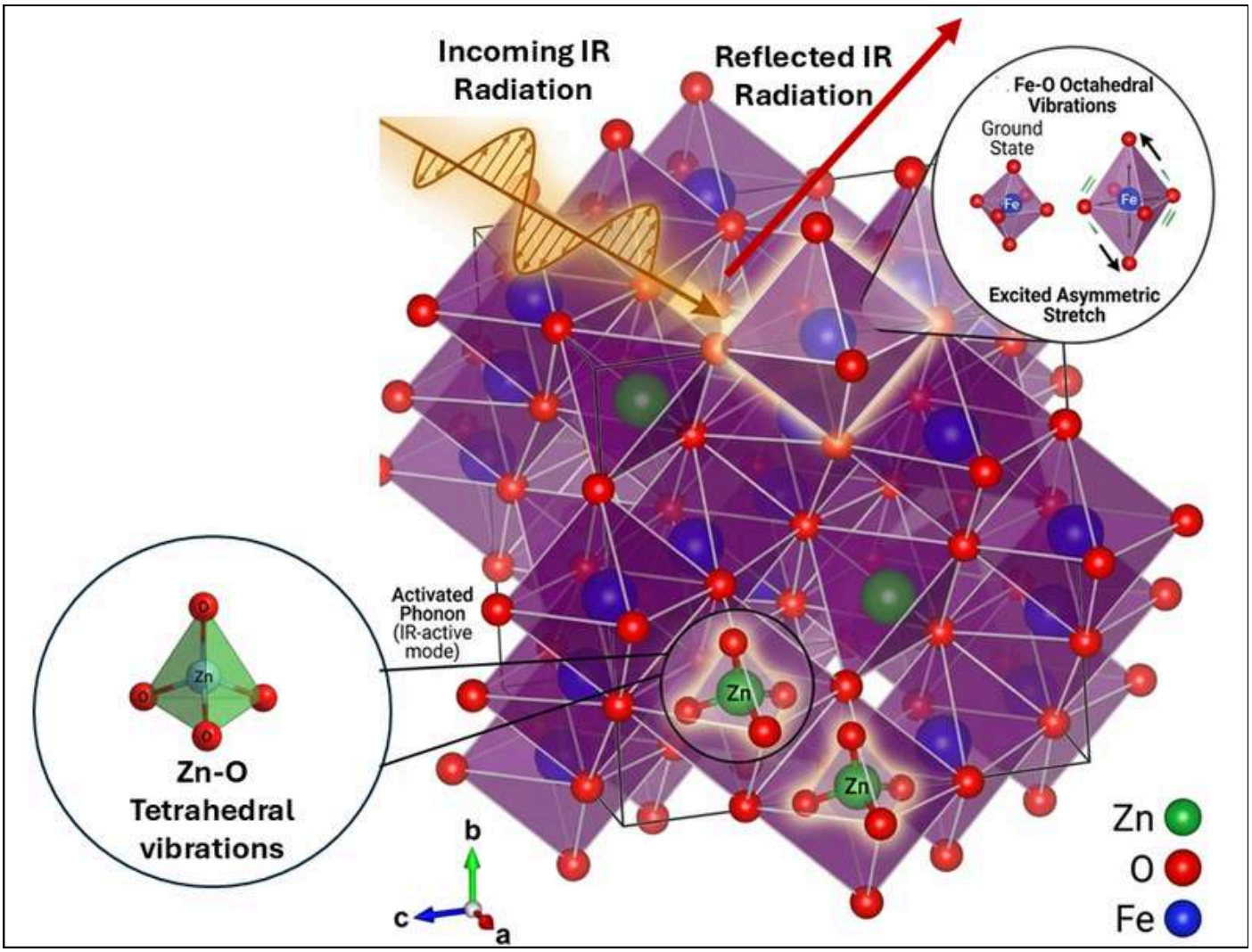


Figure 2. Infrared (IR) Reflection in a Spinel Lattice. Illustration of the interaction of incoming near-infrared (NIR) radiation with a complex spinel-type oxide crystal lattice. The lattice is composed of zinc (Zn, green spheres), iron (Fe, blue spheres), and oxygen (O, red spheres). The phonon excitations within iron-centered Fe-O octahedra; and a Zn-O tetrahedron are shown.

ely absorbing and reflecting light. Pigments are used in paints, printing inks, plastics, textiles, cosmetics, ceramics, paper, construction materials, and art. Inorganic pigments are more stable under common environmental conditions than their organic counterparts. White pigments have high light-reflecting properties, which can produce excessive brightness or glare. This may cause visual discomfort, especially under strong lighting or sunlight. Hence, dark-shaded pigments are preferred and also for their aesthetic appeal. But in terms of functionality, commercial dark pigments often absorb both visible and near-infrared radiation, which limits aesthetic applications. Hence, buildings, pavement and automotive surfaces painted with conventional dark colours can become substantially hotter under intense sunlight. This creates a challenge for modern infrastructure: people require dark, attractive colours, but dark surfaces are often linked with greater heat absorption. This challenge becomes increasingly important as cities experience rising temperatures, increasing energy demand for cooling, and more recurring extreme-heat events. Concrete jungles act as thermal sponges, exacerbating the “urban heat-island effect” documented in the cities worldwide. Buildings account for approximately 30% of the worldwide energy demand. Thus, buildings, both residential and commercial, and infrastructure need to become not only energy-efficient but also more resilient to solar heat. Many materials have been developed for their heat reflective properties. Numerous approaches have been explored to control solar heating, including reflective coatings, cool roofs, and passive radiative cooling technologies. However, the challenge lies in achieving a dark aesthetic while maintaining high solar-reflective efficiency.(Fig.1)

The present approach tackles this problem at the level of the pigment material itself.

Engineering Colour and Heat Reflection

In the present work, we focus on engineering ceramic oxide materials, specifically transition metals. Instead of accepting the usual trade-off between dark colors and heat absorption, we precisely tweak the crystal lattice at the atomic level via controlled substitution of metal ions, resulting in a targeted crystal defect. By carefully replacing selected metal ions and controlling the defects in the crystal lattice, we can tune how the pigment interacts with sunlight; absorbing visible light for a rich dark colour while reflecting much of the heat-carrying NIR radiation out. Particle size tuning effectively optimizes Mie scattering specifically for NIR photons.

This process is unique in that it allows the pigment to selectively absorb light in the visible region, producing vibrant dark hues while remaining aesthetically striking. This is the mechanism of the present patented technology. (Fig.2)

The innovation is highly suitable for industrial scalability. The developed colourants can provide efficient total solar reflectance, which is the fraction of incoming sunlight reflected by a surface, while retaining visually attractive dark shades. Importantly, the concept is not restricted to a single colour. It can be meticulously extended across a wider palette of dark shades, including brown tones, creating opportunities for applications where aesthetics is as important as thermal performance.

The pigments are primarily crystallographically designed so as to be heavy-metal-free and can be incorporated into a wide range of conventional coating formulations. Validated at TRL-4, the developed pigments easily blend into industrial acrylic and polyurethane coatings.

Thus, without requiring significant infrastructure expenditures, the present cool coatings offer an affordable, scalable urban climate adaptation technique that can greatly improve air quality, lowers peak electricity use, and increases community resilience to climate change.

The current market of infrared-reflective coatings enters a phase change of structural expansion across the construction, automotive, and defense sectors. Due to the adoption of automotive LiDAR and ADAS, industrial automation, and construction activities, the Asia-Pacific region is the largest and fastest-growing regional market. With growing demand for energy-efficient buildings and heat-resilient infrastructure, the present pigments can offer an exciting opportunity to bring dark, aesthetically appealing surfaces for the next generation of cool coatings. For industries, the present material offers a feasible path to delivering "dark by design, cool by function" solutions that could satisfy both consumer aesthetic demands and the rigorous energy mandates of the next decade.

The next stage is the transition from laboratory validation to larger-scale coating demonstrations, weather-accelerated testing, durability assessment, and optimization for different substrates and climates. Integration with building-envelope technologies and smart material design could further expand the impact. By employing low-cost raw materials and a scalable synthesis approach, this high-performance IR-reflective pigment provides an economically viable, energy-saving alternative to the current expensive commercial cool pigments.

Ultimately, the objective is straightforward: A roof does not need to be white to be cool. A vehicle does not need to sacrifice its aesthetic dark colour to manage heat. And a building does not need to choose between aesthetics and energy performance.

The present patented technology offers a pathway towards the development of a new generation of materials in which appearance and thermal function are designed together—dark by design, cool by function.

All cool surfaces may therefore need not to be white in the next generation. It may be black, brown or any colour that the end users' prefers.

Inside Pharmaceutical R&D: Translational Science, Work Culture and Career Pathways



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| Scientific Profile |
| Organization Link |
| Factors Press |

AREAS OF EXPERTISE
Cell Biology | Oncology Drug Discovery and Development | Translational Oncology | Clinical Biomarker Development

SNAPSHOT

Turning laboratory discoveries into potential cancer treatments takes scientific knowledge and teamwork. In this conversation, Dr. Payel Das, a translational biologist at Aurigene Oncology, explains how biomarkers help connect drug discovery with patient care. The discussion offers a look inside pharmaceutical research and practical advice for researchers considering a career beyond academia. It also explores daily work, the challenges of developing new medicines, and the skills needed to succeed in industry.

Q *Could you briefly describe your academic journey and what motivated you to move from university research into the pharmaceutical industry?*

A I completed my PhD in Cell and Developmental Biology from Germany where I developed a strong foundation in experimental biology. To be honest, I didn't actually plan to move to industry after my PhD. I never thought of myself as someone who could work outside academia. As strange as it might sound, I didn't actively choose cancer drug discovery, it chose me and I am glad it did. I was planning to move back to India, and came across this position on LinkedIn whose job description matched with the skills I had gained during my academic journey. I talked to an employee from the company who was kind enough to refer me for the position. Next thing I know, I got a call from the HR the very next day and within a month, everything was finalized and I had the offer letter.

Q *You currently work at Aurigene Oncology. Could you introduce the company and explain the major areas of drug discovery and development in which it works?*

A Aurigene Oncology is an oncology-focused drug discovery and development company based in India. It is a subsidiary of Dr. Reddy's Laboratories. We work on precision oncology which involves discovering and developing novel anti-cancer therapies. The work spans early target discovery and drug optimisation to preclinical development, translational research and clinical development. Several programs have progressed from laboratory research into clinical trials. Our goal is to make anti-cancer medicines easily accessible to patients.

Q *What is your role as a translational biologist, and what does a typical working day look like for you?*

A As a translational biologist, my role is to understand which patients are most likely to benefit from a drug, how we can demonstrate that the drug is working, and how we should position it clinically. My day typically involves analysing experimental or patient data, planning biomarker studies, designing and conducting experiments, reviewing literature and discussing results with the relevant cross-functional teams and stakeholders. I am fortunate to be a part of a team that works very closely with the clinical team and has the privilege of accessing and assessing patient samples directly. But it also often comes with a cost- I have to spend most of my weekends in the lab because patient samples often come during that time and need immediate processing and analysing. But overall, most days (including weekends) are fun, I discover something new almost everyday

since the field of oncology is so dynamic.

Q *Your work helps connect laboratory discoveries with clinical development. Why is this connection important for transforming a promising scientific idea into a potential treatment?*

A A molecule showing activity in a lab model is only the beginning. We need to understand why it works, which tumours are biologically dependent on its target, what dose produces the desired biological effect and which patients should receive it. Translational research tries to answer these questions before and during clinical trials. This makes drug development more hypothesis-driven rather than simply testing a molecule in an unselected patient population. Selecting the right kind of cancer patients can change the whole game for a molecule to eventually become a commercial drug and lies at the heart of translational oncology.

Q *How do biomarkers help researchers identify suitable patients, evaluate treatment responses and make decisions during clinical development?*

A *Biomarkers can serve several different purposes. Predictive biomarkers help identify patients who may be more likely to respond, pharmacodynamic biomarkers tell us whether the drug is engaging its intended biology, and response biomarkers help us understand what is happening during treatment. Together, these measurements help teams interpret clinical results and make better decisions about dose, patient selection and future development.*

Q *You have worked with PROTACs and small-molecule inhibitors. Could you explain these technologies simply and describe why they are important for developing new cancer treatments?*

A Traditional small-molecule inhibitors usually bind to a protein and block its activity. PROTACs work differently: they bring a disease-causing protein to the cell's natural protein-disposal machinery so that the protein itself is degraded. This can allow us to target cancer-driving proteins in ways that conventional inhibitors sometimes cannot. Both approaches expand the possibilities for designing more precise cancer therapies.

Q How do teams from biology, medicinal chemistry, toxicology, quality assurance and clinical development collaborate when developing a new medicine?

A Drug development is never the work of one discipline. Biologists establish the disease rationale and test activity, medicinal chemists optimise the molecule, toxicologists evaluate safety, and translational teams connect the preclinical findings with patients. Quality teams ensure that the work meets appropriate standards, while clinical teams determine how the drug can be evaluated in patients. Continuous communication between these groups is essential because decisions made by one team affect everyone else.

Q How is the working culture in the pharmaceutical industry different from that of an academic research laboratory?

A Academic research often allows greater freedom to explore an interesting scientific question in depth. Industry research is usually more goal-oriented, with defined timelines, milestones and decisions about whether a program should continue, change direction or stop. Experiments therefore need to answer specific questions that influence drug-development decisions. Documentation, reproducibility, teamwork and accountability also become extremely important. Academia, in general, is slow paced and gives you enough time to think, design and execute experiments. Industry, on the other hand, can be extremely fast-paced, sometimes decisions have to be made in a week or two, so you have lesser time to ponder over a single experiment or result.

Q What are the most rewarding aspects of working in industry, and what challenges should students be prepared to face?

A *The most rewarding part is seeing scientific work contribute to a program that may eventually reach patients. It is especially meaningful when something that began as an experimental hypothesis becomes part of a clinical strategy. At the same time, industry can be fast-paced and programs can change or stop despite years of work. Students should be prepared for deadlines, uncertainty and the need to adapt quickly when the data change the direction of a project.*

Q *Apart from laboratory expertise, which professional skills such as communication, teamwork, documentation, project management and meeting deadlines are important for succeeding in ind-*

ustry?

A Technical expertise is important, but it is not enough. You need to communicate complex science clearly to people from very different backgrounds, work effectively across teams and document your work carefully. Prioritisation and time management are also critical because several projects may require attention simultaneously. Perhaps most importantly, you need to be reliable; people should be able to trust both your data and your commitments.

Q *What practical steps should PhD students and postdoctoral researchers take if they want to switch from academia to the biotechnology or pharmaceutical industry?*

A Start by understanding how your research skills translate into drug discovery rather than simply listing experimental techniques. Learn the basics of the drug-development process, read industry papers and clinical studies, and understand concepts such as target validation, biomarkers, pharmacology and safety. Tailor your CV to the role you are applying for and highlight problem-solving rather than only publications. Networking with scientists already working in industry can also provide a much clearer picture of different career paths.

Q *What common mistakes should applicants avoid in their CVs and interviews, and what final advice would you give to students who are uncertain about making the transition to industry?*

A One common mistake is writing a highly academic CV that lists every technique and publication without explaining what problems the candidate actually solved.

During interviews, avoid giving rehearsed answers without demonstrating your scientific reasoning, teamwork or ability to handle failure. You don't need to know everything about industry before joining it. Be curious, understand the science deeply, remain willing to learn, and focus on how your skills can contribute to solving real drug-development problems.

ABOUT THE AUTHORS

Dr. Payel Das is a translational oncology scientist working to bridge drug discovery and clinical development. She holds a PhD in Cell and Developmental Biology from Universitätsklinik Erlangen, Germany, and is currently a Senior Scientist I in Translational Biology at Aurigene Oncology. Her expertise includes predictive and pharmacodynamic biomarkers, patient stratification, mechanism-of-action studies, and translational strategies for oncology therapeutics. She has contributed to multiple IND-enabling and clinical-stage programs across diverse cancer indications, helping turn preclinical evidence into clinically actionable insights. Passionate about advancing cancer research in India, she aims to help develop innovative, globally relevant therapies that improve outcomes for patients.



| OBITUARY |

Palle Rama Rao

REMEMBERING PROFESSOR PALLE RAMA RAO: A LIFE THAT STRENGTHENED INDIAN SCIENCE

(30 June 1937 – 3 October 2026)



India's scientific community has lost a distinguished researcher and leader with the passing of Professor Palle Rama Rao, an eminent metallurgist, scientific administrator and institution builder. He passed away in Hyderabad on 3 October 2026, aged 89. Throughout his career, he connected fundamental research on metals with practical engineering challenges and helped strengthen institutions dedicated to research, education and technological development. His legacy reflects the lasting contribution a scientist can make through discoveries, public service and the opportunities created for future generations.

Professor Rama Rao's academic journey placed him within some of India's leading centres of learning. He joined the Department of Metallurgy at the Indian Institute of Science, Bengaluru, in 1960 and moved to Banaras Hindu University in 1962. He obtained his doctorate from BHU in 1964 and undertook postdoctoral research at the University of Pennsylvania during 1966–1967. He became Professor of Physical Metallurgy at BHU in 1975. These years established the foundation for a career that would move between university research, defence laboratories and national scientific leadership.

At the centre of his scientific work was a question with wide practical importance: what makes a metal strong, and what causes it to fail? A metal component may appear solid and uniform, but its behaviour depends on structures far too small to see with the unaided eye. The arrangement of atoms, the size of crystalline grains and the boundaries between them influence how a material responds to force. His publications examined these relationships, including how grain size affects deformation and fracture. This research helped connect the microscopic world inside metals with their performance in engineering.

His early investigations included studies of imperfections in crystal structures using X-ray diffraction. In simple terms, this technique allows researchers to examine atomic arrangements by observing how a material scatters X-rays. His work on stacking faults concerned disruptions in the normal sequence of atomic layers. Such investigations belong to the foundations of materials science: understanding a material requires looking beyond its chemical ingredients to the way those ingredients are organised. The distinction matters because metals with similar compositions can behave differently when their internal structures differ.

Professor Rama Rao also investigated how metals behave under prolonged stress, repeated loading and elevated temperatures. These conditions can gradually damage a component even when it does not break immediately. Creep describes slow deformation under a sustained load, while fatigue involves damage accumulating through repeated loading. His research addressed both processes, alongside the initiation and growth of cracks. For a general reader, the importance is straightforward: reliable materials must do more than survive a single test. They must continue to perform throughout their working lives, under the conditions in which they are actually used.

One particularly tangible contribution was his involvement in research on steel combining very high strength with high fracture toughness. Strength concerns a material's ability to withstand force; fracture toughness concerns its resistance to the growth of an existing crack. Achieving both is a demanding challenge. A material can be strong yet vulnerable to sudden failure once cracking begins. Professor Rama Rao contributed to alloy-development programmes at the Defence Metallurgical Research Laboratory in Hyderabad, bringing fundamental understanding of metal behaviour into work directed towards demanding technological needs.

A major DMRL programme, launched in the mid-1980s, eventually produced DMR-1700, an ultrahigh-strength, low-alloy steel. Its objective was to develop a cost-effective alternative to a highly alloyed maraging steel. DRDO's account describes a research effort extending over three decades, encompassing development, production and applications. Professor Rama Rao later co-authored a monograph on this work with metallurgist G. Malakonda-

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iah. The achievement therefore reflects sustained collaboration, experimental investigation and engineering development, illustrating the considerable effort required to move a promising material from research into practical use.

DRDO reported that DMR-1700 demonstrated suitability as a replacement for maraging steel in missile casings, enabled a substantial reduction in the weight of a mortar base plate and showed superior ballistic performance in armour applications. These examples make the scientific achievement understandable beyond the laboratory. Better combinations of strength and toughness can allow equipment to perform demanding functions while addressing weight and cost. The programme showed how detailed knowledge of metals could support a material developed within India and create an alternative for important engineering applications.

His responsibilities expanded alongside his research career. He directed DMRL for nine years following his tenure at BHU and became a Distinguished Scientist in DRDO in 1989. He served as Secretary of the Department of Science and Technology from 1991 to 1995, also holding responsibility for Ocean Development. He subsequently chaired the Atomic Energy Regulatory Board during 1996–1999 and served as Vice-Chancellor of the University of Hyderabad during 1999–2002. These appointments brought his experience into decisions affecting research programmes, scientific education and technological development across the country.

His contribution to institution building included helping establish facilities such as the International Advanced Research Centre for Powder Metallurgy and New Materials, the Non-Ferrous Materials Technology Development Centre and the National Institute of Ocean Technology. His achievements earned the Shanti Swarup Bhatnagar Prize, Padma Shri, Padma Bhushan and Padma Vibhushan.

These honours recognised a career whose influence extended across research and public service. Institutions are an especially enduring part of such a legacy: they provide places where future researchers can ask questions, develop skills and turn ideas into useful knowledge.

Remembering Professor Rama Rao means recognising the patient work behind scientific progress. Understanding a crack, improving an alloy or building a research centre may demand years of effort before its full importance becomes visible.

His career brought these different forms of contribution together. For young scientists, it offers an example of how careful investigation can grow into wider service without losing its connection to fundamental questions. Science Factors extends its heartfelt condolences to his family, colleagues and the scientific community.

We honour a life devoted to understanding materials, strengthening institutions and advancing the capacity of Indian science.



By
Rosalind Franklin
Council of Scientific Research
(**RFCSR**)

SCIENCE NEWS & OPPORTUNITIES

"Science News & Opportunities" keeps you updated with the latest scientific breakthroughs and opens doors to exciting careers, scholarships, and research programs.



24 October 1632 — Antonie van Leeuwenhoek

01

Antonie van Leeuwenhoek was a Dutch microscopist who revealed a world of living organisms invisible to the unaided eye. Using carefully made single-lens microscopes, he examined water and other samples and described tiny organisms, including bacteria and protozoa. He called these creatures “animalcules.” His observations showed that apparently ordinary materials could contain abundant microscopic life. Leeuwenhoek reported his findings to the Royal Society, helping establish microscopy as a powerful method for investigating nature. He did not invent the microscope, but his skilful lens-making and patient observations greatly extended what it could reveal. His work helped lay the foundations of microbiology and changed how scientists understood living things.



10 October 1731 — Henry Cavendish

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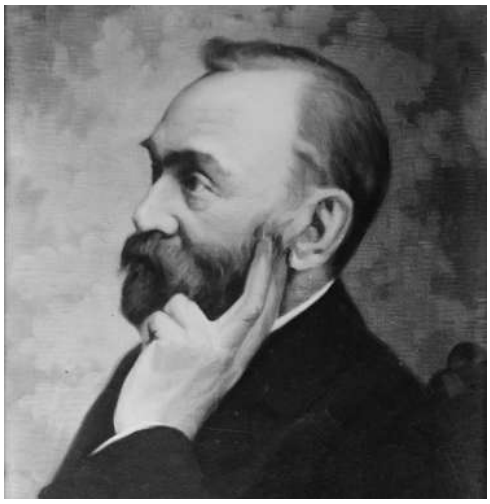
Henry Cavendish was a British scientist known for exceptionally careful experiments. His famous 1798 experiment measured the tiny gravitational attraction between objects in a laboratory. He used small lead balls suspended from a fine wire and observed how nearby larger balls caused the wire to twist. From this extremely small movement, he calculated Earth’s average density. The experiment showed that gravity between ordinary objects could be measured, even though the force was very weak. His measurements also provided the information needed to calculate the gravitational constant. Cavendish’s work became an important example of how precise laboratory experiments can reveal properties of the entire planet.



21 October 1833 — Alfred Nobel

03

Alfred Nobel was a Swedish chemist, inventor and industrialist best known for developing dynamite. Nitroglycerin was a powerful explosive, but handling it was dangerous. Nobel developed a more manageable form by combining it with an absorbent material, creating dynamite, which he patented in 1867. This made explosives more practical for activities such as mining, tunnelling and construction, although they remained hazardous. Nobel’s lasting influence also came through his will, which directed much of his fortune towards prizes recognising contributions to humanity. The Nobel Prizes became an international celebration of achievement in science, literature and peace. His legacy connects technological invention with recognition of human progress.



7 October 1885 — Niels Bohr

04 Niels Bohr was a Danish physicist who helped explain the structure of atoms. In 1913, he proposed that electrons in a hydrogen atom could occupy only certain allowed energy levels. When an electron moved between these levels, the atom absorbed or released a specific amount of energy. This explained why hydrogen produces distinct lines of light rather than every possible colour. Although later discoveries replaced parts of his atomic model, its central idea helped establish quantum physics. Bohr also built an influential research community in Copenhagen. He received the 1922 Nobel Prize in Physics for his investigations of atomic structure and radiation.



20 October 1891 — James Chadwick

05 James Chadwick was a British physicist who discovered the neutron in 1932. Scientists knew that atoms contained positively charged protons, but the structure and mass of atomic nuclei were not fully understood. Chadwick investigated penetrating radiation produced when beryllium was struck by alpha particles. His experiments showed that the radiation consisted of particles with no electric charge and a mass close to that of a proton. These particles were named neutrons. The discovery helped explain atomic nuclei and why atoms of the same element can have different masses. It opened new directions in nuclear research. Chadwick received the 1935 Nobel Prize in Physics for discovering the neutron.



6 October 1893 — Meghnad Saha

06 Meghnad Saha was an Indian physicist whose work helped scientists understand the light coming from stars. He developed the Saha ionisation equation, which explains how temperature and pressure affect whether atoms lose their electrons. These changes influence the patterns of light absorbed by gases in a star's atmosphere. His equation helped explain why different stars show different spectral lines, even when they contain similar elements. It gave astronomers a powerful tool for studying stellar temperatures and conditions. Saha's work became a foundation of modern astrophysics, showing how the behaviour of tiny atoms can reveal the properties of distant stars.



30 October 1909 — Homi Jehangir Bhabha

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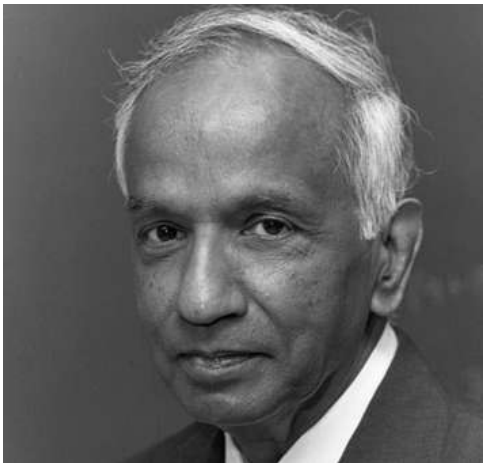
Homi Jehangir Bhabha was an Indian physicist who combined fundamental research with scientific institution building. He contributed to understanding cosmic rays and the behaviour of elementary particles. His theoretical description of interactions between electrons and their antimatter partners, positrons, became known as Bhabha scattering. He also recognised that India needed strong research institutions to develop advanced technologies. Bhabha founded the Tata Institute of Fundamental Research and helped establish the country's atomic energy programme. His efforts brought together research, training and technological development. He is remembered as a central architect of Indian nuclear science whose influence extended beyond individual discoveries to the institutions that made future research possible.



19 October 1910 — Subrahmanyan Chandrasekhar

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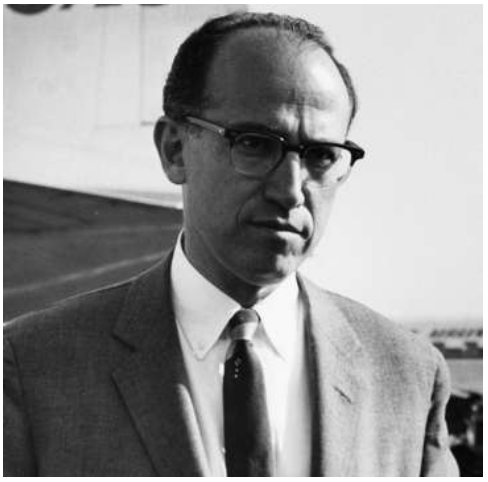
Subrahmanyan Chandrasekhar was an Indian-born American astrophysicist who transformed understanding of how stars evolve. He showed that a white dwarf, the dense remnant left by certain stars, could remain stable only below a maximum mass of approximately 1.4 times the Sun's mass. Above this threshold, the pressure supporting it cannot balance gravity. This became known as the Chandrasekhar limit. His work helped explain why stellar remnants have different fates and provided a foundation for studying stellar collapse and supernova explosions. Chandrasekhar received the 1983 Nobel Prize in Physics, sharing it with William Fowler, for theoretical work on the physical processes governing stellar structure and evolution.



28 October 1914 — Jonas Salk

09

Jonas Salk was an American medical researcher who led the development of the first successful inactivated polio vaccine. Polio could cause paralysis and sometimes death, making it one of the most feared childhood diseases. Salk's vaccine used poliovirus that had been inactivated so it could stimulate immune protection without causing infection. Following a large field trial, the vaccine was declared safe and effective in 1955. Its introduction became a major advance in preventing polio and reducing suffering. Salk later founded the Salk Institute, creating a centre for research into fundamental biological questions. His work demonstrated how laboratory research and carefully organised clinical testing could protect millions of people.



Nobel Prizes 2026: Discoveries That Changed How We Study Life, Space and Molecules

Physiology or Medicine: A Light Switch for Nerve Cells



Karl Deisseroth, Peter Hegemann and Georg Nagel

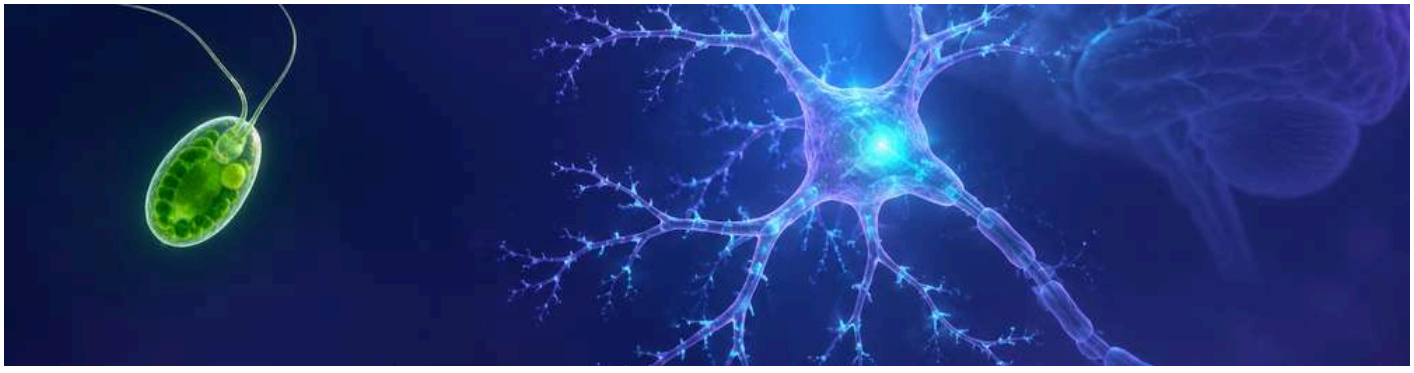
A discovery that began with a tiny green alga eventually gave scientists a powerful way to investigate the brain. The 2026 Nobel Prize in Physiology or Medicine honours Karl Deisseroth of Stanford University, USA; Peter Hegemann of Humboldt University of Berlin, Germany; and Georg Nagel of the University of Würzburg, Germany, for discoveries concerning light-sensitive ion channels and optogenetics the use of light to control selected cells.

Peter Hegemann wanted to understand how the single-celled alga Chlamydomonas responds to light. Together with Georg Nagel and colleagues, he identified proteins called channelrhodopsins. These proteins form tiny gates in the cell's outer membrane. Light opens the gates, allowing electrically charged particles to flow through and change the cell's electrical activity.

The researchers discovered that these proteins could also make other cells sensitive to light. Karl Deisseroth and colleagues took the next step by introducing a channelrhodopsin gene into mammalian nerve cells. A flash of blue light could then trigger a nerve signal. The approach subsequently became possible in living animals.

This provided a way to investigate the brain with remarkable precision. Researchers could activate selected nerve cells and observe how this changed an animal's behaviour. Rather than simply watching cells become active, they could test their contribution to particular functions. Optogenetics has helped reveal circuits involved in memory, emotions and behaviour, and is being explored in attempts to restore sight.

The discoveries emerged in the early 2000s, with a landmark demonstration in mammalian nerve cells published in 2005. Their recognition in 2026 celebrates an enduring transformation in neuroscience, showing how curiosity about a simple organism can open new paths to understanding the human brain.



Nobel Prizes 2026: Discoveries That Changed How We Study Life, Space and Molecules

Physics: Reading the Universe Through Antarctic Ice



Francis Halzen

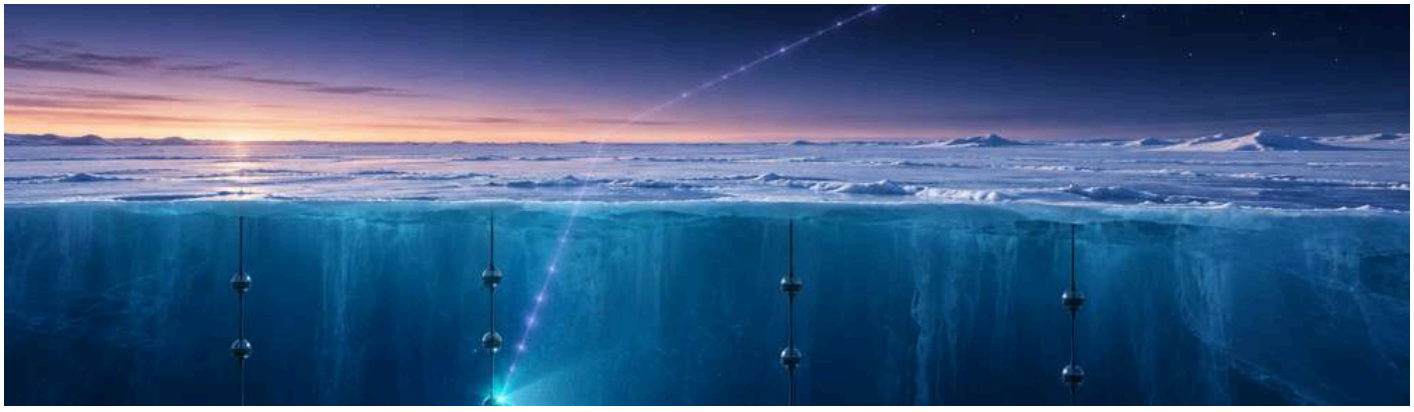
Deep beneath the South Pole, Antarctic ice has become part of an extraordinary observatory. The 2026 Nobel Prize in Physics honours Francis Halzen of the University of Wisconsin–Madison, USA, for his decisive contributions to the IceCube Neutrino Observatory and the discovery of high-energy neutrinos arriving from cosmic sources.

Neutrinos are tiny particles that interact very weakly with matter. Vast numbers pass through Earth without leaving a detectable trace, earning them the nickname “ghost particles.” Detecting them requires an enormous instrument and considerable patience. Yet they offer valuable clues about powerful processes occurring far beyond our solar system.

Halzen helped develop the idea of using deep, clear Antarctic ice as a detection medium. This vision became IceCube, an observatory monitoring approximately one cubic kilometre of ice with thousands of instruments buried below the surface. Its scale allows researchers to detect rare particle interactions and investigate the directions from which neutrinos arrive. Building and operating it required a sustained international effort.

In 2013, the IceCube collaboration reported evidence of high-energy neutrinos from astrophysical sources. Their origins were initially unknown, but later observations provided evidence connecting neutrinos with particular galaxies. In 2023, the observatory also reported neutrinos from the Milky Way. These findings opened another way of studying the universe, complementing astronomy based on light.

The achievement recognised in 2026 grew from decades of planning, instrument development and collaborative research. IceCube began operating in 2011, and its discoveries have continued to expand. Halzen’s work demonstrates how an ambitious scientific idea can turn an apparently inhospitable landscape into a window onto the distant cosmos.



Nobel Prizes 2026: Discoveries That Changed How We Study Life, Space and Molecules

Chemistry: Understanding Molecular Handedness



Henri B. Kagan and Kenso Soai

Some molecules resemble our hands: they exist in left-handed and right-handed forms. Both contain the same atoms, but their arrangements are mirror images that cannot overlap exactly. This property, called chirality, matters because living organisms can respond differently to each form.

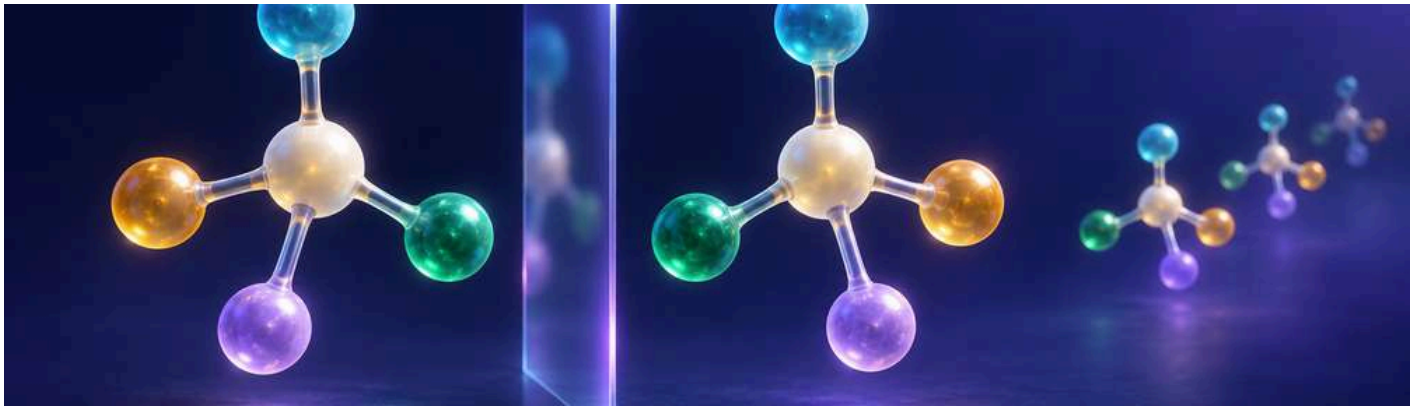
The 2026 Nobel Prize in Chemistry honours Henri B. Kagan of Université Paris-Saclay, France, formerly Université Paris-Sud, and Kenso Soai of Tokyo University of Science, Japan, for discoveries showing how chemical reactions can amplify a preference for one molecular hand.

In 1986, Kagan and colleagues demonstrated that a small imbalance in a catalyst's handedness could produce a larger imbalance in the resulting molecules. A catalyst helps a chemical reaction proceed. This unexpected relationship became known as a non-linear effect.

Soai and colleagues took amplification further. In a reaction reported in 1995, the product helped catalyse its own formation. Through this process, called autocatalysis, a tiny initial excess of one molecular form could grow until that form strongly dominated.

These discoveries advanced understanding of selective chemical synthesis, an important consideration when producing medicines. They also offered insight into how strong molecular preferences might emerge from nearly balanced beginnings, without establishing exactly how handedness originated in life.

Recognised decades after the foundational experiments, this work shows how subtle molecular differences can reveal important principles governing chemical reactions and life's chemistry.



Guide SCIENCE TOMORROW

From the dark depths of our oceans to the farthest reaches of the cosmos, countless mysteries remain unsolved. Science continues to push the boundaries of the known, revealing just how much is still left to uncover. What lies beyond our current understanding may reshape the future of humanity.

DOI: https://doi.org/10.67831/Sci.Factors.2026.1702
SCIENCE FACTORS!

EMERGING INSIGHT

Old Medicines, New Targets: Emerging Strategies Against Chronic Inflammation



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AREAS OF EXPERTISE
Immunity • Inflammation • Cytokine Signaling • Drug Targets



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AREAS OF EXPERTISE
Inflammation • Cytokine Signaling • Drug Targets

WHY IT MATTERS

Medicines developed for one condition may hold promise for treating another. In this article, Dr. Tom Skaria and Mr. Shahid Puthiyottil explore how fexofenadine, a commonly used allergy medicine, could help control harmful inflammation. Their laboratory research suggests that it can inhibit ADAM17, an enzyme that releases a powerful inflammatory signal called TNF-α. They explain how studying existing medicines could open new paths towards more affordable, personalised treatments, while highlighting the need for further testing before these findings can guide patient care.

Inflammation is one of the body's first-line defense mechanisms against infection or injury. While a regulated inflammatory response balancing pro- and anti-inflammatory mediators is essential to protect the host from pathogens or tissue damage, excessive or dysregulated proinflammatory response causes tissue damage and impairs organ function. Such dysregulated inflammatory response underlies diseases such as rheumatoid arthritis, sepsis and psoriasis, substantially affecting the quality of human life. Current estimates indicate that inflammatory diseases affect a substantial and growing proportion of the population across the globe. Moreover, the expenditure associated with inflammatory disease diagnosis and management represents a considerable and increasing economic burden across these regions. Both the prevalence of chronic inflammatory diseases such as rheumatoid arthritis, and the cost of clinical management of these diseases have increased substantially over recent decades, underscoring their societal burden. Existing anti-inflammatory drugs reduce the proinflammatory response and tissue damage. However, some of these drugs adversely affect other organ systems or carry the risk of compromising the hosts' protective immune responses, highlighting the need for new drugs with minimal adverse effects on protective immune responses or organ function.

The discovery of novel drugs including anti-inflammatory agents requires rigorous testing for their efficacy and safety through preclinical studies, non-human animal models, and clinical trials in humans, a process that is time-consuming and costly. An alternative strategy is drug repurposing, i.e. investigating the potential of existing drugs, originally developed to target molecules other than those in inflammatory response but with established safety in humans to therapeutically modulate inflammation. This approach might be more economical and faster

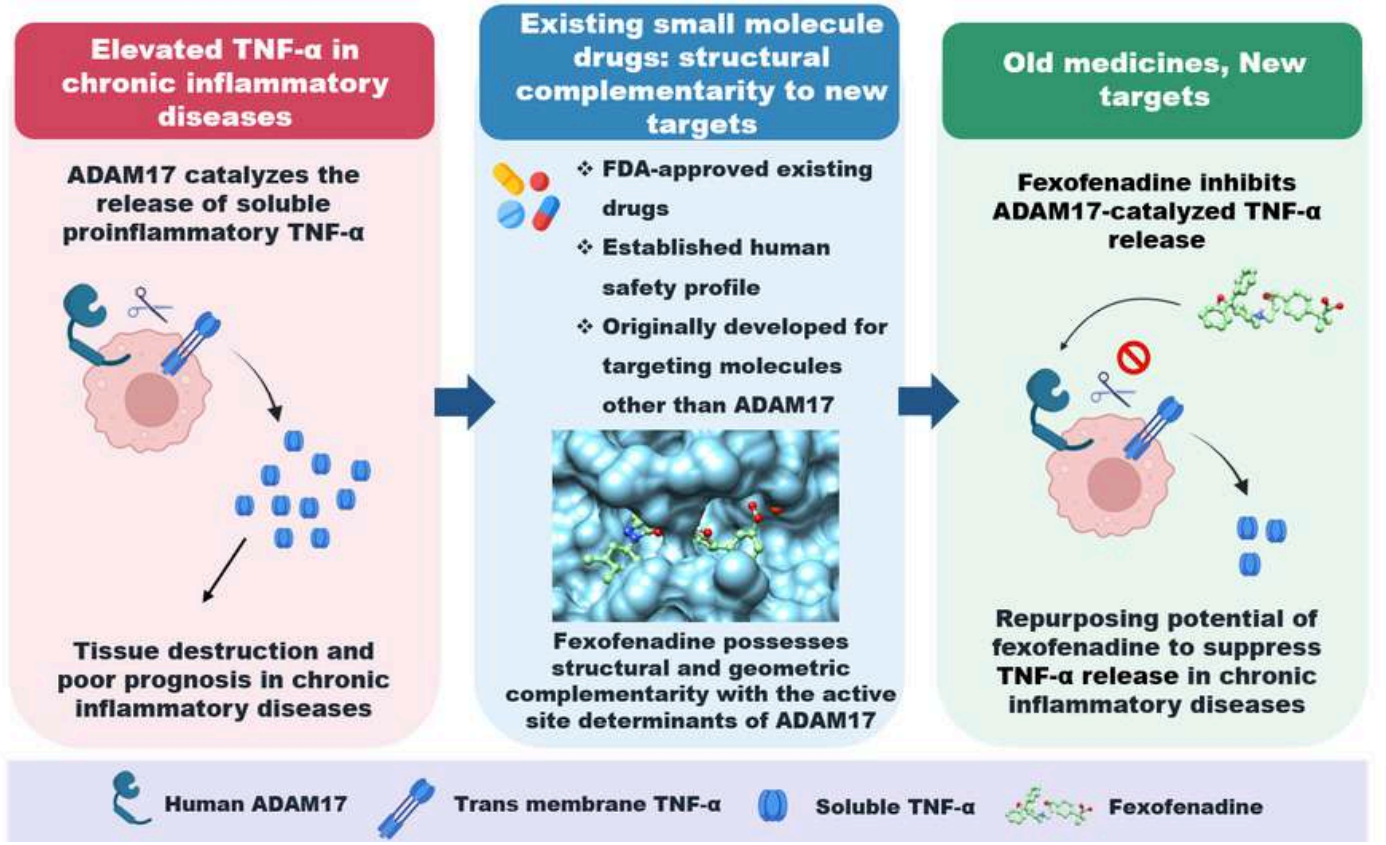


Figure 1. Elevated concentrations of the proinflammatory cytokine TNF-α mediates tissue destruction in chronic inflammatory diseases. Existing small molecule drugs (e.g. fexofenadine), originally developed to target molecules other than those in inflammatory response but with established safety in humans, possessing structural and geometric complementarity with the active site determinants of human ADAM17 could inhibit ADAM17-catalysed TNF-α release and be repurposed to treat TNF-driven inflammatory diseases.

compared with de novo drug synthesis and development.

A key inflammatory pathway component emerging as a promising target for anti-inflammatory drug discovery program is the protease ADAM17. ADAM17 mediates the cleavage of membrane-anchored precursor form of TNF-α to release soluble TNF-α, a potent proinflammatory cytokine. By inhibiting the catalytic activity of ADAM17, the production of soluble TNF-α with potent proinflammatory activity could be reduced. This could limit tissue damage associated with aberrant proinflammatory TNF-α signaling and preserve organ function. ADAM17 has an extracellular region containing the active site, transmembrane domain and a cytoplasmic domain. Existing ADAM17 inhibitors showed toxicity or lack of efficacy in clinical trials and have not received FDA approval for therapeutic use, indicating the need for new ADAM17 inhibitor drugs to treat TNF-driven inflammatory diseases.

Studies in our laboratory have shown that some of the existing small molecule drugs, developed to target biomolecules other than ADAM17 and with established safety and tolerability in humans, could inhibit ADAM17. Notably, fexofenadine, developed as an antihistamine with established safety and tolerability in humans including paediatric subjects, has been shown to inhibit ADAM17 and protect against the tissue destructive proinflammatory effects of TNF-α. It suggests the repurposing potential of fexofenadine as a new ADAM17 inhibitor drug for treating TNF-α-driven inflammatory diseases. Fexofenadine can be administered orally, and is readily available and more economical compared with current anti-TNF-α biologics which require parenteral administration. The identification of fexofenadine's repurposing potential to inhibit ADAM17 and protect against TNF-α-driven inflammation, with efficacy similar to the current anti- TNF-α biologic etanercept became possible through an integrated approach involving computational protein–small molecule interaction modeling, in vitro assays with recombinant human ADAM17, in vitro models of inflammatory-

activated human monocytic cells, and 3D cell cultures of vascular endothelial cells (which constitute the inner lining of human blood vessels). These findings align with previous independent studies reporting decreased soluble TNF-α concentration in patients following fexofenadine treatment. Collectively his evidence reveals the repurposing potential of fexofenadine, originally developed and used as an antihistamine, to reduce TNF-driven proinflammatory response and consequent tissue destruction in inflammatory diseases such as rheumatoid arthritis. Additionally, the molecular structure of fexofenadine could guide the design of novel small molecule ADAM17 inhibitors for potential therapeutic use.

Additionally, this finding has implications for precision medicine, in which treatments including drug type and dose, are tailored to individual patient, even in diseases not primarily driven by inflammatory pathology but where inflammation is a component or associated feature. It is important to note that inflammation has been shown to affect the pharmacokinetics including drug metabolism. Moreover, there may be a subset of patients in whom inflammation might accelerate tissue damage or contribute to disease progression. It is anticipated that biomarkers to define the type of inflammatory response contributing to tissue damage in patients with different diseases could be identified, enabling treatments targeting specific inflammatory components in different patient subsets of each disease setting to maximize therapeutic benefit. For example, an integrated screening determining soluble TNF-α concentration, ADAM17 activity, and proteomics signature to identify "TNF-α–high" subgroups, who are likely to respond to fexofenadine or other repurposed ADAM17 modulators could be performed. Using this approach, targeted modulation of inflammation could, in future, improve outcomes in diseases not traditionally classified as inflammatory.

Computational virtual screening to identify off-target interaction between proteins and small molecule drugs, followed by disease network analysis, and in vitro and in vivo experiments using appropriate animal models, could provide insights into the repurposing potential of existing small molecule drugs to control inflammation. By selectively inhibiting ADAM17, inflammatory responses could be controlled without increasing the risk of infection in the host. This would enable a transformation from the current anti-inflammatory therapy to precision inflammation-control therapy, potentially reducing hospitalization and healthcare expenditure. It should be noted that determination and characterization of off-target interactions could not only guide drug repurposing but also help elucidate the molecular basis of adverse drug reactions, thereby enabling a more accurate assessment of the benefit–risk ratio across different patient populations, including individuals of varying ages and developmental stages. For example, a drug that is well tolerated in adults may produce distinct or more pronounced adverse effects in paediatric patients because of age-dependent differences in drug metabolism, receptor expression, signaling pathways, and organ maturation. Characterizing such off-target interactions could therefore help identify patient subgroups that are particularly susceptible to specific adverse effects and support the development of safer, more individualized therapeutic strategies.

ABOUT THE AUTHORS

Dr. Tom Skaria and Mr. Shahid Puthiyottil study how uncontrolled inflammation damages tissues and how medicines might help limit this damage. Dr. Skaria is an Assistant Professor, and Mr. Puthiyottil is a Senior Research Fellow in the Department of Bioscience and Engineering at the National Institute of Technology Calicut, Kerala. Their research combines computer modelling and laboratory experiments to explore new uses for existing medicines, including the allergy drug fexofenadine, as potential treatments for harmful inflammation.

REFERENCES

- Puthiyottil, S., Jose, D., Kuriakose, N., & Skaria, T. (2026). ADAM17 inhibition by the common antihistamine drug fexofenadine dampens soluble proinflammatory TNF-α release. Biochemical Pharmacology, 250, 118041. DOI



DOI: https://doi.org/10.67831/Sci.Factors.2026.1707

SCIENCE FACTORS!

EMERGING INSIGHT

From Unknown Genes to Personalized Medicine: How AI Can Help Reveal Gene Function



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AREAS OF EXPERTISE

Bioinformatics • Data Analytics • Geo Spatial Analysis

WHY IT MATTERS

Reading DNA is becoming faster, but understanding what every gene does remains a major challenge. In this article, Prof. Kudipudi Srinivas explores how artificial intelligence can help reveal the roles of poorly understood genes and connect genetic changes with disease. He explains how combining information about genes, proteins and their interactions could support the search for new treatments and personalised medicine, while highlighting why computer predictions must be tested through biological research and laboratory experiments.

The Genome We Can Read but Cannot Yet Fully Understand

The human genome contains over three billion DNA bases, but reading the genetic code is only the beginning of understanding human biology. Only a small fraction of the genome consists of protein-coding regions, while the non-coding landscape contains regulatory elements, non-coding RNAs, and other regions whose functions are still being uncovered. Even among the roughly 20,000 human protein-coding genes, many remain poorly characterized or incompletely annotated.

Next-generation sequencing (NGS) technologies can now generate enormous amounts of genomic information rapidly, yet translating these vast lists of DNA variants into meaningful biological knowledge remains a major challenge.

This functional annotation gap becomes particularly important in translational medicine. When an NGS pipeline identifies a rare genetic variant, identifying the alteration is only the first step; the more difficult question is determining what that change actually does. A genetic alteration may affect gene regulation, protein structure or function, molecular interactions, or biological pathways. Connecting these molecular changes to disease mechanisms is essential if medicine is to move beyond simply reading genomes toward truly understanding them.

What Does an Unknown Gene Do?

Traditional gene-function annotation relies on several complementary approaches, including sequence similarity, evolutionary conservation, protein-domain analysis, protein–protein interactions, and curated biological databases. While these methods remain foundational, the increasing scale and diversity of biomedical data create an opportunity for artificial intelligence to learn relationships across multiple biological dimensions.

Our early work focused on protein function using domain analysis and protein–protein interaction information. One example was Butyrylcholinesterase (BChE), where we investigated conserved domains and interaction partners to generate computational hypotheses about its biological functions. This work showed how computational analysis can provide clues about poorly understood biological roles.

This experience established an important principle that continues to guide our research. Biological function is rarely determined by one piece of information alone.The same principle became increasingly

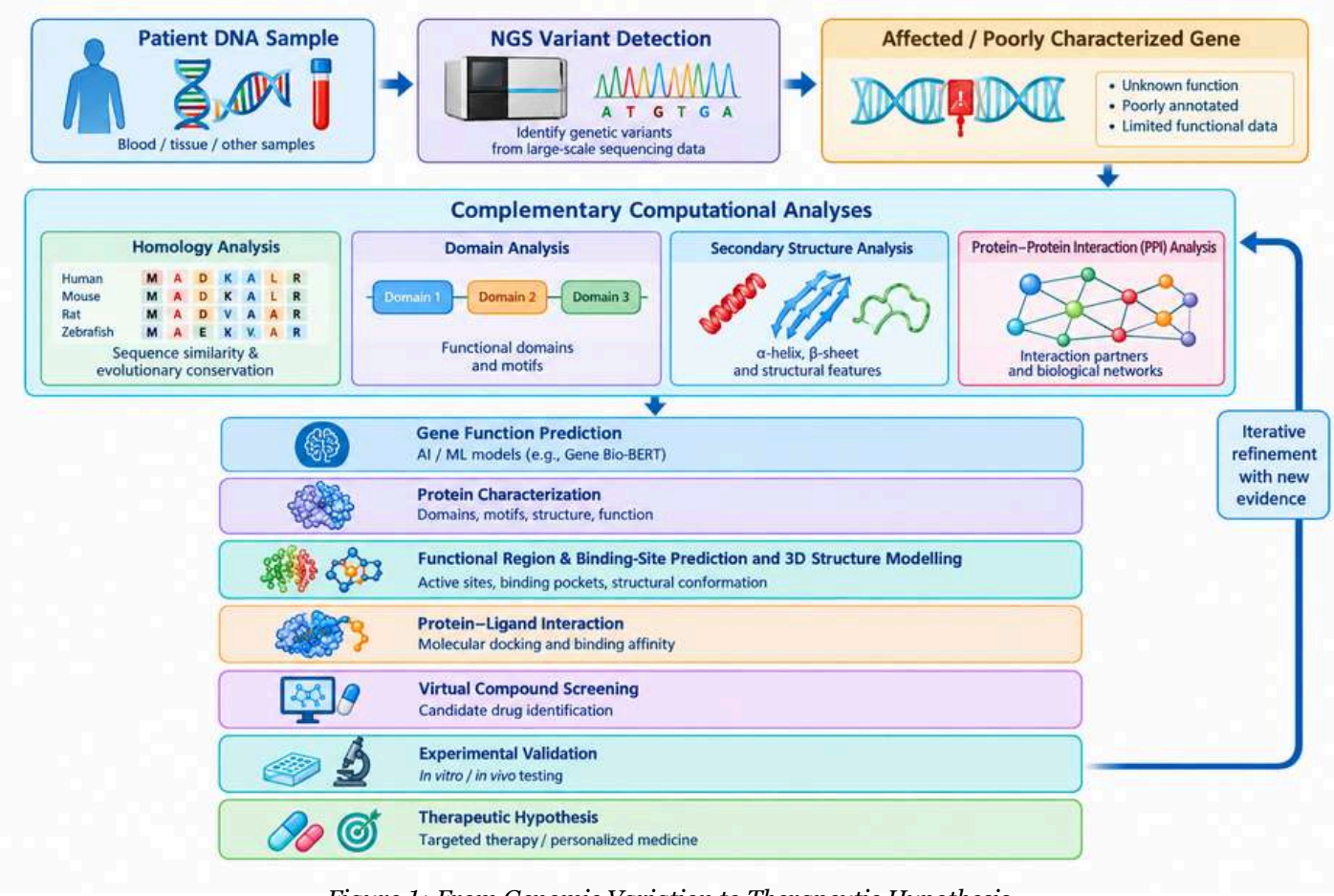


Figure 1: From Genomic Variation to Therapeutic Hypothesis

important when our research moved from individual proteins to disease-associated networks. In Alzheimer's disease, we used computational approaches to investigate protein interaction networks and relationships among disease-associated proteins.

This network-centric perspective provided a foundation for the next stage of our work, which connects biological understanding with therapeutic discovery. We subsequently explored computational approaches for protein–compound prediction and candidate drug identification. However, these investigations highlighted a fundamental challenge: how can we confidently investigate a potential therapeutic target when the biological function of the underlying gene is itself poorly understood? This precise question led us toward the use of deep representation learning for gene-function prediction.

AI for Predicting Gene Function

To address this challenge, we developed Gene Bio-BERT, a deep learning framework for predicting the functionality of poorly annotated human genes. The framework uses human gene information, transformer-based contextual representations, and feature integration to generate functional predictions for poorly characterized genes.

In our study, Gene Bio-BERT achieved 94.5% accuracy and an F1 score of 0.87, demonstrating the potential of deep representation learning for gene-function prediction. An evaluation involving an unannotated gene also produced a similarity score of 0.84, illustrating how such models can generate candidate functional descriptions for genes with limited annotation.

The significance extends beyond prediction itself. An AI-generated biological hypothesis can be investigated using gene-expression data, protein-interaction networks, structural modelling, and laboratory experiments. In this sense, AI should not replace biological research; rather, it should help scientists determine which biological questions are most valuable to test experimentally.

From Genes to Disease Mechanisms

Understanding the baseline function

of a gene provides an important foundation for investigating how genetic variation contributes to disease. Diseases such as breast cancer, Alzheimer's disease, and Parkinson's disease involve complex interactions among genes, proteins, and biological pathways. Similarly, congenital conditions, including structural heart defects, can involve genomic variants whose biological consequences are difficult to interpret from sequence information alone.

A variant may affect a gene, alter the function or regulation of its encoded product, influence interactions with other proteins, and ultimately disturb a biological pathway. Computational network analysis can help investigate these relationships at a systems level.

Emerging AI technologies are expanding these capabilities. Protein language models can learn representations from protein sequences, while Graph Neural Networks (GNNs) can model biological systems as networks of proteins and their relationships. Combining sequence-based and network information could provide richer models of protein function. However, these computational predictions require biological and experimental validation before they can be considered established mechanisms.

Figure 1 illustrates an integrated research pathway from genomic information and NGS variant detection to investigation of an affected or poorly characterized gene. Complementary computational analyses including homology, domain, secondary-structure, and protein–protein interaction (PPI) a nalysis will provide evidence for understanding gene and protein function. These insights can be extended through AI-based gene-function prediction, protein characterization, functional-region and binding-site prediction, 3D structure modelling, protein–ligand interaction analysis, and virtual compound screening. The resulting computational hypotheses require experimental validation before they can contribute to a therapeutic hypothesis. The figure represents a conceptual research pipeline rather than a strictly linear workflow; researchers may move iteratively between stages as new genomic, structural, interaction, and experimental evidence becomes available.

New Technologies Driving the Next Breakthrough

The next major advance in functional genomics is likely to come from integrating different types of biological information. Future multimodal AI systems could combine genomic variants with biomedical literature, gene-function information, protein sequences, structural information, interaction networks, and disease phenotypes.
Explainable AI will also become increasingly important. In biomedical applications, a prediction alone is rarely sufficient; researchers need to understand the evidence supporting a prediction, its uncertainty, and the biological relationships that influenced the model. The objective should therefore be to develop AI systems whose predictions are interpretable, reproducible, and experimentally testable.

Where Do We Go From Here?

Over the next five to ten years, I anticipate increasing convergence between genomics, artificial intelligence, structural biology, and systems biology. Future systems may place genetic variants within a broader context of affected genes, predicted functions, protein structures, interaction partners, pathways, and disease phenotypes.

Such integration could be particularly valuable for complex diseases where individual genetic variants remain difficult to interpret in isolation. For Breast cancer, Alzheimer's disease, Covid-19 and Parkinson's disease, combining genomic information with AI-based functional prediction and biological networks may help researchers investigate how genetic changes influence molecular and cellular processes. Similar approaches may help investigate variants associated with developmental disorders.

AI-generated predictions, however, should remain hypotheses until supported by appropriate biological evidence and experimental validation. The most valuable biomedical AI will not necessarily be the system that simply produces the highest prediction score. It will be the system that generates biologically meaningful, interpretable, and experimentally testable hypotheses.

The journey from an unknown gene to personalized medicine is therefore not a single technological step, but a chain of discoveriesfrom identifying a genetic change, to understanding its functional consequences, to connecting those consequences with disease biology, and eventually to developing evidence-based therapeutic strategies. Artificial intelligence can become an important bridge between genomic information

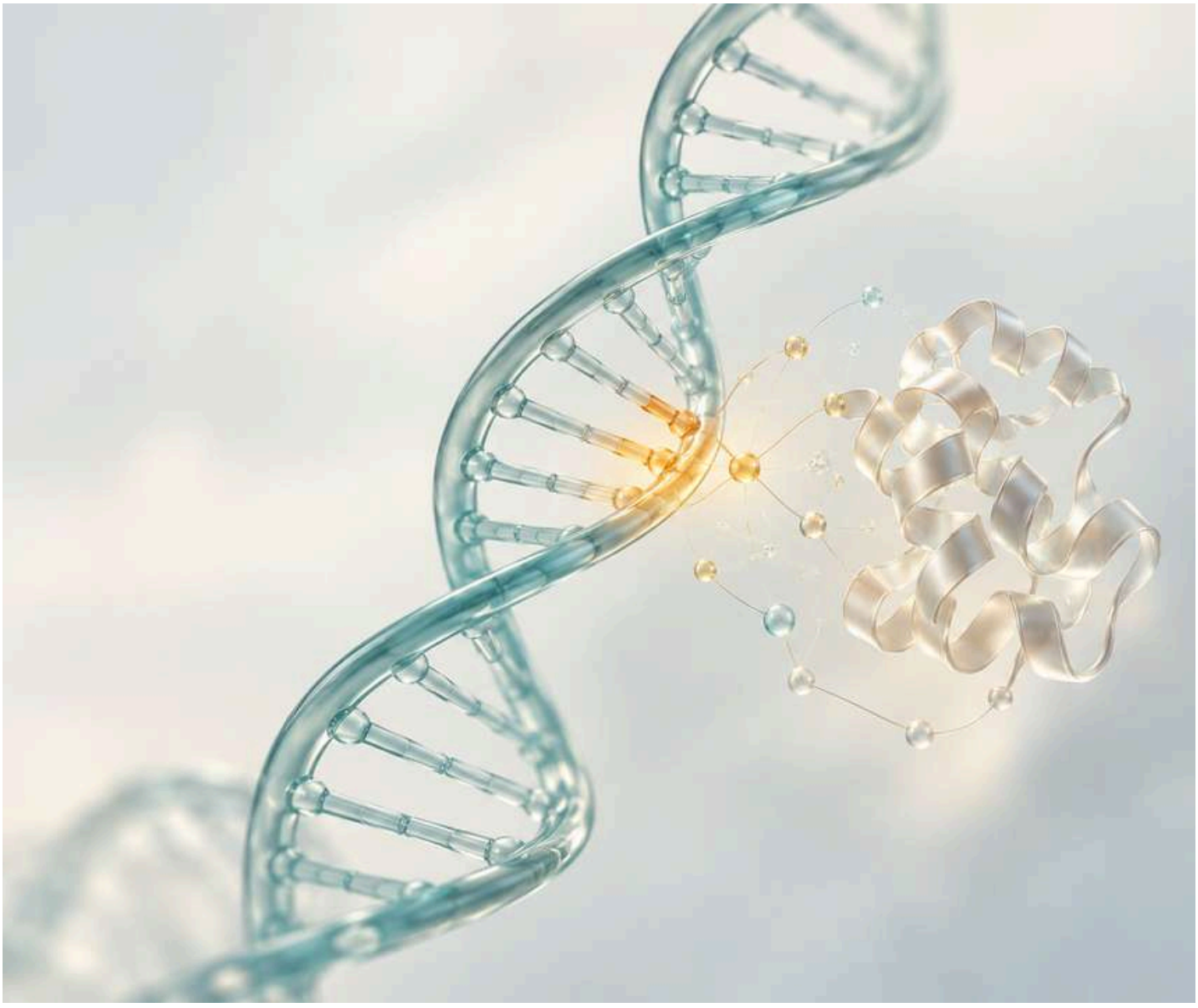
and biological knowledge, helping transform unknown genes into testable hypotheses and genomic information into new possibilities for personalized medicine.

ABOUT THE AUTHORS

Prof. Kudipudi Srinivas works in the Department of Computer Science and Engineering at Siddhartha Academy of Higher Education, Vijayawada, Andhra Pradesh. He uses computer methods and artificial intelligence to study what genes and proteins do, how they interact in diseases, and which molecules could become targets for new treatments. His research includes protein networks associated with Alzheimer's disease and Gene Bio-BERT, an AI model that predicts possible functions of poorly understood human genes. His work aims to connect genetic information with biological understanding and future personalised medicine.

REFERENCES

- Kudipudi, S., Chirumamilla, V. D., & Ippili, P. (2026). A deep learning model for prediction of unknown gene functionality: Gene Bio-BERT. Proteomics, e70173. DOI
- Rao, A. A., Srinivas, K., Rajender, R., & Das, U. N. (2008). Prediction of butyrylcholinesterase function through domain analysis and protein-protein interaction. Current Nutrition & Food Science, 4(3), 176–184. DOI
- Sridhar, G. R., Rao, A. A., Srinivas, K., Nirmala, G., Lakshmi, G., Suryanarayna, D., Nageswara Rao, P. V., Kaladhar, D. G. S. V. G. L., Kumar, S. V., Devi, T. U., Nitesh, T., & Hanuman, T. (2010). Butyrylcholinesterase in metabolic syndrome. Medical Hypotheses, 75(6), 648–651. DOI



DOI: https://doi.org/10.67831/Sci.Factors.2026.1712

SCIENCE FACTORS!

EMERGING INSIGHT

Sacroiliac Joint Pain: New Directions in Rehabilitation and Patient Care



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| Organization Link |
| Factors Press |

AREAS OF EXPERTISE
Fitness • Pilates • Aerobic Rehabilitation • Myofascial release and Taping



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| Factors Press |

AREAS OF EXPERTISE
Women Health • Fitness • Gait training and Myofascial Release

WHY IT MATTERS

Sacroiliac (SI) joint pain is considered a significant contributor to chronic low back pain, accounting for nearly one-quarter of cases among adults with prominent symptoms. Unlike typical midline low back pain, discomfort arising from the SI joint is generally felt on one side and occasionally affects both sides. Women appear to be affected more frequently than men, which may be partly related to differences in pelvis biomechanics. The SI joint in women allows greater mobility, potentially increasing mechanical stress, loading demands, and strain on the supporting pelvic ligaments. These biomechanical reasons may help explain why SI joint dysfunction is more common during pregnancy and the postpartum period, when substantial changes occur in pelvic structure and loading.

Sacroiliac (SI) joint pain is considered a significant contributor to chronic low back pain, accounting for nearly one-quarter of cases among adults with prominent symptoms. Unlike typical midline low back pain, discomfort arising from the SI joint is generally felt on one side and occasionally affects both sides. Women appear to be affected more frequently than men, which may be partly related to differences in pelvis biomechanics. The SI joint in women allows greater mobility, potentially increasing mechanical stress, loading demands, and strain on the supporting pelvic ligaments. These biomechanical reasons may help explain why SI joint dysfunction is more common during pregnancy and the postpartum period, when substantial changes occur in pelvic structure and loading.

Pain associated with SI joint dysfunction is often experienced not only in the lower back but may also extend downward toward the leg. Functional movements that can intensify these symptoms, include transitions from seated to standing or from lying down to standing. Activities that place greater mechanical demand on the pelvis, such as climbing up or walking down stairs, may also aggravate the pain.

When the Pain Doesn't Tell the Whole Story

SI joint pain can be a real diagnostic puzzle. The joint sits deep within the pelvis, and pain arising from this region can appear in different ways and may overlap with symptoms from the lower back, hip, or surrounding muscles. This makes it difficult to identify the SI joint as the true source of pain based on the symptoms alone.

So, how do clinicians solve the puzzle?

A careful clinical assessment is the

first step. The physiotherapist looks at the patient's history, movement patterns, and areas of tenderness around the SI joint. Although commonly used assessments, such as walking pattern observation and the Trendelenburg test, can provide useful information, they may also be influenced by problems outside the SI joint and, therefore, cannot be relied upon alone.

This is where the provocation test becomes particularly valuable. Tests such as Gaenslen's thigh thrust, distraction compression, and FABER test are designed to place stress on the SI joint and determine whether the patient's familiar pain can be reproduced. Rather than depending on one test, clinicians often consider the findings from several tests together to build a clearer clinical picture.

When the diagnosis remains uncertain, image-guided injection of a local anesthetic into the SI joint has traditionally been used as a reference method to determine whether the joint contributes to pain.

The key message is that a single test cannot always identify SI joint pain. However, a combination of patient history, physical examination, pain-provocation tests, and appropriate investigations can help clinicians move from uncertainty towards a more confident and individualized rehabilitation plan.

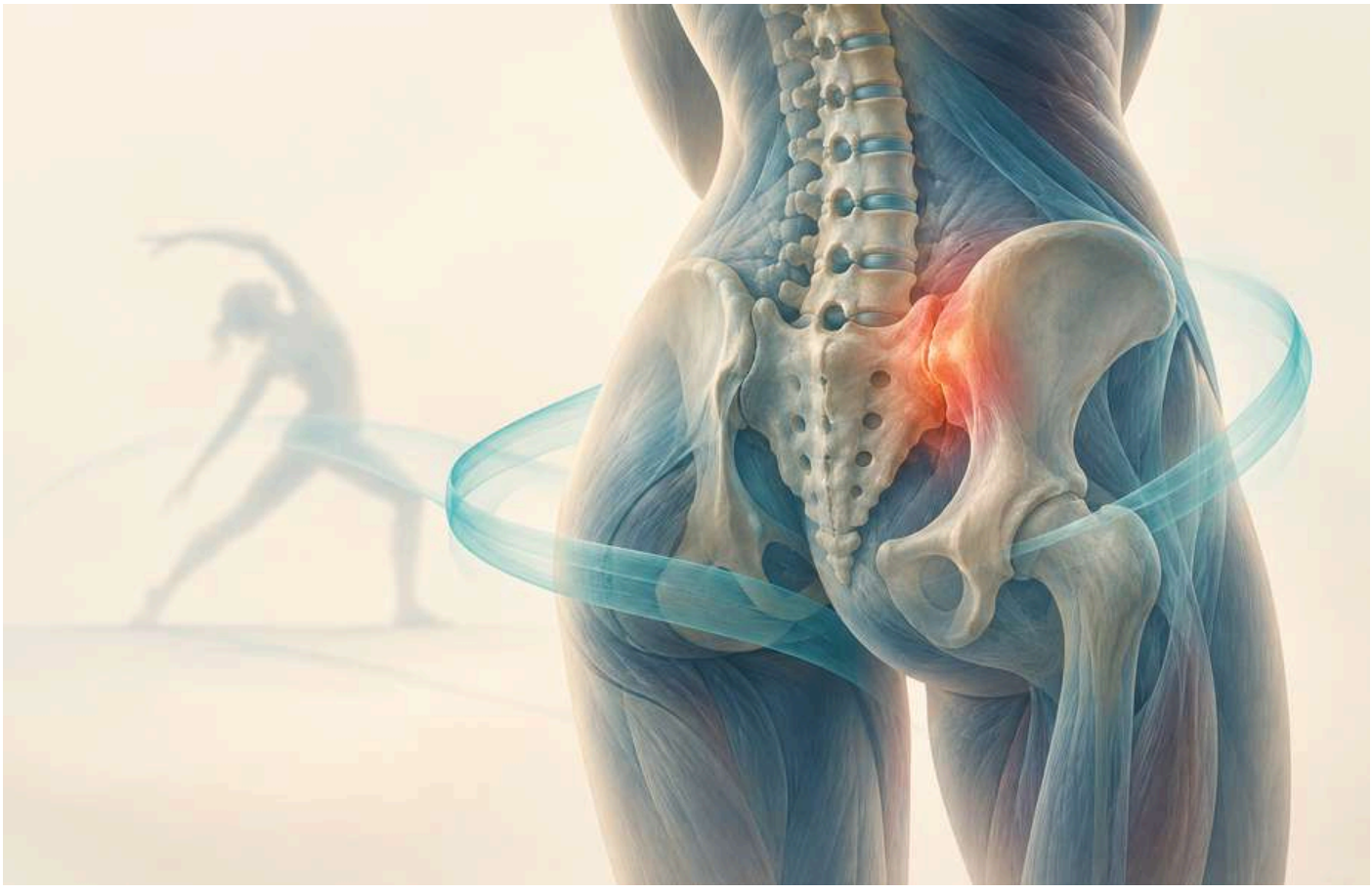
Treating SI Joint Pain: Back to Basics

Once SI joint dysfunction is identified, physiotherapy plays an important role in restoring movement and reducing pain.

Traditionally, treatment has focused on a combination of therapeutic

exercise, manual therapy, joint mobilisation, stretching, strengthening, massage, patient education, and physical modalities such as heat, ultrasound and TENS.

The aim is not simply to reduce pain, but to improve mobility, stability, strength, and confidence in everyday movement. However, SI joint related symptoms are often grouped under the broad label of low back pain, which can make specific management challenging. This is why a more focused physiotherapy approach is gaining attention, recognizing the SI joint as a potential source of symptoms and tailoring treatment to the individual rather than treating every case as routine back pain.



Looking beyond Traditional Treatment

For young physiotherapists and researchers stepping into the field of SI joint pain, the future belongs to those willing to look beyond traditional boundaries.

Rehabilitation is gradually moving towards a more integrated approach that combines clinical reasoning, biomechanics, exercise therapy, manual therapy, and emerging therapeutic technologies. Approaches such as laser therapy, induction therapy, matrix-rhythm therapy, magnetotherapy, shockwave therapy, manual therapy, and myofascial therapy using tools, manual, as well as self-administered techniques are attracting growing interest as potential components of comprehensive rehabilitation. However, innovation must always be guided by scientific evidence and patient needs. SI joint pain can be complex, and no single treatment approach is likely to work equally well for every patient.

The next generation of physiotherapists should therefore focus on evidence-based practice, not only on learning new techniques but also on understanding when, why, and for whom a particular intervention should be used. Careful assessment, clinical reasoning, patient education, individualized exercise, and continuous evaluation should remain at the heart of rehabilitation.

The future will also depend on collaboration. When clinicians, physiotherapists, researchers, and technology developers work together, new possibilities can emerge for improving pain management, mobility, function, and quality of life.

For young researchers, this is an exciting time to contribute to a field that is constantly evolving.

Ultimately, the goal is not simply to introduce newer modalities, but to make rehabilitation safer, more effective, evidence-based, and truly patient-centered.

The coming years will bring important advances in how SI joint pain is assessed and managed, and young physiotherapists and researchers will play a key role in shaping that future.

ABOUT THE AUTHORS

Prof. Amita Aggarwal is a Professor at MM Institution of Physiotherapy and Rehabilitation, Mullana, Haryana. Her research focuses on muscle and joint problems, exercise and hands-on treatments. Dr. Rama Taneja is an Assistant Professor at the University Institute of Allied Health Sciences, Chandigarh University, Punjab. Their work in physiotherapy and rehabilitation aims to help people manage pain and improve movement. Their joint research includes a clinical trial protocol designed to compare two physiotherapy approaches for sacroiliac joint pain.

REFERENCES

- Taneja, R., & Aggarwal, A. (2026). Determining the efficacy of self-myofascial release technique versus muscle energy technique in sacroiliac pain management: A clinical trial protocol. Pain Management. DOI
- Newman, D. P., & Soto, A. T. (2022). Sacroiliac joint dysfunction: Diagnosis and treatment. American Family Physician, 105(3), 239–245. DOI
- Sabrina, S., Farooqui, S., Khan, M. A., Khan, A. A., & Khan, F. A. (2023). Effectiveness of evidence based physical therapy management approaches in sacroiliac joint dysfunction: A meta-analysis. Journal of the College of Physicians and Surgeons Pakistan, 33(5), 572–577. DOI



DOI: https://doi.org/10.67831/Sci.Factors.2026.1717

SCIENCE FACTORS!

EMERGING INSIGHT

Why Does Long COVID Persist in Children? Could Blood Vessels Hold the Key?



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| Organization Link |
| Factors Press |

AREAS OF EXPERTISE
Computational Biology • Molecular Modelling and Drug Discovery • SARS-CoV-2 and Long COVID • Protein-Protein Interactions

WHY IT MATTERS

For some people, the effects of COVID-19 persist long after the initial infection has passed. Understanding why remains an important scientific challenge. In this article, Dr. Parth Sarthi Sen Gupta explores how viral proteins, blood-clotting processes and inflammation may interact at the lining of blood vessels. He discusses the proposed connection between SARS-CoV-2 spike protein and fibrinogen, its possible relevance to Long COVID in children and young adults, and why experimental validation is essential before these ideas can guide future diagnosis or treatment.

For many people, recovery from COVID-19 means returning to normal health after the acute infection has resolved. Yet a proportion of individuals continue to experience symptoms such as fatigue, exercise intolerance, cognitive difficulties, headache, sleep disturbance and breathlessness for weeks or months. Children and young adults can also experience persistent symptoms, raising an important question: what keeps the disease process going after the acute infection has passed?

Long COVID is unlikely to have a single biological cause. Persistent viral material, immune dysregulation, endothelial activation, altered coagulation, platelet responses and inflammatory pathways may interact in different combinations between individuals. One emerging possibility is that the vascular system may serve as a biological convergence point where several of these processes meet.

Our recent work has led us to explore one potentially important molecular connection: the interaction between SARS-CoV-2 spike protein and fibrinogen, a major blood-clotting protein. This perspective raises the possibility that interactions involving spike, fibrinogen, fibrin, immune cells and endothelial cells could contribute to a persistent thromboinflammatory environment.

The vascular system is an active participant

Blood vessels are not simply tubes that transport blood. Their inner lining, the vascular endothelium, regulates permeability, blood coagulation, immune-cell trafficking and communication between the circulation and tissues.

The endothelial cells can be activated during infection. This is usually a protective mechanism that assists coordinate inflammation and repair. However, continued vascular activation, may lead to endothelial dysfunction and abnormal blood cell-vessel wall interactions with coagulation proteins.

This possibility is particularly interesting in Long COVID. There are reported abnormalities in endothelial function, coagulation, platelet activity and inflammatory pathways. Some studies have also found unusual forms of fibrin referred to as microclots or fibrinaloid particles.

The interpretation of these observations must be done carefully. The presence of microclots does not prove that they are the primary cause of Long COVID. They may be a result of long-term inflammation, a factor that facilitates disease persistence, or part of a vicious cycle of coagulation and immune activation.

In our recent Pediatric Research Comment, we explored this issue specifically for the pediatric population, noting that endothelial activation and thromboinflammation may be important factors in Long COVID biology in children and young adults.

The central question is therefore not simply whether or not there are

vascular abnormalities, but whether they play a role in sustaining the disease state.

Could fibrinogen connect viral proteins with vascular dysfunction?

Fibrinogen provides an intriguing molecular link.

Fibrinogen is a blood protein that is converted to fibrin in blood coagulation. Then fibres of fibrin create the structure of a blood clot. However, fibrinogen and fibrin are also biologically active molecules that can interact with cells and inflammatory pathways.

In our 2025 ACS Pharmacology & Translational Science Viewpoint, we proposed that the SARS-CoV-2 spike protein can interact with fibrinogen through its N-terminal domain. We suggested that this interaction could provide an immune-evasion advantage by masking a relatively conserved region of spike from recognition by neutralizing antibodies.

This observation led to a broader question: could the same interaction have consequences beyond immune evasion?

Our subsequent 2026 ACS Pharmacology & Translational Science Viewpoint proposed that fibrinogen may function as a molecular bridge between SARS-CoV-2 immune evasion and endothelial access. We hypothesized that when spike associates with fibrinogen, the resulting molecular arrangement could influence how spike-associated complexes interact with cellular receptors, including integrins, potentially facilitating interactions with endothelial cells.

This remains a mechanistic hypothesis, not an established explanation for Long COVID. Its

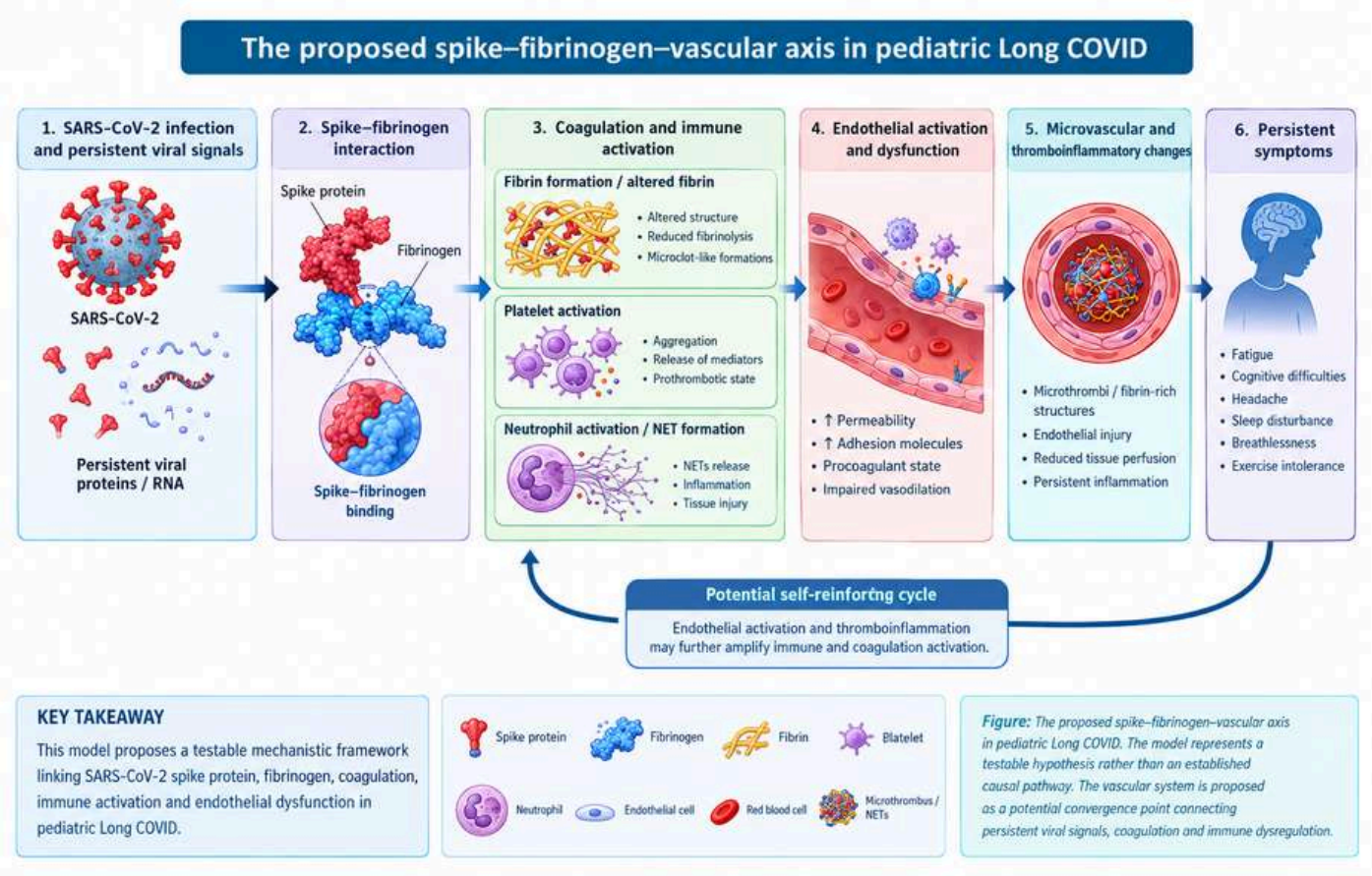


Figure 1: Proposed conceptual framework linking SARS-CoV-2 spike protein, fibrinogen, fibrin, platelet and neutrophil activation with endothelial dysfunction in Long COVID. The model illustrates: (1) Persistent viral signals and spike protein release; (2) Direct spike-fibrinogen binding; (3) Downstream coagulation and immune activation (altered fibrin resistant to lysis, platelet hyperactivation, and neutrophil NETosis); (4) Endothelial activation marked by increased permeability, adhesion molecule upregulation, and impaired vasodilation; (5) Microthrombi formation and tissue hypoperfusion; and (6) Manifestation of persistent symptoms in children. The bottom feedback loop highlights how endothelial activation and thromboinflammation amplify ongoing immune and coagulation activation. The model represents a testable hypothesis to guide mechanistic studies, biomarker discovery, and targeted therapeutics.

importance lies in its testability.
If the proposed interaction can be demonstrated experimentally under physiologically relevant conditions, it could provide a molecular connection between viral proteins, coagulation biology and vascular dysfunction.

From spike-fibrinogen interaction to thromboinflammation

A broader model can now be considered.
Persistent viral material or viral proteins could provide continuing inflammatory signals. Spike-fibrinogen interactions could influence the biological behaviour of fibrinogen or fibrin-associated complexes. Altered fibrin structures could interact with platelets and immune cells. Activated neutrophils can release neutrophil extracellular traps, or NETs, which are useful in host defence but can also contribute to inflammation and thrombosis when excessively activated.
The endothelium may then become persistently activated or dysfunctional.
This creates the possibility of a reinforcing biological network:
Persistent viral signals → spike–fibrinogen interaction → altered fibrin biology → platelet and neutrophil activation → endothelial dysfunction → further thromboinflammation
Such a framework could help explain why abnormalities in viral persistence, coagulation and immunity may coexist in some individuals with Long COVID.
It also provides a possible explanation for why the vascular system deserves particular attention in children and young adults. These individuals generally have fewer traditional risk factors for vascular disease. If vascular and thromboinflammatory abnormalities are detected after SARS-CoV-2 infection, infection-associated mechanisms may therefore deserve closer investigation.
The vascular system may not be the single cause of Long COVID. Rather, it may represent a convergence point where several biological pathways interact.

What should we investigate next?

The next stage of Long COVID research should move beyond asking whether a particular abnormality is present. We need to determine what initiates the process, what maintains it and which molecular interactions are therapeutically actionable.
Several questions are particularly important.
Does persistent spike or other viral material directly activate endothelial cells? Does spike-fibrinogen binding alter fibrin formation, structure or fibrinolysis? Can fibrin-associated viral components influence platelet activation or NET formation? Are these mechanisms different in children compared with adults? Can combinations of vascular, coagulation, immune and viral biomarkers identify biologically distinct forms of Long COVID?
Answering these questions could also improve patient stratification. Long COVID may represent a collection of overlapping biological phenotypes rather than a single disease mechanism. Some individuals may have dominant vascular or thromboinflammatory abnormalities, whereas others may have predominantly immune, neurological, metabolic or autonomic disturbances.
This distinction is important for therapeutic development. A Treatment designed to modify coagulation or platelet activity, for example, should not be assumed to benefit every patient with Long COVID. Such interventions must be evaluated carefully, particularly in children, because normal coagulation is essential for health and excessive interference can cause harm.
The immediate priority is therefore mechanistic validation.

Looking toward the future

Our three recent publications represent complementary steps toward this question. The first one identified a potential interaction between spike protein and fibrinogen. The second considered how endothelial activation and thromboinflammation could contribute to persistent symptoms in pediatric Long COVID. The third proposed fibrinogen as a possible molecular bridge connecting spike-mediated immune evasion with endothelial access.
All together these observations suggest a research model in which viral proteins, coagulation and vascular biology are viewed as a system of interconnected pathways instead of separate pathways.
The future challenge is to determine whether this proposed molecular network operates in patients, which components are causal, and whether disrupting specific interactions can alter disease progression.
The blood vessels may therefore not be the key to Long COVID. But they may be one of the places where several important biological pathways converge.
Recognizing this vascular interface could be useful to answer one of the most fundamental questions: why do some children get over SARS-CoV-2

infection without any symptoms and others continue to experience symptoms long after the acute infection has ended?

If future studies establish a causal connection between spike–fibrinogen interactions, thromboinflammation and endothelial dysfunction, this could open new opportunities for biomarker discovery and targeted therapeutic strategies.

The next chapter of Long COVID research may therefore begin not only with the virus itself, but with understanding what happens at the interface between the virus, the blood and the vascular system.

THREE SCIENTIFIC TAKEAWAYS

1. The vascular system may be a convergence point in Long COVID.
Persistent immune, coagulation and endothelial abnormalities may interact rather than operate as independent mechanisms.

2. Fibrinogen may provide a molecular connection between SARS-CoV-2 and vascular biology.
The proposed spike-fibrinogen interaction raises the possibility that a coagulation protein may influence both immune evasion and endothelial access.

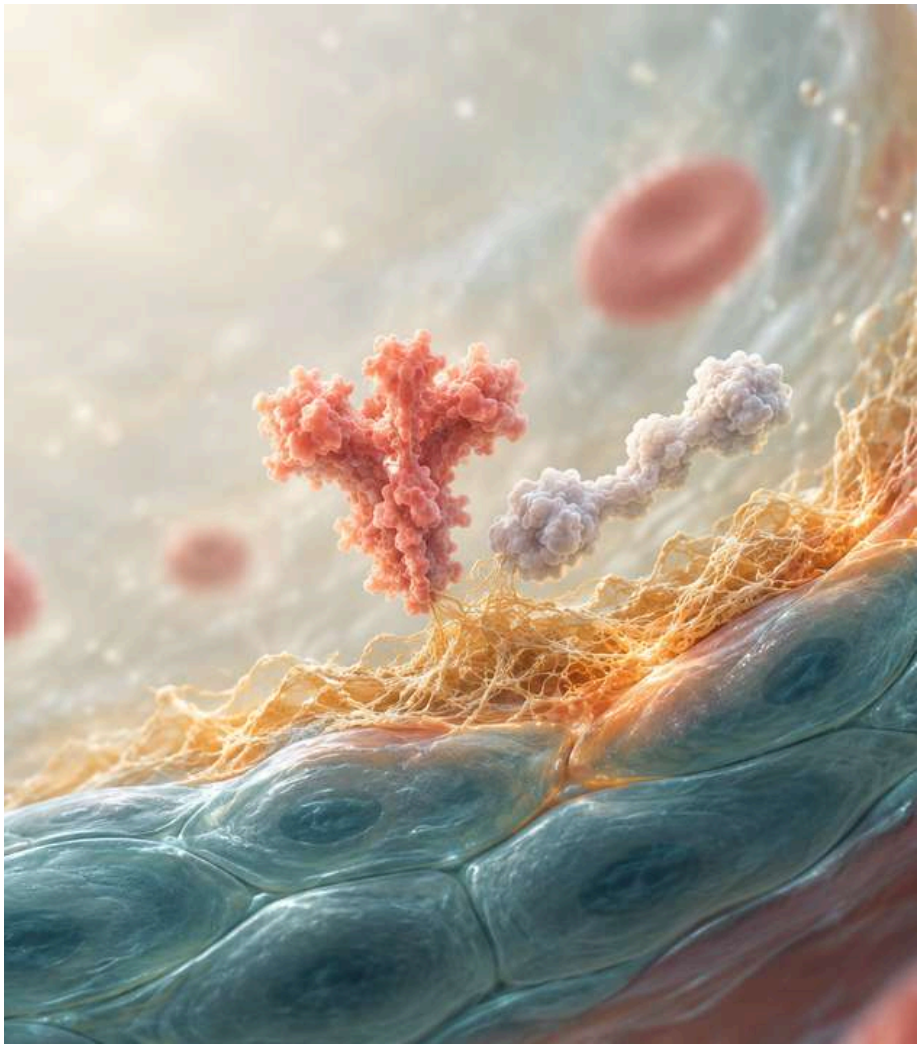
3. The next step is mechanistic validation.
Determining whether spike-fibrinogen interactions, abnormal fibrin, platelet activation and NET formation form a causal pathway could guide future biomarkers and therapeutic strategies.

ABOUT THE AUTHORS

Dr. Parth Sarthi Sen Gupta is a researcher at the School of Biosciences and Bioengineering, D Y Patil International University, Pune. He uses computer models to understand how molecules interact and to help identify possible medicines and design vaccines. His recent work explores whether the COVID-19 virus's spike protein interacts with a blood-clotting protein in ways that could affect blood vessels and contribute to lasting symptoms after infection. These ideas could help researchers understand lasting symptoms in children and young adults.

REFERENCES

- Panda, S. K., Singh, S., & Sen Gupta, P. S. (2025). Spike protein-fibrinogen interaction: A novel immune evasion strategy of SARS-CoV-2? ACS Pharmacology & Translational Science, 8(5), 1182–1184. DOI
- Panda, S. K., Singh, S., Bhalla, M., & Sen Gupta, P. S. (2026). Endothelial activation and thromboinflammation in Long COVID: Revisiting the vascular axis in pediatric populations. Pediatric Research. DOI
- Panda, S. K., Singh, S., & Sen Gupta, P. S. (2026). Fibrinogen as a molecular bridge linking SARS-CoV-2 immune evasion and endothelial access? ACS Pharmacology & Translational Science. DOI



DOI: https://doi.org/10.67831/Sci.Factors.2026.1720

SCIENCE FACTORS!

EMERGING INSIGHT

A Healthier Heart Through Mind and Movement: Rethinking Hypertension Prevention



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Scientific Profile | Organization Link | Factors Press

AREAS OF EXPERTISE
Aerobic Training • Hypertension & Lifestyle Modifications • Mental Health • Cardio-respiratory Fitness

WHY IT MATTERS

High blood pressure is often considered a problem of older age, but cardiovascular risk can begin much earlier, particularly among young adults who are physically inactive. Finding simple ways to reduce this risk before hypertension develops could help protect long-term heart health. In this article, Dr. Imtiyaz Ali Mir explain how combining aerobic exercise with mindfulness-based mental training may help lower blood pressure and resting heart rate, highlighting how training both the body and the mind could offer a practical approach to improving cardiovascular health in young adults.

Elevated blood pressure is increasingly becoming a concern among young adults, particularly those who are physically inactive. Although high blood pressure is often associated with older age, cardiovascular risk can begin much earlier. Evidence indicates that elevated blood pressure is already prevalent among young populations, while physical inactivity remains widespread. In Malaysia, elevated blood pressure has been reported in approximately 41–46% of adults, while physical inactivity affects more than one-third of adults and an estimated 41.4–66.4% of young adults. This combination is concerning because prolonged inactivity can negatively affect cardiovascular fitness, vascular function and autonomic regulation, potentially increasing future cardiovascular risk.

One important but sometimes overlooked marker is resting heart rate. Resting heart rate reflects the balance between the sympathetic and parasympathetic branches of the autonomic nervous system and can provide an indication of cardiovascular efficiency and autonomic function. Persistent elevations may therefore signal an unfavourable cardiovascular profile. Addressing risk factors early, before hypertension becomes established, provides an important opportunity for prevention.

This perspective was one of the motivations for examining both physical and psychological contributors to cardiovascular health. Physical activity is well established as an important component of blood pressure management, while psychological stress and poor stress regulation can also influence cardiovascular function. Mindfulness-based approaches, particularly mindfulness-based stress reduction, have received increasing attention because they may help regulate stress responses and autonomic activity. However, relatively little research had examined whether combining mindfulness-based mental training with aerobic exercise could provide greater cardiovascular benefits than either approach alone. Our study therefore investigated a combined mental and physical training approach, referred to as MAPT. The underlying idea was straightforward: cardiovascular health is influenced not only by how we move, but also by how our bodies respond to psychological stress. Addressing these complementary factors together could potentially provide a more comprehensive approach to early cardiovascular risk reduction.

In simple terms, exercise trains the

cardiovascular system, while mindfulness may help regulate the body's response to stress. Aerobic exercise places a controlled demand on the heart and circulatory system, encouraging adaptations that can improve cardiovascular efficiency, vascular function and autonomic regulation. Over time, these adaptations can contribute to lower blood pressure and resting heart rate. Mindfulness works through a different but complementary pathway. Practices such as breathing meditation and body awareness encourage individuals to focus attention on the present moment and regulate their responses to stress. By reducing excessive stress-related sympathetic activation and supporting autonomic balance, mindfulness may help create conditions that are more favourable for cardiovascular regulation. These mechanisms should not be viewed as completely separate: psychological and physical processes continuously interact to influence cardiovascular function. To examine this, we conducted a randomized controlled trial involving 58 physically inactive young adults with elevated blood pressure. Participants were assigned to one of four groups: mindfulness-based mental training, aerobic physical training, combined mental and physical training, or an active control involving the Dietary Approaches to Stop Hypertension (DASH) diet. Training was conducted three times per week for six weeks.

The most striking finding was the magnitude of the systolic blood pressure reduction in the combined MAPT group. Mean systolic blood pressure declined from approximately 129.7 mmHg at baseline to 116.9 mmHg after six weeks, representing a reduction of about 12.8 mmHg. The reduction was approximately 4.2 mmHg with mental training and 3.9 mmHg with physical training alone. The combined intervention also produced a substantial reduction in resting heart rate, approximately 13.3 beats per minute, compared with approximately 7.4 beats per minute following physical training alone.

Statistically, MAPT demonstrated the strongest effect on systolic blood pressure among the interventions. Resting heart rate also declined significantly in the physical and combined training groups, with the combined intervention producing a greater reduction than the active control. Diastolic blood pressure decreased within the mental, physical and combined training groups, although the differences between groups were not statistically significant. What was particularly interesting was the apparent advantage of combining the two approaches. Exercise and mindfulness may influence cardiovascular regulation through complementary pathways. Exercise directly challenges and conditions the cardiovascular system, whereas mindfulness may help reduce excessive stress-related autonomic activation. Together, these effects may create a broader influence on cardiovascular regulation than either approach alone.

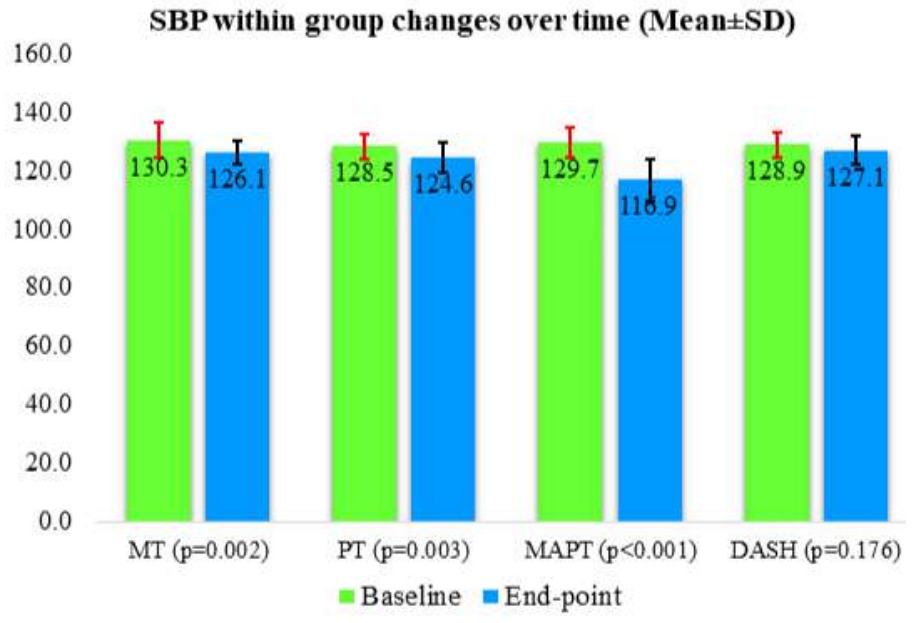


Figure 1. Changes in SBP over 6-weeks' Time

There is also a potential behavioural explanation. Physical activity and mindfulness may reinforce one another by encouraging greater awareness of the body, stress responses and daily health behaviours. However, the findings should be interpreted carefully. The combined MAPT intervention lasted 60 minutes per session, whereas the individual mental and physical training sessions lasted 30 minutes. Therefore, the larger effect cannot be attributed solely to a synergistic interaction between mindfulness and exercise. The greater intervention dose may have contributed to the observed benefit.

Future studies using time-matched interventions are needed to determine whether the combination itself provides an additional advantage.

From a practical perspective, this approach is encouraging because neither component necessarily requires sophisticated equipment. Aerobic exercise can involve accessible activities such as brisk walking, jogging or treadmill exercise, while mindfulness can involve structured breathing, meditation and body-awareness practices. These activities could potentially be incorporated into university wellness programmes, workplace health initiatives or broader strategies aimed at preventing cardiovascular risk among young adults. The key challenge, however, is sustainability. A six-week intervention can demonstrate short-term physiological changes, but long-term prevention depends on whether individuals can maintain healthy behaviours. Programs therefore need to be realistic, flexible and enjoyable enough to become part of everyday life rather than being viewed as a temporary treatment. The approach should also complement, rather than replace, established strategies such as healthy eating, adequate sleep, regular physical activity and appropriate medical assessment.

There are several important next steps for this research. Larger studies involving more diverse populations are needed, including women, different age groups, individuals with overweight or obesity, and people with established hypertension. Longer intervention periods could determine whether the improvements observed over six weeks are sustained and whether longer exposure produces clearer effects on diastolic blood pressure and vascular health. Future research should also use time-matched intervention groups to distinguish the effects of the combined approach from the effects of a greater training dose. Objective monitoring of physical activity and dietary adherence would strengthen the evidence, while 24-hour ambulatory blood pressure monitoring could provide a more comprehensive assessment of cardiovascular changes than clinic measurements alone.

Ultimately, the broader message is that prevention may need to begin before hypertension becomes established. Young adulthood represents an important period during which cardiovascular behaviours and physiological patterns can be shaped. A strategy that trains both the body and the mind may offer a promising way of addressing multiple contributors to cardiovascular risk simultaneously.

The findings from our study suggest that combining mindfulness-based mental training with aerobic exercise can produce meaningful reductions in systolic blood pressure and resting heart rate among physically inactive young adults with elevated blood pressure. While further research is necessary before drawing conclusions about long-term hypertension prevention, the results provide encouraging evidence for a more integrated approach to cardiovascular health—one that recognizes that the heart is influenced not only by movement, but also by the way we respond to stress.

ABOUT THE AUTHORS

Dr. Imtiyaz Ahmad Mir is an Assistant Professor at the M. Kandiah Faculty of Medicine and Health Sciences, Universiti Tunku Abdul Rahman (UTAR), Malaysia. His research focuses on exercise, cardiovascular health and lifestyle-based approaches to disease prevention. He is particularly interested in how aerobic exercise, mental well-being and lifestyle changes can help improve blood pressure, heart health and physical fitness.

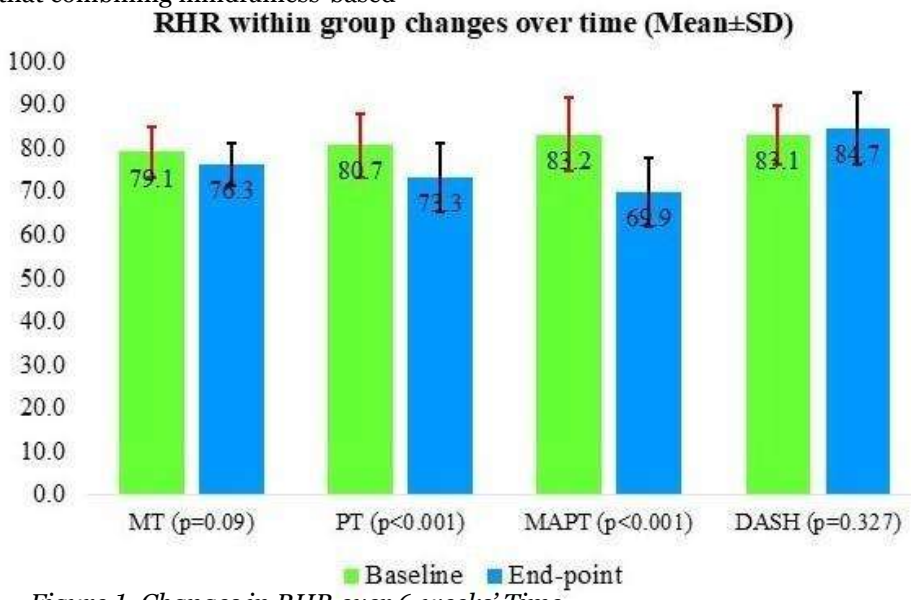
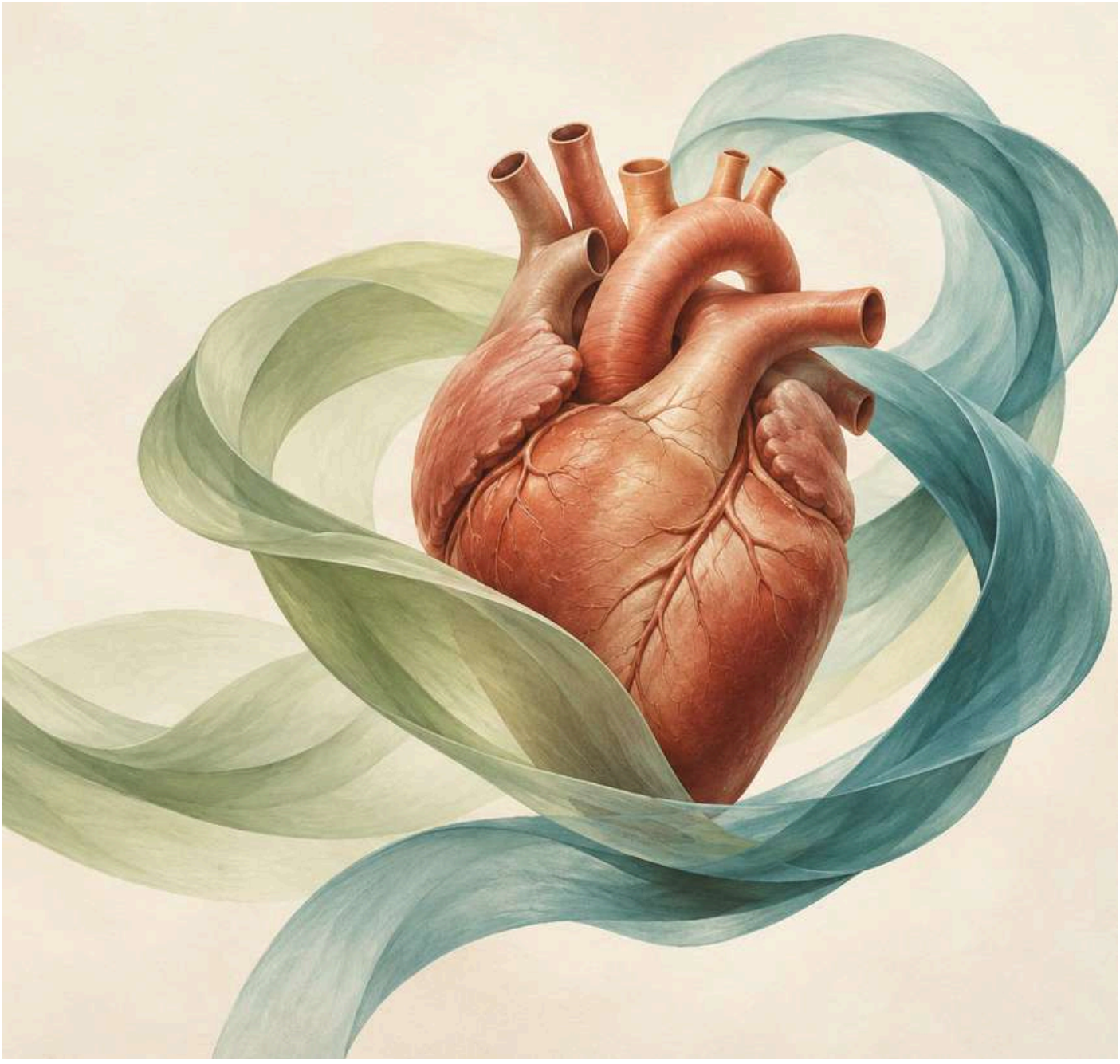


Figure 1. Changes in RHR over 6-weeks' Time

REFERENCES

- Malone, G. T., Adams, T. L., LeMense, A. T., Schafer, E. A., Winchester, L. J., MacDonald, H. V. (2027). Occupational aging: The influence of age and firefighting experience on cardiovascular health indices. Applied Ergonomics, 138, 104851. DOI
- Lee, I. M., Shiroma, E. J., Lobelo, F., et al. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy. The Lancet, 380, 219–229. DOI
- Zhang, F., Zhao, J., Zhang, Y., Tian, Z., Li, J., Lü, Q., Wang, W., Hong, T., Shan, Z., Yan, L., Peng, Y., Tong, N. (2026). Clinical guidelines on physical activity and exercise therapy for Chinese adults with type 2 diabetes: A clinical practice guideline from the Chinese Society of Endocrinology. Journal of Sport and Health Science, 15, 101124. DOI
- Mir, I. A., Humayra, S., John, A. T., et al. (2026). Efficacy of mental and physical training on blood pressure and resting heart rate among physically inactive young adults with elevated blood pressure: A randomized controlled trial. Scientific Reports, 16, 24026. DOI



DOI: https://doi.org/10.67831/Sci.Factors.2026.1742

SCIENCE FACTORS!

EMERGING INSIGHT

Predicting Molecular Excitations: New Tools for Future Light-Emitting Materials



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AREAS OF EXPERTISE

Double Hybrid Range-separated Density Functional • Computational Chemistry • Inverted Singlet-Triplet Gap

WHY IT MATTERS

Developing better light-emitting materials is important for future displays, sensors, and solar-energy technologies. However, accurately predicting how molecules absorb and release light remains a major scientific challenge. Dr. Manash Protim Borpuzari and his research collaborators have developed computational approaches that adjust to the unique electronic properties of individual molecules, improving the prediction of their excited states. This advancement could help scientists identify promising materials before producing them in laboratories, reducing trial and error and accelerating the development of next-generation light-based technologies.

An electron in a molecule absorbs energy and is excited to an electronically excited state; this is a simple molecular event that is the basis of many technologies involving light, including organic light emitting devices, sensors, solar-energy devices and other novel photonic materials. The energy of the excited molecule may release as light, passes to another molecule, turns into heat or is used to start a chemical reaction.

If such accurate prediction of these excited states were possible, a major paradigm shift in the discovery of new molecular materials would ensue. Rather than synthesizing various candidate molecules and running them in the lab to determine their optical properties, a researcher could first try quantum mechanical computation method to design a molecule with those properties.

But this is not an easy task.

Absorption of light causes the electrons to redistribute and start to interact in a more complex manner than a simple promotion of an electron from one orbital to another. The energies of the excited states can vary slightly and the electronic character of the states may vary.

For one particularly difficult example, the singlet–triplet energy gap is defined as

$$\Delta E_{ST} = E(S_1) - E(T_1)$$

Here S_1 and T_1 represent the lowest singlet and triplet excited states, respectively. The singlet is above the triplet in most molecules and ΔE_{ST} is positive. There are molecules, however, with the opposite situation: The singlet is lower than the triplet, which yields an inverted singlet–triplet gap.

These strange systems are an extreme challenge for excited-state theories. For many applications, the conventional linear-response time-dependent density functional theory (TDDFT) is very successful, but the commonly used adiabatic approximations are inadequate for the description of effects arising from the genuine double excitations. This restriction is significant in some molecules that have singlet–triplet inversion.

A step forward in improving this description is to take the electron exchange more seriously. Range Separated density functionals separate the electron–electron interaction into a short-range and a long-range part. The short-range part is treated using the density-functional approximations, and exact Hartree–Fock exchange is added at long range. The range at which this separation occurs is controlled by a parameter μ.

However, the value of μ is system dependent.

We thus investigated in our previous

work system specific tuning of this parameter. We then went on to devise a range-separated double-hybrid density functional method, where we included perturbative electron correlation in the range-separated framework. This brings in another important parameter, ac that regulates perturbative correlation. Now, the fundamental question of whether or not to allow the correlation contribution to change, depending on the molecule.

The basic concept is to get information directly from the distribution of electron in the molecule. Using an electronic localization function (ELF) along with frontier-orbital energies, the range separation parameter is determined. The tuned μ along with the HOMO–LUMO overlap are then used to calculate the proper perturbative correlation contribution.

The dual tuning framework gives the balance of long-range exchange and electron correlation the flexibility to adapt to the molecular system itself, rather than imposing the same computational parameters on all molecules.

It has been applied to a variety of molecular systems, such as molecules with inverted singlet–triplet gaps and systems with conventional positive gaps. The overall results indicated an improvement of the agreement with the reference data. The averaged absolute error dropped from 0.07 to 0.02 eV and the averaged root mean square error dropped from 0.14 to 0.03 eV for the benchmark under consideration with dual tuning versus tuned-μ for molecules with inverted singlet-triplet gap. Remarkably, this improvement did not come as a result of just pushing molecules towards inverted singlet–triplet ordering. The mean absolute error was decreased to 0.06 eV from 0.14 eV with dual tuning for systems with conventional positive gaps. Hence, the approach maintained its capacity to differentiate between regular and inverted electron structures. These findings point towards a more general future for quantum chemistry, in which the electronic structure of a molecule can guide the way in which the calculation is carried out.

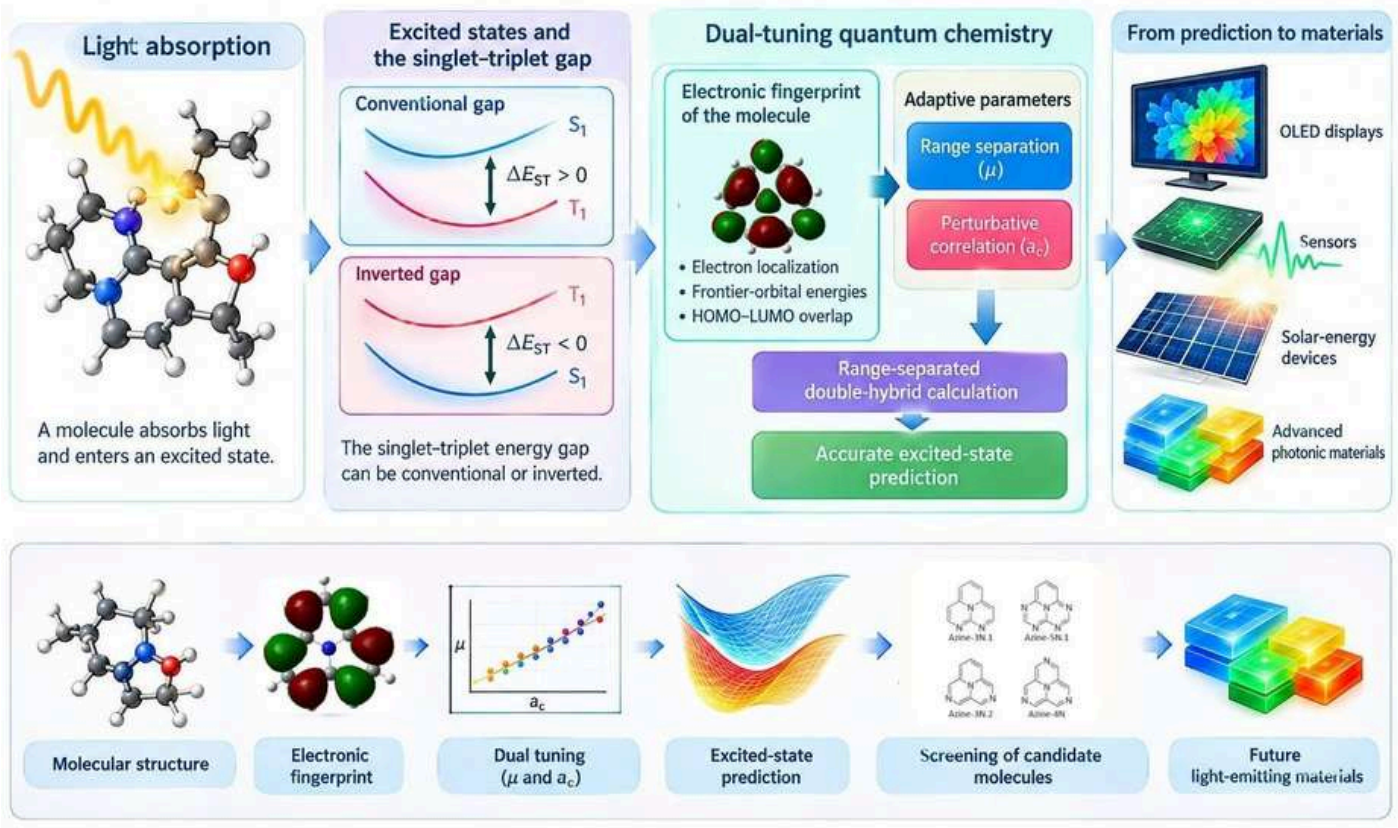


Figure 1: Schematic representation of the dual-tuning framework for predicting molecular excited states. Electron localization, frontier-orbital energies, and HOMO-LUMO overlap provide an electronic fingerprint of the molecule, guiding the selection of the range-separation parameter μ and perturbative correlation coefficient ac. The resulting range-separated double-hybrid calculations aim to improve the prediction of conventional and inverted singlet–triplet gaps, supporting future computational screening and design of advanced light-emitting and photonic materials.

The possibilities for impact go beyond improvements to a benchmark. The prediction of excited states could eventually be used as part of the design of new light-emitting materials. For instance, before synthesizing molecules, computational screening can be used to look for those that have specific singlet–triplet energetics. This may prove particularly useful in the design of TADF and other advanced organic emitters, where fine differences in the energetics of the excited state may play a significant role in the photophysical properties.

But there are key issues to be addressed. More elaborate and efficient treatments for electron correlation as well as solvent effects are needed for larger molecules.

The next big leap could then be the addition of adaptive quantum chemistry with AI, high throughput screening and experiments. Machine learning can make a pass for huge chemical spaces, and physics-based excited-state calculations can offer more robust assessment of promising candidates. Experimental data can then be input into computational models, which can then be used for prediction, synthesis, validation and improvement in a cycle.

In the coming 10 years, this integration could slowly alter the face of computational chemistry. Use of calculations to explain properties of molecules that have been synthesized is common today. They could be of growing importance in the future in deciding which molecules to synthesize in the first place.

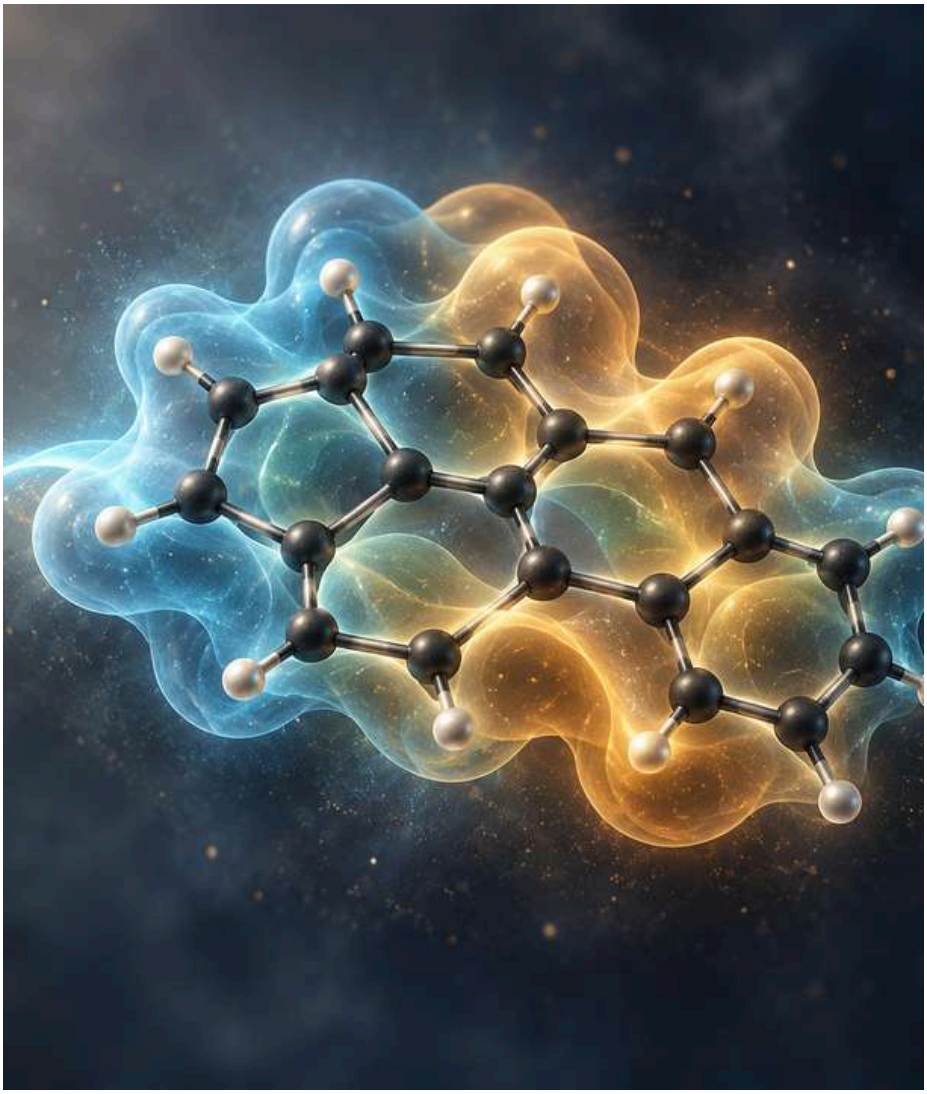
REFERENCES

- M. P. Borpuzari, A transferable dual-tuning framework for range-separated double hybrids: Accurate prediction of inverted and conventional singlet–triplet gaps, J. Chem. Phys, 165, 094120 (2026) DOI

- S. Bhuyan, B. Gogoi, M. Phukan, S. Neog, M. P. Borpuzari, A tuned double hybrid range-separated functional: Accurate reproduction of inverted singlet–triplet gap, J. Chem. Phys 163, 214119 (2025) DOI

ABOUT THE AUTHORS

Dr Manash Protim Borpuzari is a researcher at Dhemaji College, Dhemaji, Assam working in the field of Density Functional Theory. His research focuses on the development of range-separated density functionals and double-hybrid methods for accurate prediction of molecular electronic properties. His work explores molecule-specific tuning of exchange and electron correlation to improve the description of challenging excited states, particularly inverted singlet–triplet gaps. This research connects fundamental quantum chemistry with the future design and computational screening of advanced light-emitting materials.



DOI: https://doi.org/10.67831/Sci.Factors.2026.1728

SCIENCE FACTORS!

EMERGING INSIGHT

Beyond BCG: Building the Next Generation of TB Vaccines



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AREAS OF EXPERTISE

Neuroviral infection • Viral Encephalitis •Traumatic brain injury Extra Cellular Vesicles

WHY IT MATTERS

Better vaccines are needed to strengthen protection against tuberculosis beyond what BCG currently offers. In this article, Dr. Alok Kumar explores how tiny particles prepared from the TB bacterium's outer membrane could engage several parts of the immune system. He explains findings from laboratory studies using human blood samples and outlines the next steps towards vaccine development, including testing safety, lasting immune responses and whether these particles can provide protection against infection.

Tuberculosis (TB) remains a serious health problem worldwide. Bacillus Calmette–Guérin (BCG) has been the only widely used TB vaccine for many years and protects against severe TB in children, but its protection against other TB, such as pulmonary TB in older children and adults, is inconsistent. The continuing burden of TB and the rise of drug-resistant Mycobacterium tuberculosis (Mtb) highlight the need to develop additional vaccine approaches. Current TB vaccine research has largely focused on T-cell-mediated immunity, particularly CD4+ T-cell responses and IFN-γ production. However, immune responses to Mtb involve multiple components, including innate cytokine responses, macrophage activity, T-cell responses and antibody production. Recent findings with Mtb plasma membrane-derived styrene–maleic acid lipid particles (MtM-SMALPs) demonstrate that a membrane-derived preparation can stimulate several of these immune responses simultaneously.

A broader view of TB vaccine immunity

Macrophages are among the first host cells to interact with Mtb and are central to antigen processing, cytokine production, and intracellular control of mycobacteria. T cells subsequently contribute to macrophage activation and cellular immune responses. B cells and antibodies also contribute to the Mtb immune response. Our recent MtM-SMALP study shows that stimulation of different immune components can be observed following exposure to the membrane-derived preparation. In blood cultures from healthcare workers with previous Mtb exposure, MtM-SMALPs increased production of IL-6, TNF-α, and IL-1β, cytokines related to innate immune activation. IFN-γ production was also noted, suggesting an adaptive immune response. These findings support a broader investigation of TB vaccine-induced immunity.

Mtb Plasma Membrane as a Potential Source for TB Vaccine Development

The plasma membrane of Mtb contains a range of proteins, lipoproteins, and glycolipids and interacts with host immune cells. However, isolating membrane proteins without disturbing their surrounding lipid environment is technically difficult. Styrene–maleic acid (SMA) provides an alternative approach for extracting membrane components while retaining membrane-associated molecules within lipid particles. Earlier characterization demonstrated that MtM-SMALPs contain several Mtb membrane-associated components, including PRA, PstS1, LpqH, Ag85 and lipoarabinomannan (LAM). In contrast, they largely excluded some peripheral membrane proteins, including Acr and PspA. MtM-SMALPs appeared as nanoparticles

with diameters of approximately 10–90 nm, with the largest proportion ranging from 20–40 nm. This characterization is important because SMA-derived MtM-SMALPs selectively retain a defined subset of membrane-associated components and show biological activity linked to their molecular composition.

Key Immunological Findings of the Recent Study

In our recent study (Sinha et al 2026) we evaluated immune responses to MtM and MtM-SMALPs using blood samples from 15 healthcare workers from North India with evidence of previous Mtb exposure. We measured cytokine production, T-cell proliferation, and antibody response after stimulation stimulation. IFN-γ production was with MtM or MtM-SMALPs. Our main findings were a concentration-dependent increase in IL-6, TNF-α, and IL-1β after MtM-SMALP also detected. In contrast, higher concentrations of crude MtM suppressed some cytokine responses, with a significant reduction particularly observed for IL-1β. Thus, immune stimulation induced by MtM-SMALPs differed from that induced by the crude membrane preparation. Further, MtM-SMALPs induced T-cell proliferation, assessed by Ki67 expression in CD3+ cells, and IFN-γ production was detected after stimulation. It was also observed that T-cell proliferation was positively correlated with IFN-γ production. These findings suggest that MtM-SMALPs trigger immune responses (cellular) in addition to cytokine production. Antibody responses were also found to be differ between the two preparations. IgM responses were more prominent after exposure to crude MtM, whereas IgG responses were more prominent after stimulation with MtM-SMALPs. The detection of MtM-SMALP-specific IgG responses demonstrates that the membrane-derived particles can induce an antibody response and highlights their ability to engage both cellular and humoral components of immunity. Although the overall antibody levels were relatively modest, these findings provide a basis for further characterization and optimization of the MtM-SMALP-induced antibody response. Overall, the observed cytokine, T-

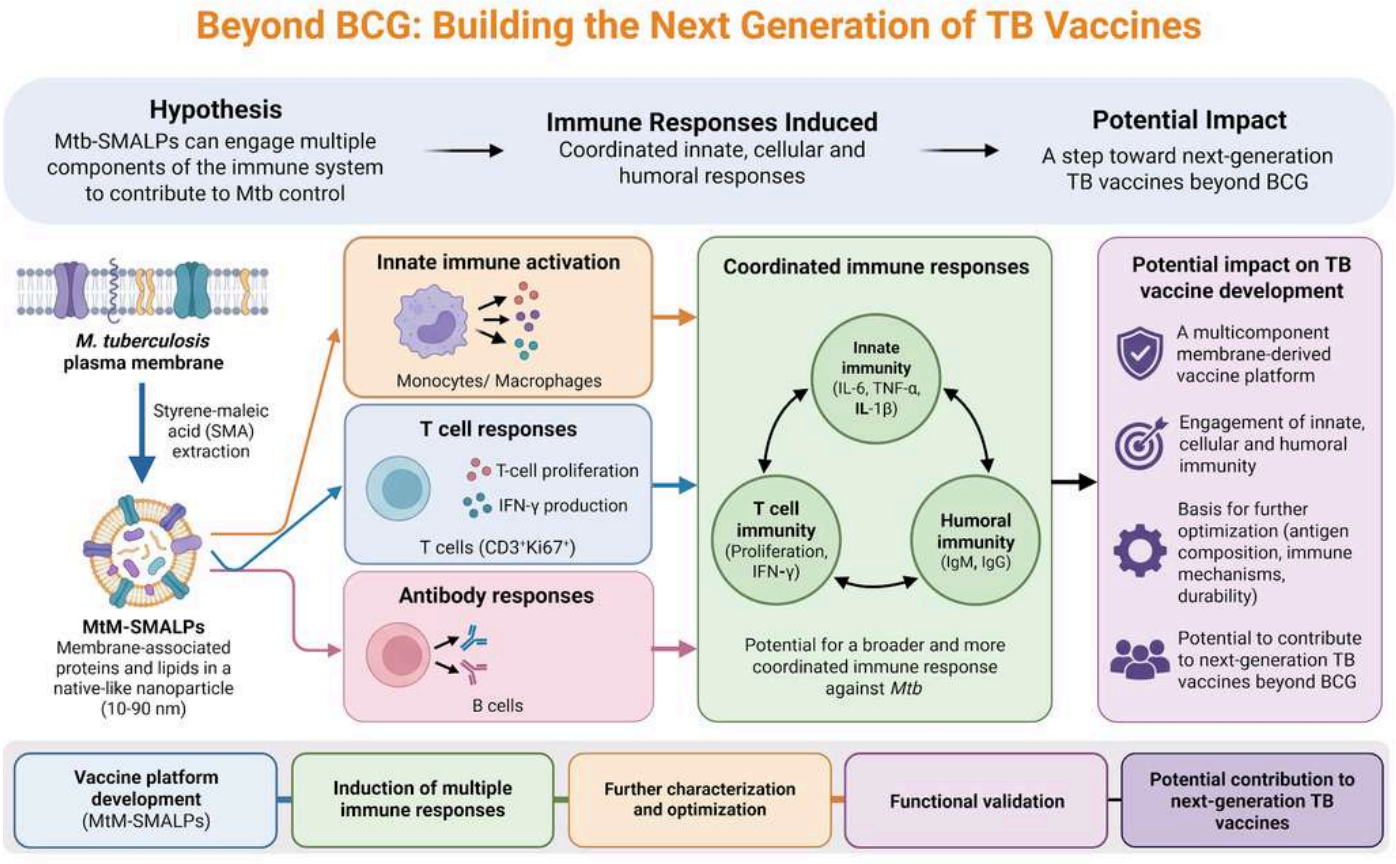


Figure 1: Proposed pathway for MtM-SMALPs in next-generation TB vaccine development. MtM-SMALPs induce innate, cellular, and humoral immune responses, providing a basis for further development and functional validation as a potential TB vaccine platform.

cell, and antibody responses indicate the immunological potential of MtM-SMALPs and support their further validation as a potential platform for TB vaccine development.

Key Research Directions for Further Characterization and Development of MtM-SMALPs

The next stage should focus on defining the relationship between MtM-SMALP composition and immune activity. Proteomic and lipidomic analyses can be used to establish the components consistently retained during SMALP preparation and to determine their relationship with cytokine, T-cell and antibody responses.

A second direction is to examine macrophage responses more directly. The current study demonstrated cytokine production in blood cultures, but the contribution of individual innate immune cell populations requires further characterization. Studies using isolated monocytes and macrophages can determine how MtM-SMALPs influence activation and subsequent immune-cell interactions.

A third direction is to further characterize T-cell responses. The published study demonstrated Ki67+CD3+ T-cell proliferation and IFN-γ production. Future work should define the responding T-cell populations and determine whether these responses are maintained following repeated stimulation.

Antibody responses require additional characterization. Because IgG responses were more prominent against MtM-SMALPs but overall antibody levels were low, subsequent studies should examine antibody titers alongside binding characteristics and functional activity.

Finally, the immunological findings need to be connected with functional control of Mtb. Cytokine production, T-cell proliferation and antibody responses provide measurable indicators of immune activation, but their relevance to protection must be established in appropriate experimental models. Reproducibility of MtM-SMALP preparation, molecular composition, safety, immune durability, and protective activity will therefore be important steps in further development.

Conclusion

Developing next-generation TB vaccines requires a comprehensive understanding of the immune responses that contribute to effective control of Mtb. The recent findings on MtM-SMALPs provide encouraging evidence that a membrane-derived preparation can engage multiple components of the immune system, including innate cytokine responses, IFN-γ production, T-cell proliferation, and antibody responses. The observed induction of IL-6, TNF-α, IL-1β and IFN-γ, together with measurable T-cell and antibody responses, highlights the multifaceted immunological activity of MtM-SMALPs and provides a strong basis for their continued investigation as a potential TB vaccine platform.

These findings establish an important foundation for further development. The membrane-derived composition of MtM-SMALPs provides an opportunity to investigate multiple Mtb-associated immune determinants within a single preparation, while the observed cellular and humoral responses provide measurable parameters for evaluating and optimizing the platform.

Further studies can build on these findings by defining the membrane components associated with specific immune responses, characterizing macrophage and T-cell activation, and improving the understanding of MtM-SMALP-induced antibody responses.

A key next step will be to connect these measurable immune responses with functional activity against Mtb. Evaluation in appropriate experimental systems, together with assessment of response durability, safety, reproducibility and protective activity, will help establish the translational potential of this approach.

This stepwise progression—from molecular characterization and immune activation to functional validation—can provide a clear framework for advancing MtM-SMALPs from an experimental membrane-derived preparation toward a more developed TB vaccine platform.

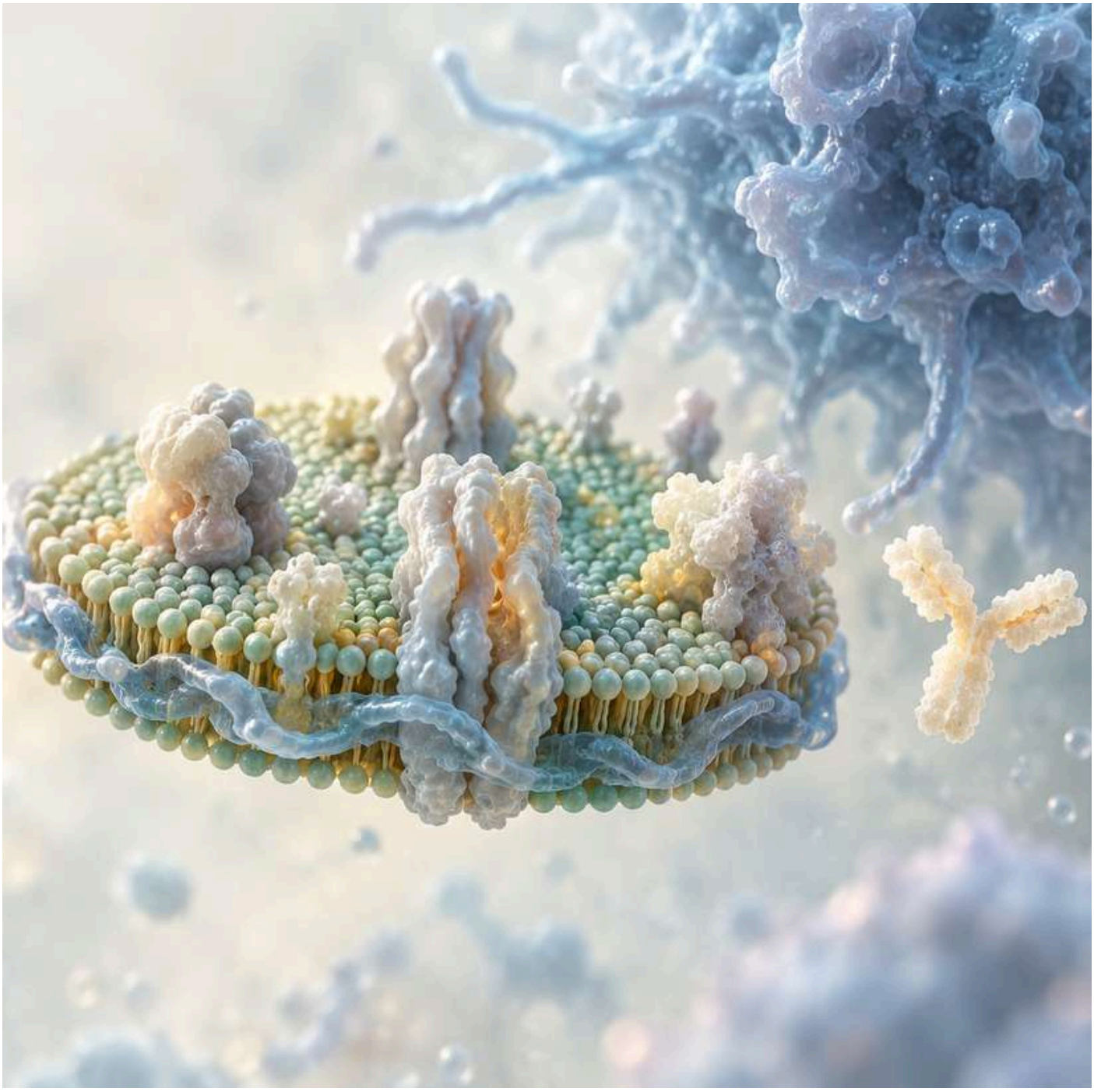
Overall, the current evidence positions MtM-SMALPs as a promising, innovative approach to broadening TB vaccine research. Continued investigation of their molecular composition, immunological activity, and functional relevance may contribute to the development of new vaccine strategies capable of generating coordinated innate and adaptive immune responses against Mtb.

ABOUT THE AUTHORS

Dr. Alok Kumar is an Additional Professor in the Department of Molecular Medicine and Biotechnology at Sanjay Gandhi Postgraduate Institute of Medical Sciences, Lucknow. His work explores how tiny particles prepared from the tuberculosis bacterium's membrane interact with the immune system. He studies their ability to activate immune cells and antibody responses, with the aim of understanding whether they could help develop future TB vaccines. His research provides a foundation for further testing of their safety, lasting immune effects and ability to protect against TB.

REFERENCES

- Sinha, S., Athar, S., Agrawal, V., Aggarwal, A., & Kumar, A. (2026). Styrene maleic acid lipid particles prepared from Mycobacterium tuberculosis plasma membrane can potentially induce innate and adaptive immune responses in healthy individuals of a tuberculosis hyperendemic region. Current Microbiology, 83, 544. DOI



DOI: https://doi.org/10.67831/Sci.Factors.2026.1732

SCIENCE FACTORS!

EMERGING INSIGHT

Five Colourful Crystals of One Molecular Pair: The Hidden Diversity of Pharmaceutical Co-crystals



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AREAS OF EXPERTISE

Supramolecular Chemistry • Crystal Engineering • Pharmaceutical Solids • Porous Materials

WHY IT MATTERS

A medicine's properties depend on how its molecules fit together in a crystal. In this article, Dr. Sonali Ghosh explains how the same combination of an anti-tuberculosis drug and saccharin can form five different crystals, with distinct colours, structures and responses to heat. Understanding these differences could help scientists better control how medicines are made and stored, and guide the design of more reliable pharmaceutical materials.

At first glance, a crystal may seem like one of the simplest forms of matter. Molecules arrange themselves into an ordered structure, the crystal grows, and the story appears to be finished.

But crystals can be surprisingly unpredictable. Two samples can contain exactly the same molecules in exactly the same ratio and still form crystals with different structures, shapes, colours, stability and physical properties. This phenomenon, known as 'Polymorphism', is one of the fascinating challenges of solid-state chemistry and is particularly important in pharmaceutical science.

A recent study published in RSC Advances has revealed an unusually colourful example of this phenomenon. Researchers from the Indian Institute of Technology Bhubaneswar have discovered five distinct polymorphic forms of a 1:1 Prothionamide-Saccharin pharmaceutical salt, obtained by carefully changing crystallization conditions. The crystals showed different morphologies and striking red, orange and yellow colours.

Same molecules:different crystals

The central question behind the research is deceptively simple: If we use the same two molecules, why don't they always make the same crystal? To investigate this question, the researchers selected Prothionamide (PA), an antituberculosis drug, and Saccharin (SA), a generally recognized as safe (GRAS) co-former. When these two molecular components interact during crystallization, they form a pharmaceutical salt with a 1:1 stoichiometric ratio. However, maintaining the same molecular ratio does not guarantee the exact single crystal structure. By controlling the crystallization environment, particularly the solvent and temperature, the researchers isolated five different forms, designated Forms I–V. This is where the chemistry becomes particularly interesting. The five forms had the same overall chemical composition, but their molecules were arranged differently in the solid state. The crystals also developed different shapes, including blocks, hexagonal, plates, rods and rectangular crystals, along with visible differences in colour. In other words, the molecules were the same, but the molecular arrangement was different.

Why molecular arrangement matters

In molecular chemistry, we often focus on what molecules are present. In solid-state chemistry, however, another question becomes equally important: A crystal is an organized three-dimensional assembly of molecules. Small changes in molecular orientation, conformation or intermolecular interactions can alter the entire packing arrangement. This is the essence of polymorphism. In pharmaceutical materials, this

distinction can matter because different crystal forms can have different physical properties. Crystal packing can influence properties such as thermal behaviour, stability, solubility and other characteristics relevant to pharmaceutical solids. Therefore, finding one crystalline form does not necessarily mean that the structural landscape of a material has been completely explored. The Prothionamide-Saccharin system provides a particularly clear demonstration of this principle.

One molecular pair, five crystal forms

The five forms were obtained using solution-based crystallization under different conditions. Although all five retained the same 1:1 stoichiometry, single-crystal X-ray diffraction revealed that they possessed different unit-cell parameters and packing motifs. This distinction is fundamental. Imagine five rooms built from exactly the same set of furniture. The furniture itself has not changed, but its arrangement inside each room can be completely different. The same idea applies at the molecular level.

In one crystal form, molecules may adopt one orientation and establish a particular network of intermolecular interactions. In another form, the molecules can change their orientation or conformation, allowing a different packing arrangement to emerge. The researchers found evidence that this molecular flexibility plays an important role in the formation of the five polymorphs.

The flexibility of Prothionamide

One of the important findings of the study was that Prothionamide is conformationally flexible. The molecule can adopt different conformations because portions of its molecular substituent can rotate. Detailed analysis of torsion angles showed that the Prothionamide molecules adopt different conformations in the five crystal forms. This flexibility provides the molecule with several ways of fitting into a crystal lattice. Different molecular conformations can influence how molecules interact with neighbouring molecules, which in turn can produce different crystal packing arrangements. The study identified both conformational polymorphism and packing polymorphism among the five forms, showing that more than one structural mechanism contributes to the observed diversity. This is an important lesson in crystal engineering: molecular flexibility can increase the number of possible ways in which molecules organize themselves in the solid state.

Why are the crystals different colours?

Perhaps the most visually striking aspect of the work is the colour. The five polymorphs exhibited red, orange and yellow colours, making the structural differences visible even before sophisticated characterization was performed. But colour alone cannot tell us why a crystal looks the way it does. To understand the origin of these differences, the researchers investigated the materials using UV-visible spectroscopy and photoluminescence measurements, supported by computational studies. The results demonstrate how changes in the solid-state environment can influence the electronic properties of molecular materials. This is one of the fascinating features of solid-state chemistry. The colour of a material is not determined only by the isolated molecule. The way molecules interact and pack together can also influence how the material absorbs and emits light. Thus, the five crystals provide a visible reminder that molecular organization matters.

Looking inside the crystals

The heart of the investigation was single-crystal X-ray diffraction (SCXRD). For a crystallographer, an apparently simple crystal can contain an enormous amount of information. By analysing how X-rays are diffracted by the ordered crystal lattice, researchers can determine the three-dimensional arrangement of atoms. In this study, SCXRD established that the five materials shared the same overall stoichiometry while possessing different crystal structures. Powder X-ray diffraction further supported the distinction between the forms. Additional techniques, including **differential scanning calorimetry (DSC)** and **variable-temperature powder X-ray diffraction (VTPXRD)**, were used to investigate their thermal behaviour. The study also examined intermolecular interactions and relative stability using **Hirshfeld surface analysis** and **lattice-energy calculations**. Together, these techniques allowed the researchers to move from a simple observation, “there are five different crystals,” to a deeper structural question: **What makes each crystal form different, and how stable is each arrangement?**

When heat changes a crystal

The crystals also revealed interesting behaviour when heated. Forms I, II,

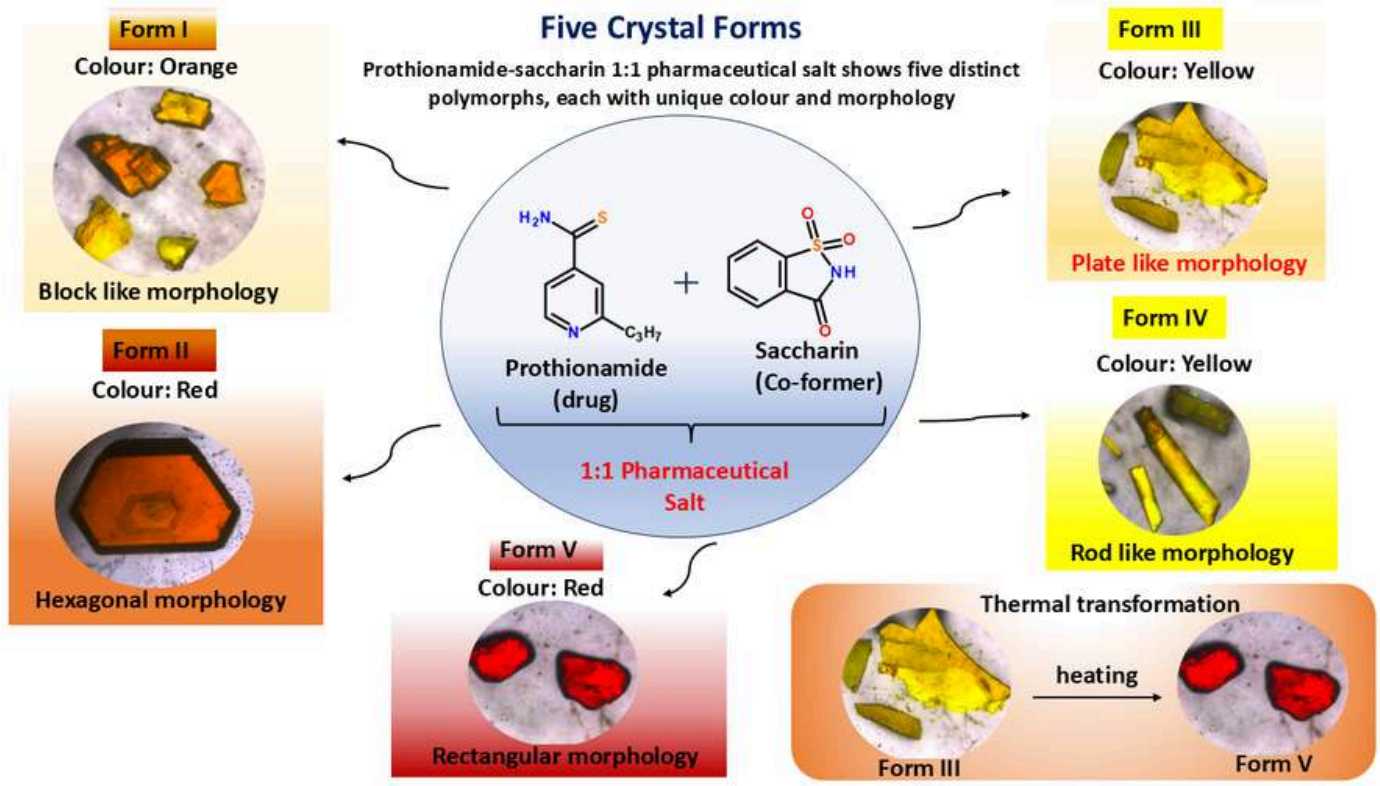


Figure 1: Five colourful polymorphic forms of the prothionamide-saccharin salt.

IV and V remained intact under the any sort of thermal conditions. Whereas, Form III transformed into Form V upon heating. This observation provides another glimpse into the dynamic nature of crystal structures. A crystal may appear static, but its molecular arrangement is governed by a balance of intermolecular interactions and thermodynamic stability. When external conditions such as temperature change, one arrangement can become more favourable than another. The transformation of Form III into Form V therefore demonstrates that polymorphs are not simply different static structures. Under suitable conditions, one solid form can transform into another.

Why crystal forms matter for medicines

The importance of this research extends beyond producing colourful crystals.

Pharmaceutical compounds are often developed as solid materials, and their properties depend not only on molecular composition but also on their solid-state structure. When different polymorphs are possible, controlling which form is produced becomes an important part of pharmaceutical solid-state research. For pharmaceutical co-crystals and salts, this becomes even more interesting because more than one molecular component participates in the crystal structure. The discovery of five polymorphic forms in a single Prothionamide-Saccharin system demonstrates how extensive the solid-state landscape of a pharmaceutical material can be. It also highlights a practical challenge: Changing a crystallization condition can change the crystal that you obtain.

Solvent, temperature, concentration, evaporation rate and other experimental parameters can influence nucleation and crystal growth. Consequently, systematic crystallization studies are essential when investigating pharmaceutical solids.

The hidden complexity of crystals

Chemistry is often taught through molecular structures drawn on paper: atoms connected by lines, functional groups identified by names, and reactions represented by arrows. But once molecules enter the solid state, another layer of chemistry emerges. Molecules have to arrange themselves in three dimensions. They interact with their neighbours. They compete for space. They adopt different conformations. They form networks through hydrogen bonding and other intermolecular interactions. And sometimes, surprisingly, the same molecules can organize themselves in several different ways. The five

Prothionamide-Saccharin polymorphs offer a striking example of this hidden complexity.

Looking ahead

The future of pharmaceutical solid-state chemistry lies in moving beyond simply discovering new crystal forms toward predicting, controlling, and deliberately designing them. One of the biggest unanswered questions is whether we can accurately predict the most stable or functionally useful solid form before it is experimentally discovered. Crystal packing depends on a complex balance of hydrogen bonding, π–π interactions, electrostatic forces, molecular flexibility, and solvent effects. Understanding these competing factors remains essential for developing medicines with improved solubility, stability, dissolution, and bioavailability. The next major breakthrough will likely come from combining high-throughput crystallization, advanced X-ray diffraction, thermal analysis, computational modelling, and artificial intelligence. Machine-learning approaches could eventually help researchers identify promising co-formers and predict polymorphic landscapes, while real-time diffraction and spectroscopy could reveal how one crystal form transforms into another during heating, cooling, hydration, or exposure to different solvents. Over the next 5–10 years, I envision pharmaceutical crystal engineering becoming increasingly predictive, automated, and application-driven. Instead of treating unexpected polymorphs as a challenge encountered during drug development, researchers may increasingly use polymorphism as a design tool. The integration of crystal engineering with computational chemistry, AI, advanced characterization, and pharmaceutical development could allow scientists to design solid forms with specific properties before entering the laboratory. Readers should watch for one major shift: the transition from "finding" pharmaceutical crystals to "designing" them. This could fundamentally change how the solid forms of medicines are discovered, optimized, and ultimately developed into more effective and reliable pharmaceutical products.



ABOUT THE AUTHORS

Dr. Sonali Ghosh's active academic research focuses on advanced solid-state chemistry, pharmaceutical crystal engineering and polymorphism, with particular emphasis on deeply understanding how molecular interactions and crystal packing directly govern essential material properties. Her published work on Prothionamide-Saccharin polymorphism clearly demonstrates how subtle changes in molecular arrangement can successfully generate distinct crystalline forms with entirely different optical, thermal and structural properties, highlighting the critical importance of predictive computational approaches to pharmaceutical solid-form design and therapeutic development.

REFERENCES

- Ghosh, S., Easmin, S. & Pedireddi, V. R. Co-crystal polymorphism: five colourful forms of prothionamide-saccharin co-crystal. RSC Advances 16(42), 50358–50373 (2026). DOI
- Weatherston, J., Probert, M. R. & Hall, M. J. Polymorphic ROYalty: The 14th ROY polymorph discovered via high-throughput crystallization. Journal of the American Chemical Society 147(14), 11949–11954 (2025).DOI
- Parent, S. D., Smit, J. P., Purcell, D. K., Smith, P. A., Le Maguerès, P., Bauser, H. C. & Radocea, A. Crystal structure of ritonavir Form IV and thermodynamic relationships between ritonavir polymorphs. Crystal Growth & Design 26(3), 1386–1392 (2026) DOI.

DOI: https://doi.org/10.67831/Sci.Factors.2026.1736

SCIENCE FACTORS!

EMERGING INSIGHT

Climate, Catastrophes and the Growing Threat to Lung Health



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AREAS OF EXPERTISE
Respiratory Health • Epidemiology • Health Promotion • Environmental Science

WHY IT MATTERS

Disasters can threaten lung health long after the immediate danger has passed. Smoke, dust and mould can worsen breathing problems, especially among children, older adults and people with existing lung conditions. In this article, Dr. Arundhati Garud explores how climate-related disasters and social inequalities increase these risks. She explains why air-quality monitoring, early warnings and clean-air shelters deserve a place in disaster preparedness and recovery, helping communities protect their health beyond the emergency.

Climate, Catastrophes and the Growing Threat to Lung Health

When a disaster strikes, people's immediate concerns revolve around survival, securing shelter, finding food, and ensuring the safety of their loved ones. However, even after the initial danger subsides, a hidden threat lingers in the environment: smoke, dust, toxic gases, mould, and infectious particles that can silently harm the lungs. For instance, when the earthquake hit Türkiye in 2023 and when floodwaters inundated Valencia in October 2024, images of widespread devastation captured global attention. Yet, one aspect of these disasters went largely unphotographed: the weeks that followed. During this time, fallen debris and dust began to jeopardise health, while mould proliferated in water-damaged homes, leading to allergies and exacerbating respiratory issues for those with asthma and related conditions.

Disasters vary enormously in appearance, but very little is known about how they injure the lung. In almost every event, inhaled particles and gases trigger oxidative stress, a form of chemical damage within the airway lining. The lung's protective barrier weakens, inflammation sets in, and with repeated exposure, the airways thicken and scar; in the worst cases, this leads to cancer. The main culprit is particulate matter, particularly its smallest fractions. PM2.5, particles under 2.5 micrometres wide (for comparison, a single strand of human hair has a width of about 50-70 micrometres), travel deep into the lung. Ultrafine particles like PM1, smaller than a tenth of a micrometre, go even further, passing into the bloodstream and reaching other organs. With inhaled pollution, size matters more than anything else.

Every year, hundreds of thousands of tonnes of sand from the Sahara Desert travel across the Atlantic Ocean and ultimately settle on the east coast of the United States. These ultrafine dust particles are so minuscule that they can penetrate blood vessels and impact various internal organs. In a related context, the wildfires that occur almost annually on the West Coast of the U.S. and in northern Canada contribute significantly to air quality issues. Smoke generated by these fires can drift far beyond the burning areas, exposing entire communities to harmful fine particles. These smoke particles contain a wide range of particulate matter, some big, and some very tiny, commonly referred to as PM0.1, which can be 500 to 700 times smaller than the width of a human hair. Wildfire smoke poses serious health risks, particularly for individuals suffering from asthma and chronic obstructive pulmonary disease (COPD), while also increasing the likelihood of bronchitis, pneumonia, and other infections. Vulnerable populations, such as children, the elderly, pregnant women, and individuals with pre-existing cardio-respiratory diseases, are particularly susceptible

to these health impacts.

Climate change is having a significant impact on respiratory health, especially during heatwaves, when high temperatures stress the body and elevate ozone and other air pollutants. These conditions lead to increased pollen levels, which can worsen allergies and asthma. Research shows a correlation between extreme heat and an uptick in asthma attacks, hospitalisations for chronic obstructive pulmonary disease (COPD), and respiratory-related deaths. Children, older adults, individuals with chronic lung diseases, outdoor workers, and families living in poorly ventilated homes are particularly at risk. In addition to heatwaves, droughts and dust storms pose further threats to respiratory health. Dry soil and vegetation can produce airborne dust that irritates the airways and exacerbates conditions such as asthma and COPD. This dust can also carry harmful fungal spores and microorganisms, increasing the risk of chronic diseases, including interstitial lung disease. Flooding presents its own hazards, as damp environments encourage mould growth. Mould spores can trigger asthma and allergic reactions, while contaminated water sources, crowded living conditions, and poor sanitation can elevate the risk of respiratory infections. For individuals with pre-existing lung conditions, homes may feel unsafe even if the structure itself seems intact. Additionally, storms and thunderstorms introduce more risks. Strong winds can carry dust, debris, and pollutants, and damage to buildings can release mould and harmful chemicals. Thunderstorms can also trigger a phenomenon known as thunderstorm asthma, in which rain and wind break pollen into tiny particles that can penetrate deep into the airways, sometimes resulting in severe asthma attacks.

Earthquakes and volcanic eruptions expose people to a different mixture of hazards. Collapsed buildings release silica, asbestos and fine dust. Damaged gas lines can release carbon monoxide, while radon from the ground may increase long-term lung cancer risk. Volcanic ash contains sharp mineral particles, and volcanic gases can cause coughing, bronchitis, asthma attacks and acute respiratory distress. Rescue workers are often exposed to these substances while clearing debris or assisting survivors.

One further pattern runs through everything: a hurricane does not choose its victims, but a society can. Low-income and marginalised communities already have higher asthma rates, poorer housing, and fewer resources to prepare or recover. A patient who cannot afford a spare inhaler is at genuine risk when the pharmacy closes or floods. However, some people face these situations even more harshly. Firefighters and other first responders take the heaviest exposures, and those who fight wildfires are often the least well-protected of any group we studied. Breathing tests show that people with a history of smoke exposure have weaker lungs, a higher chance of developing asthma, and worse outcomes if they catch infections, such as influenza or COVID-19. However, most of this information comes from single tests rather than long-term studies, an area that needs more research.

We believe respiratory protection must be included in every stage of disaster planning. Authorities should monitor air quality, issue early warnings, and provide clean-air and cooling shelters. While none of this is inevitable, precautions are important. Our key message: A disaster does not end when the flames are extinguished or the floodwater disappears. Its respiratory danger may remain in smoke, mould, dust and contaminated air long after the headlines have moved on.

ABOUT THE AUTHORS

Dr. Arundhati Garud is a Research Assistant at Ahmedabad University, Gujarat. Her research focuses on asthma and other chronic respiratory diseases, using clinical and population data to understand breathing symptoms, lung function, healthcare use and limitations in daily activities. She examines how environmental exposures and social inequalities affect respiratory health, particularly among vulnerable populations. Her work informs the article's discussion of climate-related threats to lung health and the need for better preparedness and protection.

REFERENCES

- Annesi-Maesano, I., Bayram, H., Cecchi, L., et al. Natural disasters and respiratory health. European Respiratory Journal 66(4), 2402563 (2025). DOI



DOI: https://doi.org/10.67831/Sci.Factors.2026.1738

SCIENCE FACTORS!

EMERGING INSIGHT

Can "Bioalchemistry" Transform Pharmaceutical Science Towards a Greener and Healthier Tomorrow?



Anil Kumar Kanuri
In Silico Pharmaceutical Suite (INSPirE), Department of Pharmaceutical Chemistry
Faculty of Pharmacy, Universiti Malaya
Kuala Lumpur, Malaysia

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AREAS OF EXPERTISE

Artificial intelligence-driven drug discovery • Medicinal Chemistry-Pharmaceutical Analysis Interface • Natural product sciences • Green chemistry

WHY IT MATTERS

Modern medicines improve human health, but their development and manufacturing can generate chemical waste, consume large amounts of resources, and harm the environment. Anil Kumar Kanuri, a researcher at Universiti Malaya, Malaysia, proposes an emerging interdisciplinary concept called "Bioalchemistry," which brings together chemistry, biology, pharmaceutical science, artificial intelligence, and sustainable practices. His vision highlights how greener drug development, safer chemical testing, and smarter manufacturing could reduce environmental damage without compromising medicine quality or patient safety. This approach could help shape a future where pharmaceutical innovation protects both human health and the planet.

Pharmaceutical science has always been driven by one fundamental objective: improving human health. Yet, as the demand for medicines continues to increase, an important question is emerging alongside this objective: Can we develop and manufacture medicines in ways that are not only effective and safe for patients, but also safer for the environment?

The future of pharmaceutical science will increasingly depend on answering this question. Green and sustainable practices are no longer limited to reducing laboratory waste or replacing a hazardous solvent with a safer alternative. Sustainability is becoming a broader design principle that can influence how medicines are discovered, synthesized, manufactured, analyzed, packaged and ultimately introduced into healthcare systems. One of the biggest unanswered questions is how to achieve this transformation without compromising pharmaceutical quality, safety, affordability, or accessibility. A pharmaceutical process must satisfy stringent requirements for purity, potency, stability, reproducibility and patient safety. The challenge is therefore not simply to make a process "greener," but to redesign it so that environmental responsibility becomes an intrinsic part of pharmaceutical quality.

From green chemistry to sustainable-by-design pharmaceuticals

A major opportunity lies in moving sustainability upstream. Traditionally, environmental considerations may receive greater attention during process development or manufacturing. However, decisions made much earlier during drug discovery and route selection can determine the environmental footprint of a medicine for years to come. Solvent choice is a particularly important example. Recent analysis has highlighted the enormous contribution of solvents to pharmaceutical waste and environmental impact, with solvents accounting for a substantial proportion of waste streams associated with pharmaceutical manufacturing. This means that sustainability should begin when scientists select synthetic routes, reaction conditions, purification strategies and analytical methods. Choosing reactions with better atom economy, reducing unnecessary protection and deprotection steps,

minimizing solvent-intensive purification and considering solvent recovery or recycling can collectively produce substantial improvements.
The next step is to move from "greener processes" to "sustainable-by-design pharmaceuticals." This requires considering environmental impact alongside conventional parameters such as yield, cost, purity and scalability from the earliest stages of development.

The analytical laboratory must become greener too

An often-overlooked component of pharmaceutical sustainability is analytical science, where repeated testing across the drug development and quality-control lifecycle can result in significant cumulative consumption of solvents, reagents and other resources, despite the use of samples from micro to ultra-micro range. Every pharmaceutical product requires extensive analytical testing throughout research, development, manufacturing, quality control and stability assessment. Chromatographic techniques such as high-performance liquid chromatography are indispensable for pharmaceutical analysis, but they can consume significant quantities of organic solvents and generate analytical waste.

This creates an important opportunity for Green Analytical Chemistry.

Analytical methods should aim to reduce solvent consumption, hazardous reagents, energy requirements, sample preparation and waste while maintaining or improving analytical performance. Approaches such as shorter chromatographic methods, miniaturized analytical platforms, safer solvents, direct analysis, automation and solvent-efficient separation technologies can contribute to this transition that we

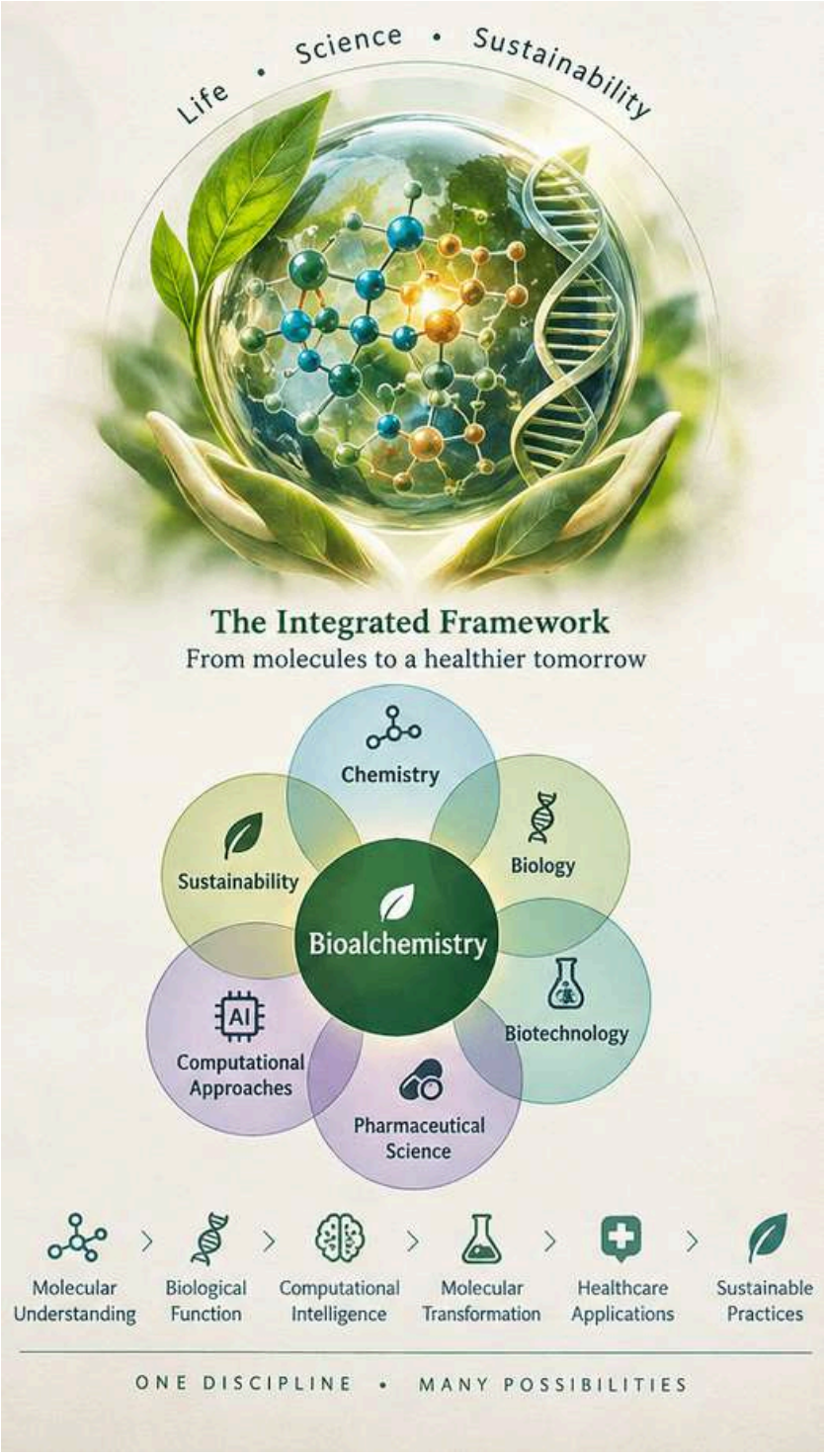


Figure 1: Bioalchemistry is envisioned as an interdisciplinary approach integrating chemistry, biology, pharmaceutical science, computational methods, and sustainability principles across drug discovery & development continuum. The framework illustrates how these interconnected domains can support the design, analysis, optimization, and evaluation of pharmaceutical processes and products with greater emphasis on efficiency, safety, environmental responsibility, and human health.

reported in our previous works.

Importantly, sustainability should not be treated as an afterthought added to an already established method. The analytical procedure itself should be designed with sustainability in mind. Green metrics can help scientists quantitatively compare methods rather than relying solely on qualitative claims of being "green." This shift toward measurable sustainability is particularly important because a method can appear environmentally friendly in one aspect while creating another hidden burden. A truly sustainable assessment should therefore consider the complete life cycle of materials, energy consumption, waste generation, occupational safety and environmental impact.

Artificial intelligence as an accelerator for sustainability

Artificial intelligence and machine learning could become important enablers of sustainable pharmaceutical science. AI can help scientists predict molecular properties, identify promising compounds, optimize synthetic routes, select experimental conditions and reduce the number of experiments required during development. In manufacturing, digital technologies can support process monitoring, anomaly detection, predictive maintenance and adaptive process control. The FDA already identifies automation, digitization, artificial intelligence, process intensification and smart manufacturing among important areas of advanced manufacturing.

However, AI should not be viewed simply as a faster way of doing conventional pharmaceutical science. Its greater potential may lie in enabling different ways of designing pharmaceutical processes.

Imagine a future in which an AI-assisted platform evaluates a proposed drug synthesis not only for predicted yield and cost, but simultaneously for solvent toxicity, material consumption, energy demand, waste generation, scalability and overall environmental impact. Scientists could then compare multiple synthetic pathways before entering the laboratory.

Such systems could transform sustainability from a retrospective assessment into a predictive design parameter.

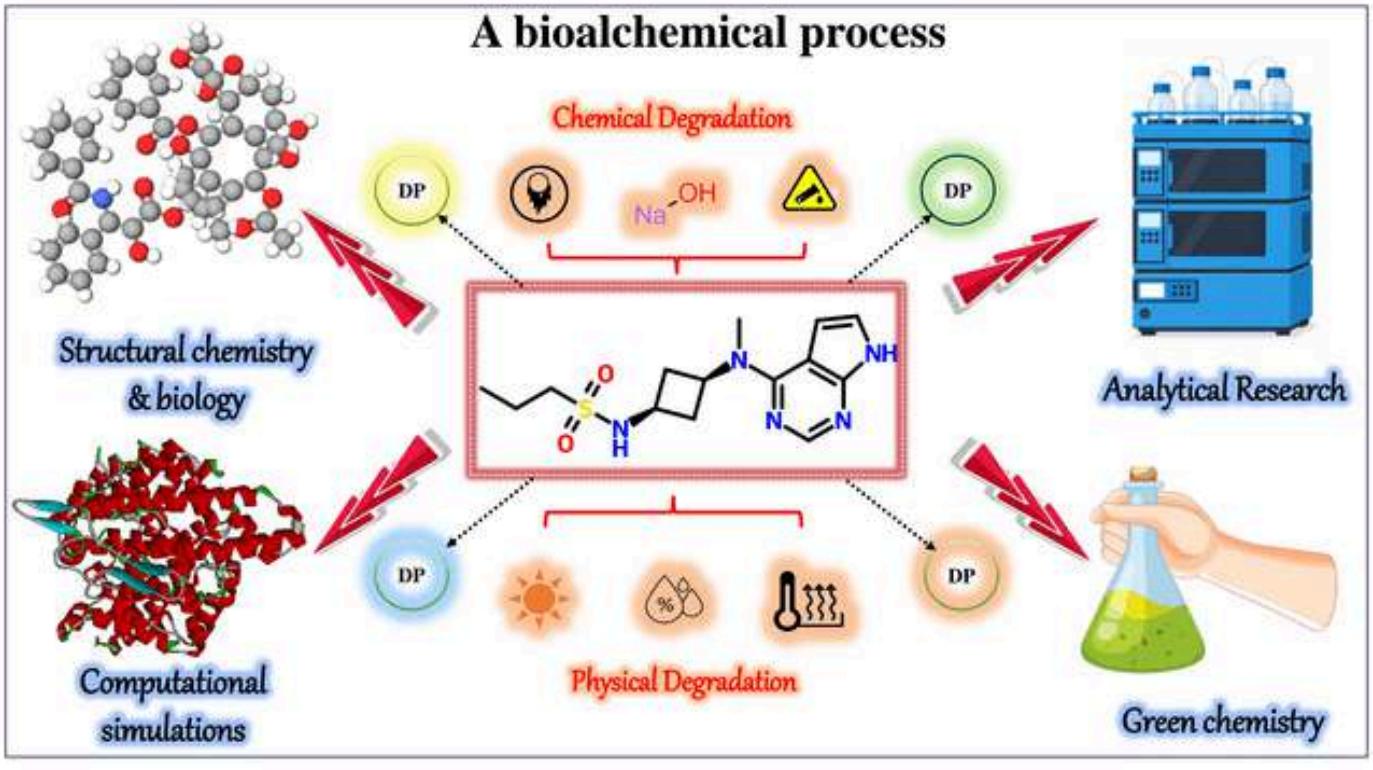


Figure 2: A conceptual workflow integrating chemistry, pharmaceutical analysis, biological evaluation, computational modelling, in silico prediction, and sustainability assessment, derived from approaches and insights reported across our recent research. The workflow illustrates how these interconnected components can be brought together within a broader bioalchemical framework to support more efficient, informed and sustainable pharmaceutical research and development.

What breakthroughs are still needed?

Several scientific and technological advances will be necessary to realize this vision.

- First, we need better standardized sustainability metrics that allow meaningful comparisons between pharmaceutical processes. Metrics such as process mass intensity, solvent intensity, energy consumption, carbon footprint, water use and waste generation are valuable, but they need to be integrated into decision-making rather than reported only after a process has been established.
- Second, greener alternatives must be practical, scalable and economically competitive. Replacing a hazardous solvent in a laboratory experiment is not enough if the alternative cannot be recovered, supplied reliably, or implemented at manufacturing scale.
- Third, we need greater integration between chemistry, biology, engineering, analytical science, data science and regulatory science. Sustainability is inherently multidisciplinary. No single technology will solve the pharmaceutical industry's environmental challenges.

Finally, sustainability assessments must consider the entire lifecycle of a pharmaceutical; from raw materials and discovery through manufacturing, distribution, use and disposal. Our recent works in pharmaceutical research has highlighted the growing importance of green chemistry principles in drug testing and analytical processes, reinforcing the need to extend sustainability beyond the manufacturing stage and throughout the pharmaceutical lifecycle.

The future of Health

Over the next decade, I expect pharmaceutical sustainability to move from being a specialized area of research toward becoming a more integrated component of pharmaceutical development. We are likely to see wider adoption of continuous and intensified manufacturing, increased use of safer solvents and catalytic processes, greater emphasis on solvent recovery and circularity and continued development of greener analytical methodologies. Mechanochemistry and other low-solvent or solvent-free approaches are also promising areas for investigation, particularly where they can be translated successfully from laboratory studies to scalable manufacturing.

At the same time, AI and digital technologies may increasingly connect molecular design with process design. The most exciting developments may occur where these disciplines converge: AI-guided drug discovery combined with sustainable chemistry, automated experimentation, real-time analytics and intelligent manufacturing.

The pharmaceutical laboratory of the future may therefore look very different from today's laboratory. It may be more automated, more data-driven, more resource-efficient and increasingly capable of making sustainability decisions in real time.

Ultimately, the goal should not be to choose between pharmaceutical innovation and environmental responsibility. The challenge and opportunity are to advance both simultaneously.

must be included in every stage of disaster planning. Authorities should monitor air quality, issue early warnings, and provide clean-air and cooling shelters. While none of this is inevitable, precautions are important. Our key message: A disaster does not end when the flames are extinguished or the floodwater disappears. Its respiratory danger may remain in smoke, mould, dust and contaminated air long after the headlines have moved on.

I am working toward the development of a first-of-its-kind emerging scientific discipline, for which I have proposed the term ‘Bioalchemistry” derived from “bio” (life and biological systems) and “alchemy” (an ancient tradition of natural philosophy and early scientific inquiry that sought to transform matter, achieve universal healing and discover an elixir of immortality). My ongoing work focuses on defining its scope, scientific foundations, applications, and potential contribution to the future of health sciences. “Bioalchemistry is the proposed scientific discipline and the terms “Bioalchemical”, “Bioalchemy” and “Bioalchemist” applies to the process, process of practicing and the professional who practices “Bioalchemistry” respectively.

The terms are intended to symbolize the modern scientific transformation of biologically relevant molecules through the integration of chemistry, biology, biotechnology, pharmaceutical science, computational approaches and sustainability. While established disciplines such as biochemistry, chemical biology, medicinal chemistry, computational chemistry

and bioinformatics address important aspects of these areas, “Bioalchemistry” is proposed as an integrative concept that brings together molecular understanding, biological function, computational intelligence, molecular transformation, technological advancement, healthcare applications, and sustainable scientific practices within a unified perspective. Through this concept, I aim to provide a broader terminology for interdisciplinary research concerned with understanding, designing and transforming biologically relevant molecules and translating such knowledge toward sustainable applications in drug discovery, molecular design, chemical biology, healthcare and allied disciplines.

A healthier tomorrow requires more than discovering new medicines. It requires us to rethink how those medicines are created. By embedding green chemistry, sustainable analytical science, advanced manufacturing, pharmaceutical and intelligent technologies into healthcare development, we can work toward a future in which better medicines and a healthier planet are not competing objectives, but complementary achievements.

ABOUT THE AUTHORS

Anil Kumar Kanuri is a Graduate Research Assistant (PhD) at the University of Malaya, under the supervision of Associate Professor Dr. Rozana Othman, with around five years of prior pharmaceutical industry experience in analytical research, development quality assurance, and quality control across active pharmaceutical ingredient and biologics environments. His current research spans AI-driven drug discovery, with a focus on deep learning, computational chemistry, natural product sciences. His interdisciplinary experience connects pharmaceutical research with emerging analytical and computational approaches to drug discovery.

REFERENCES

- Chintanippul NR, Rao BPC, Kanuri AK, Bhargavi P. A stability-indicating green RP-HPLC method for single-run quantification of ten related substances and abrocitinib, a selective JAK1 inhibitor. Journal of Pharmaceutical Sciences. 2026;115(9):104429.DOI
- Bhoomi VR, Rao TN, Randhi U, Kanuri AK, et al. Quantitative characterization and in silico toxicity assessment of degradation products from the dopamine and norepinephrine reuptake inhibitor solriamfetol. Discover Chemistry. 2026;3:407. DOI
- Bhoomi VR, Rao TN, Patrudu TB, Devi RU, Kanuri AK. Integrated GC–MS/MS and LC–MS/MS determination of potential genotoxic impurities in HER2 inhibitor tucatinib with in silico toxicological risk assessment and green analytical evaluation. Next Research. 2026;12:102165. DOI



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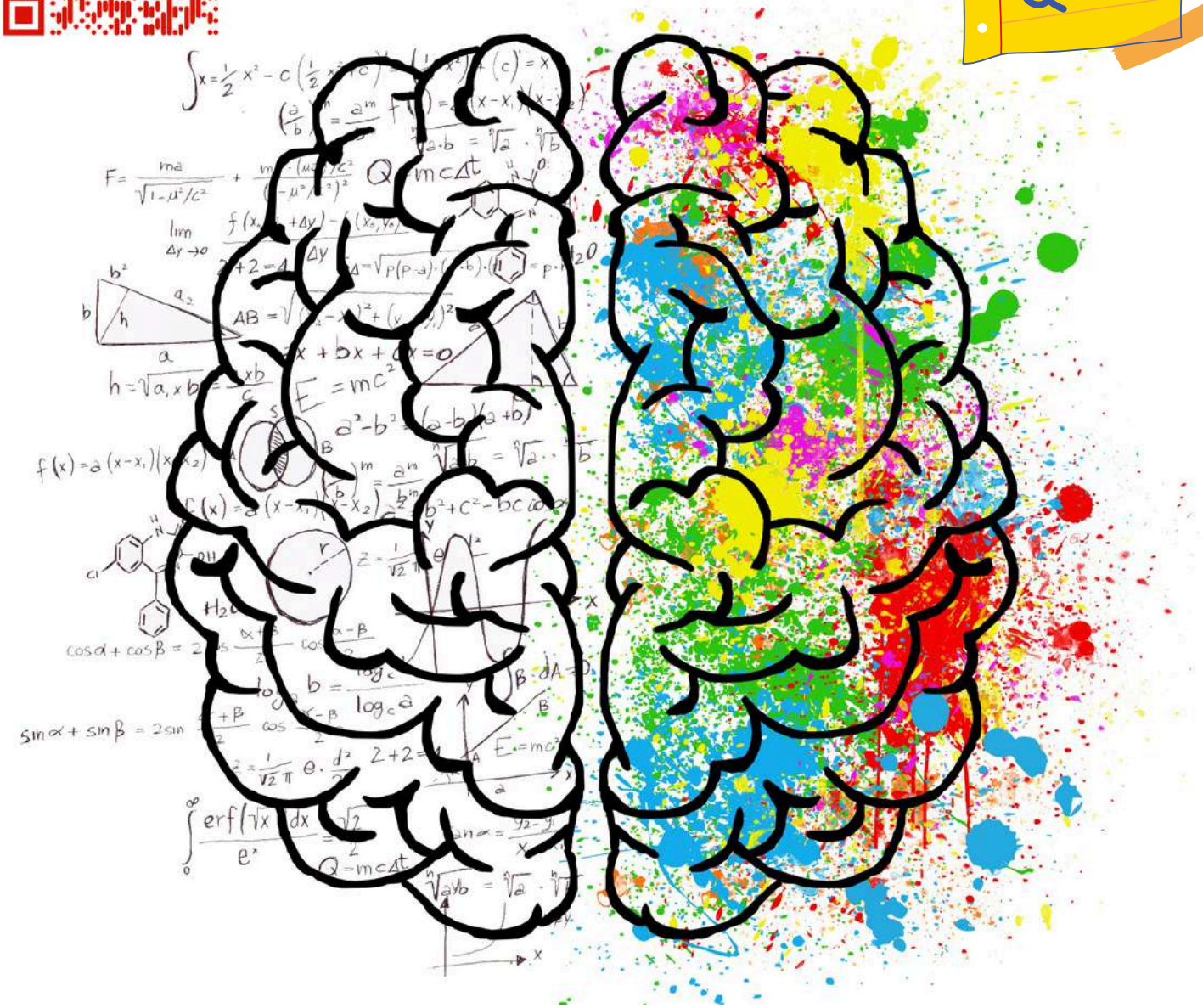
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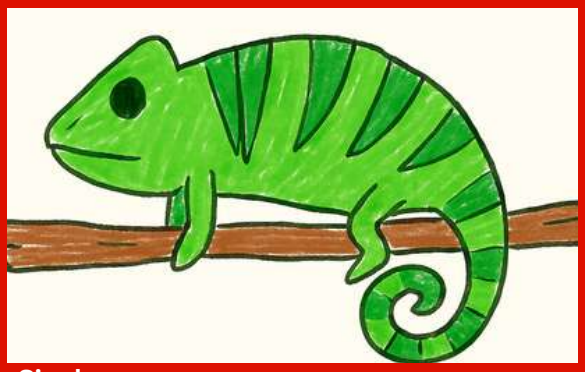
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back to school





NAME: **Riddhiman Singh**

Age: 4 **Years**

SCHOOL: **Junior Delhi Public School**

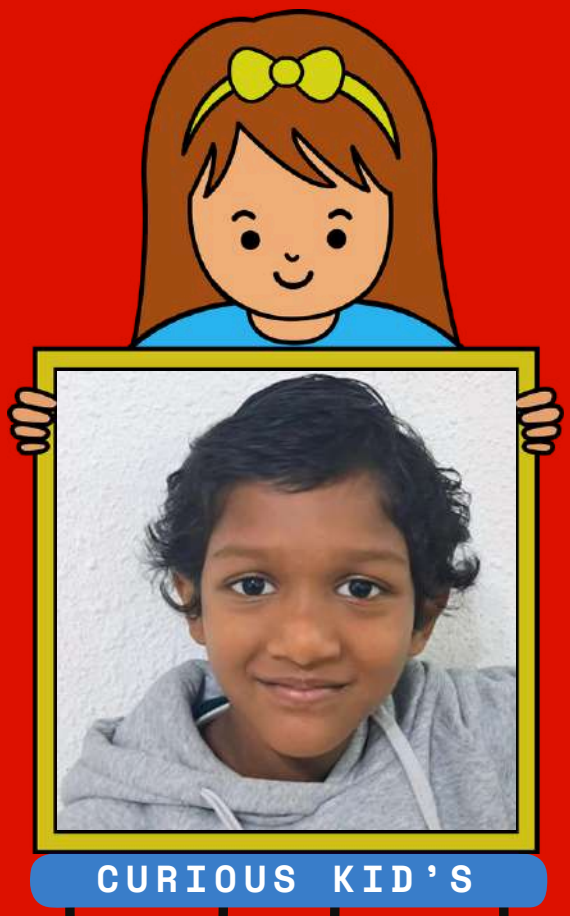
FOCUS:

My Feelings, My Colors!

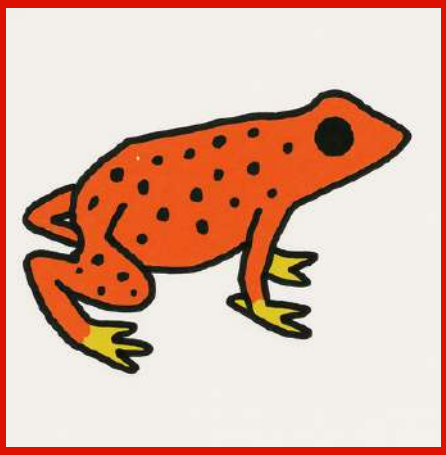
This is a chameleon. It can change its color, not like paint, but to show its feelings.
When it is calm, it stays green.
When it feels angry or scared, it turns dark.
When it is excited or hot, it becomes bright.
Its colors show how it feels inside



back to school







NAME: **Shai Sri Rakshan**

Age: **6 Years**

SCHOOL: **Moshe Smilansky School Rehovot, Israel**

FOCUS:

Look but Don't Touch!

These frogs are very bright and colorful. Their colors work like a warning sign. They are saying, "Do not touch me!" Poison dart frogs have poison in their skin. If another animal touches or bites them, it can feel pain and become very sick. So predators learn to stay away.Long ago, people used a little bit of this frog's poison on arrows for hunting. That is why they are called poison dart frogs.



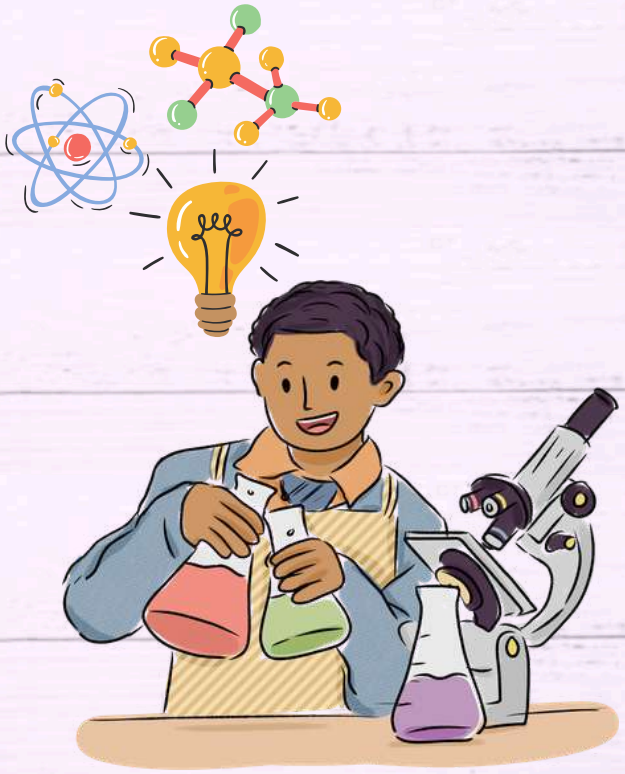
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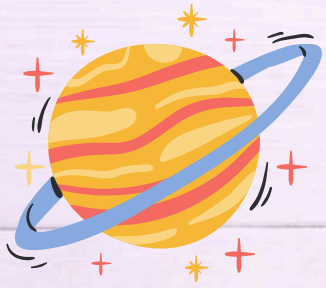
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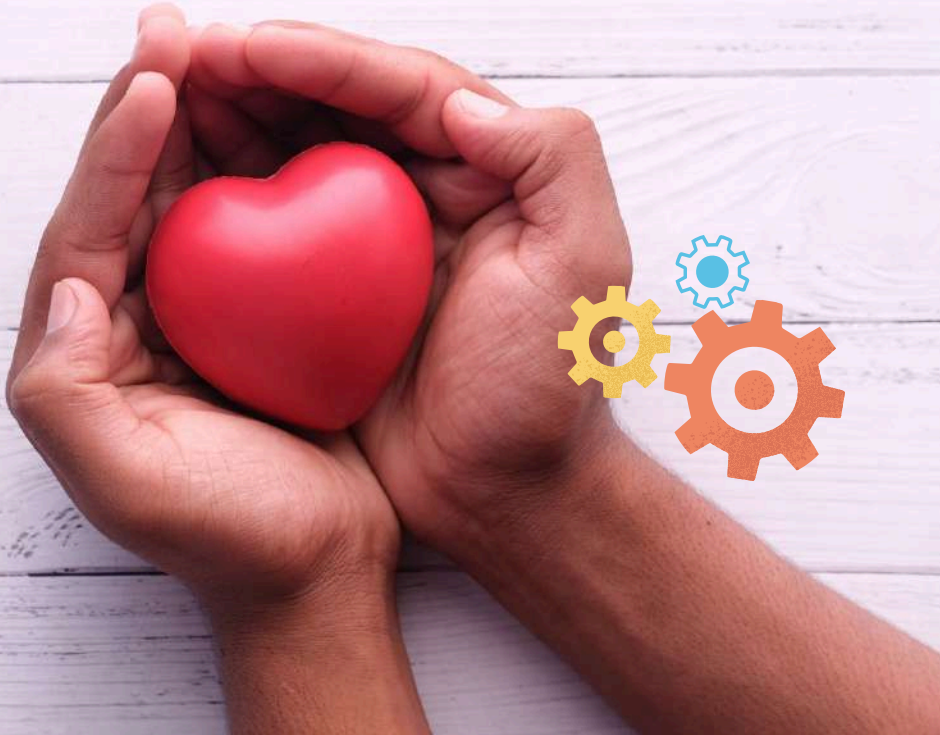
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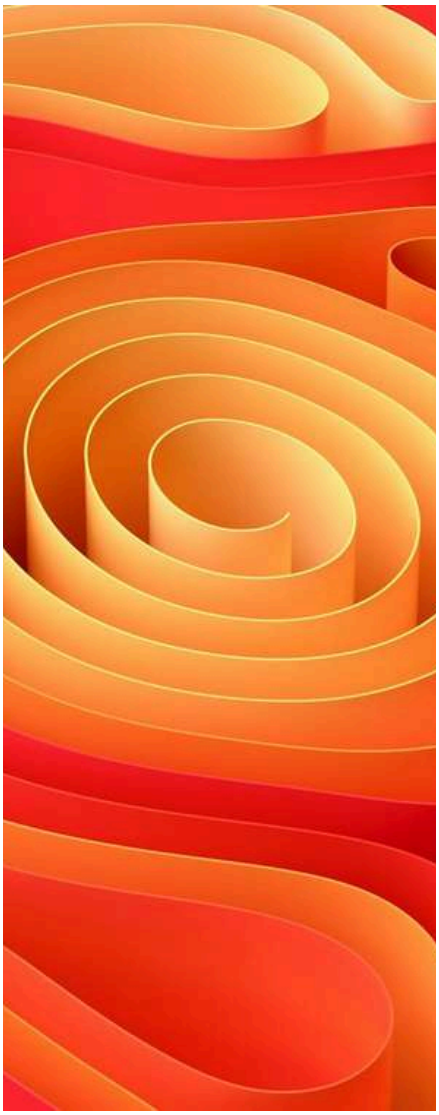














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