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INSIGHT, DISCOVERY, LEARNING, INNOVATION, AND IMPACT

By
Rosalind Franklin
Council of Scientific Research (RFCSR)
June 01, 2026

ANCIENT CHEMICAL CLUES !

MARS REVEALS NEW SECRETS.

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Scientific Research Empowers Social Progress !

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"In a world flooded with information, *Science Factors* stands out for its clarity, creativity, and commitment to truth. It brings the latest discoveries from top global journals into classrooms, cafés, and conversations—without losing the wonder that makes science so human. I believe this magazine will inspire not just students, but scientists too, to see their work through fresh, curious eyes."

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LETTER *from the* EDITOR

Dr. Animesha Rath
The Editor-in-Chief

Dear Readers,

Science is all around us. It shapes our health, our environment, our technology, and even our understanding of the universe. In this issue of Science Factors, we bring together stories that show how discoveries both big and small are helping us better understand the world we live in.

This month, we explore fascinating questions from many areas of science. Could ancient Mars have preserved the ingredients needed for life? Can a tiny icy world far beyond Pluto hold an atmosphere? These discoveries remind us that the universe still holds many mysteries waiting to be uncovered.

We also look at how science is changing healthcare. New advances in artificial intelligence are helping doctors detect diseases earlier and more accurately. A simple eye scan, for example, may one day help identify several health conditions before symptoms even appear. Such innovations show how technology can improve lives and make healthcare more accessible.

Our expert contributors discuss exciting developments in medicine and materials science. From next-generation antibody therapies to new ways of designing advanced materials, these stories highlight how research is creating solutions for real-world challenges.

At the same time, science helps us understand important issues facing society today. In this issue, we explore topics such as environmental change, sustainable technologies, public policy, and the hidden connections between human activities and the natural world. These stories remind us that science is not only about discovery, it is also about making informed decisions for a better future.

For students, young readers, and lifelong learners, we continue our mission of making science easy to understand, engaging, and enjoyable. Through science news, discovery highlights, opportunities, and fun learning sections, we hope to inspire curiosity and encourage more people to explore the wonders of science.

As you read this issue, we invite you to think about the many ways science touches our daily lives. Every breakthrough begins with a question, and every question brings us one step closer to understanding our world.

At Science Factors, we remain committed to our vision of *Science for Society*, connecting scientific knowledge with people, communities, and the future.

Happy Reading.

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SCIENTIFIC RESEARCH EMPOWERS SOCIAL PROGRESS !

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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. Avijit Das

MARS KEPT THIS SECRET FOR BILLIONS OF YEARS

FEATURED

On a cold Martian morning, as the Sun cast a faint glow across the red landscape of Gale Crater, a small rover named Curiosity stood quietly beside an ancient rock. To most eyes, the rock looked ordinary, dusty, cracked, and unchanged for billions of years. But Curiosity had traveled millions of kilometers from Earth to study stones just like this one, because hidden inside them might be the answer to one of humanity's oldest questions: Was there ever life on Mars?

Far away on Earth, Dr. Elena Carter and her team of planetary scientists were waiting eagerly for Curiosity's next discovery. For years, they had studied images and chemical data from Mars, searching for places where traces of ancient chemistry might still be preserved. Their attention was drawn to a region called Glen Torridon, a landscape rich in clay minerals. On Earth, clay acts like a natural safe, protecting delicate organic molecules from destruction. If Mars had preserved any chemical record from its wetter past, Glen Torridon was one of the best places to search.

The team selected a rock and gave it the name Mary Anning 3, in honor of the famous fossil hunter. This rock was no ordinary stone. It had formed around 3.5 billion years ago, when Mars was a much warmer world with flowing rivers and long-lasting lakes. At that time, water covered parts of the planet, and the conditions may have been suitable for life.

Curiosity drilled into the rock and collected a spoonful of fine powder. It transferred the powder into its onboard laboratory, known as SAM, Sample Analysis at Mars. SAM is a miniature chemistry lab that can heat rocks and identify the gases released from them.

This time, the scientists decided to use a special chemical called TMAH. Dr. Carter liked to describe it as a master key. Many organic molecules are trapped inside larger, m-

| By Dr. Avijit Das

ore complex materials and remain hidden during normal analyses. TMAH breaks apart those large structures and releases the smaller molecules locked inside.

As Curiosity heated the sample, data began streaming back to Earth. Lines and peaks appeared on computer screens in the laboratory. To most people, they looked like meaningless patterns. But to Dr. Carter and her colleagues, they were a message from ancient Mars.

One signal revealed naphthalene, a molecule made of two connected carbon rings. Another showed methyl benzoate, a compound containing oxygen. Then came benzothiophene, a sulfur-containing molecule never before clearly confirmed on Mars. As the analysis continued, more and more compounds appeared.

When the experiment was complete, the team had identified more than twenty organic molecules.

The room fell silent for a moment as the scientists absorbed the significance of the discovery. Organic molecules are the building blocks of life. They are found in all living organisms on Earth, but they can also form naturally through chemistry or arrive inside meteorites. Their presence does not prove that life once existed on Mars, but it does show that the ingredients needed for life were present.

Even more remarkable was the age of these molecules. For more than 3.5 billion years, they had survived inside the rock despite exposure to cosmic radiation, harsh oxidizing chemicals, and dramatic temperature swings. The clay minerals had protected them like a time capsule preserving a chapter of Martian history.

The scientists then asked the most important question: Where did these molecules come from?

Some may have been delivered by meteorites that bombarded the young planet. Others may have formed when water reacted with rocks deep underground. And some might have been produced by biological processes if life ever arose on Mars.

The study could not determine which explanation was correct. But it revealed that Mars still holds a rich chemical archive from a time when the planet had lakes, flowing water, and environments that may have supported life.

One molecule in particular, benzothiophene, drew special attention. On Earth and in meteorites, it is associated with complex carbon-rich material. Its discovery suggested that large and durable organic structures were preserved within the Martian rock.

The team also detected hints of nitrogen-containing compounds. Nitrogen is a critical component of DNA, RNA, and proteins. While these findings require further confirmation, they make the chemistry of Mars even more intriguing.

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Williams, A.J., Eigenbrode, J.L., Millan, M. et al. Diverse organic molecules on Mars revealed by the first SAM TMAH experiment. *Nat Commun* 17, 2748 (2026). https://doi.org/10.1038/s41467-026-70656-0

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| By Dr. Priyanka

THE HIDDEN ATMOSPHERE AT THE EDGE OF THE SOLAR SYSTEM

FEATURED

On a cold winter night in Japan, a curious schoolgirl named Yuki stood beside Dr. Aiko Tanaka at the Kiso Observatory. Yuki loved space and had come to spend the night with astronomers who were trying to study a tiny world far beyond Pluto. Dr. Tanaka pointed to a dot on her computer screen and said, “Tonight we are watching a small icy object called 2002 XV93. It lives in the Kuiper Belt, a region of the Solar System filled with frozen worlds.”

Yuki had heard of Pluto, but not of 2002 XV93. “Why is this little object important?” she asked. Dr. Tanaka smiled and explained, “Pluto has a thin atmosphere made of gas. But scientists believed that objects much smaller than Pluto are too tiny to hold an atmosphere. Their gravity is weak, so any gas should quickly escape into space.” Yuki thought for a moment and said, “So tonight we are checking whether that idea is correct?” “Exactly,” said Dr. Tanaka.

The astronomers were waiting for a special event called a stellar occultation. This happens when a distant object passes in front of a star and blocks its light. Dr. Tanaka explained it using a simple example. “Imagine you hold a coin in front of a flashlight. If the coin has no surrounding gas, the light disappears suddenly. But if the coin is surrounded by fog, the light fades slowly because the fog bends the light.” Yuki nodded. “So if the star fades slowly, that means 2002 XV93 has an atmosphere.”

At the same time, teams in Kyoto and Fukushima were also watching the event. In Fukushima, an amateur astronomer named Mr. Hosoi was observing from his own telescope. Yuki was amazed. “So even someone with a backyard telescope can help make discoveries?” Dr. Tanaka nodded. “Yes. Science works best when professionals and passiona-

| By Dr. Priyanka

te amateurs work together."
The predicted moment arrived. Everyone watched the star on their screens. Suddenly, the star began to dim. But instead of vanishing instantly, its light faded gradually over about one and a half seconds. When the star emerged from behind the object, it brightened slowly in the same way. A message came from Mr. Hosoi in Fukushima: he had observed a similar pattern. Dr. Tanaka turned to Yuki with excitement. "This is exactly what we would expect if 2002 XV93 has an atmosphere." Yuki's eyes widened. "A tiny world beyond Pluto has a real atmosphere?" "Yes," Dr. Tanaka said. "That is what the data are telling us."

Back in the laboratory, the team used computer models to understand what kind of gas could explain the observations. They tested methane, nitrogen, and carbon monoxide. All three gases matched the data well. The pressure at the surface was estimated to be between 100 and 200 nanobars.

Yuki asked, "Is that a lot?" Dr. Tanaka laughed gently. "Not at all. Earth's atmospheric pressure is about one billion nanobars. So the atmosphere around 2002 XV93 is about ten million times thinner than the air we breathe." Yuki imagined a few invisible molecules drifting above a frozen surface. "So it is more like a whisper of gas than a real sky."

But this created a bigger mystery. "If the object is so small," Yuki asked, "how can it keep any atmosphere at all?" Dr. Tanaka explained that 2002 XV93 is only about 250 kilometers in radius. Its gravity is weak, so gas molecules can easily escape into space. If no new gas is added, the atmosphere may survive for only 100 to 1,000 years.

Yuki was surprised. "That is nothing compared with the 4.5-billion-year age of the Solar System." "Exactly," said Dr. Tanaka. "This means the atmosphere is probably temporary, and we are lucky to observe it now."

"Where does the gas come from?" Yuki asked. Dr. Tanaka described two possible explanations. The first is cryovolcanism. Unlike volcanoes on Earth that erupt molten rock, cryovolcanoes release cold gases and icy materials from beneath the surface. The second possibility is a recent impact. A small comet or icy object may have crashed into 2002 XV93 and released trapped gases into space.
"So either the object is leaking gas from inside," Yuki said, "or something hit it and knocked gas loose." Dr. Tanaka smiled. "That is exactly right."

A few weeks later, Yuki presented the discovery at her school science fair. She told her classmates, "Scientists believed that only large worlds like Pluto could have atmospheres. But a tiny object called 2002 XV93 proved them wrong. Even small icy worlds far beyond Neptune can temporarily wear a thin veil of gas."

She ended her presentation by saying, "This discovery teaches us that the universe is full of surprises. Sometimes the smallest and quietest worlds can reveal the biggest secrets."

Far beyond Pluto, 2002 XV93 continued its silent journey through the darkness. It was a tiny frozen world with a delicate atmosphere, reminding astronomers that there is still much to learn about the distant edges of our Solar System.

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Arimatsu, K., Yoshida, F., Hayamizu, T. et al. Detection of an atmosphere on a trans-Neptunian object beyond Pluto. *Nat Astron* (2026). https://doi.org/10.1038/s41550-026-02846-1

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By Dr. Preeti Sharma

THE EYE THAT SAW MORE THAN VISION

FEATURED

Dr. Mei Lin had worked for nearly twenty years as a physician in a busy community clinic in Guangzhou, China. Every morning, her waiting room filled with patients concerned about diabetes, high blood pressure, high cholesterol, and other chronic illnesses that often develop silently over many years. One of her regular patients, Mrs. Chen, was a 52-year-old schoolteacher who appeared healthy and energetic. During her annual checkup, Mrs. Chen told Dr. Lin that both her father and older sister had developed diabetes. “I feel perfectly fine,” she said, “but I worry that something may be happening inside my body without me knowing.” In the past, Dr. Lin would have ordered blood tests and asked her to return the next day. But this time, Dr. Lin was testing a new artificial intelligence system called Reti-Pioneer. Instead of drawing blood, she asked a nurse to take photographs of Mrs. Chen’s retinas. Mrs. Chen was surprised. “Can my eyes really tell you whether I have diabetes?” she asked. Dr. Lin smiled. “The retina is the only place in the body where we can directly see tiny blood vessels and nerves. Diseases affecting the whole body often leave their fingerprints there long before symptoms begin.”

The idea behind Reti-Pioneer was both simple and revolutionary. Scientists had trained the system using more than 107,000 retinal photographs from over 53,000 people in China, the United Kingdom, and Singapore. Each image was linked to medical records showing whether the individual had type 2 diabetes, hypertension, high cholesterol, gout, osteoporosis, or thyroid disease. By comparing thousands of examples, the AI learned to recognize patterns too subtle for the human eye to detect. It also included a quality-aware module that first assessed whether an image was sharp or blurry and adjusted its predictions accordingly. This was important because real-world clinics do not always capture perfect images. In the internal validation studies, Reti-Pioneer showed impressive accuracy, especially for diabetes and gout, and performed well for osteoporosis, hypertension, and other

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diseases. The remarkable part was that a single eye image could provide clues about six different health conditions at the same time.

After the nurse captured Mrs. Chen's retinal images, the photographs were uploaded to the Reti-Pioneer platform. Dr. Lin and Mrs. Chen watched the screen as the AI analyzed the images. In just 30 seconds, a report appeared. It showed an elevated risk for type 2 diabetes and osteoporosis, while the other conditions appeared normal. Mrs. Chen looked astonished. "All of that from my eyes?" she asked. Dr. Lin ordered standard blood tests and a bone density scan to confirm the findings. When the results came back the next day, they matched the AI's predictions almost exactly. Mrs. Chen had early diabetes and low bone density, but because these conditions were detected before symptoms appeared, she could begin treatment immediately. "If we had waited until you felt unwell," Dr. Lin explained, "the disease might already have caused damage." Mrs. Chen was grateful that a simple eye scan had revealed what years of silent changes had been building inside her body.

Dr. Lin was impressed, but she wanted to know whether the technology worked only in one hospital or across many populations. The researchers had tested Reti-Pioneer in people from Tibet, Xinjiang, Guangxi, and Singapore, representing different ethnicities, healthcare systems, and image qualities. The system performed consistently well across these diverse settings, showing that it could be used globally. It even predicted which individuals might develop diabetes, hypertension, or high cholesterol years into the future using retinal images from the UK Biobank. To help doctors trust the AI, the researchers generated heatmaps showing which parts of the retina influenced each prediction. They also linked these retinal features to disease-related proteins in blood samples, demonstrating that the AI was detecting real biological signals rather than random patterns. In studies where ophthalmologists interpreted images with and without AI assistance, their accuracy improved significantly when supported by Reti-Pioneer. This confirmed that the system was not designed to replace doctors, but to act as a highly skilled assistant.

As Dr. Lin reviewed Mrs. Chen's retinal image later that evening, she felt she was looking into the future of medicine. The eye was no longer just an organ for sight; it had become a window into the health of the entire body. In large clinical trials involving more than 1,000 participants, Reti-Pioneer generated reports in about 30 seconds, compared with nearly eight hours for standard laboratory workflows. Patients and clinicians reported high satisfaction, and the system proved particularly useful in identifying people unlikely to have diabetes, allowing doctors to focus laboratory testing on those most in need. Dr. Lin knew that blood tests would still be necessary to confirm diagnoses, and that larger studies and regulatory approval were needed before widespread adoption. But she imagined a day when portable retinal cameras in rural clinics around the world would allow millions of people to receive fast, painless screening for chronic diseases. As she turned off the lights in her office, she thought of an old saying: the eyes are the window to the soul. Thanks to artificial intelligence, they were also becoming one of the most powerful windows into human health.

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Zhang, X., Li, Q., Liang, Y. et al. AI framework for multidisease detection via retinal imaging. *Nat Med* (2026). https://doi.org/10.1038/s41591-026-04359-w

Joint Shantou International Eye Center of Shantou University and The Chinese University of Hong Kong.

| EXPERT OPINION |

Can Engineered Antibodies Replace IVIG in Autoimmune Therapy?

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

Areas of expertise: Immunology | Immunotherapy | Autoimmune diseases | inflammation Host-Pathogen interaction | Vaccine

Intravenous immunoglobulin (IVIG) has been a cornerstone in the management of autoimmune and inflammatory diseases for over five decades.

Originally developed as a replacement therapy for primary immunodeficiencies, IVIG is now widely used in the therapy of diverse autoimmune conditions, including immune thrombocytopenia, Kawasaki disease, Guillain–Barré syndrome, chronic inflammatory demyelinating polyneuropathy, and other systemic autoimmune disorders. Despite its long-standing clinical usage, IVIG remains a complex and incompletely understood immunotherapeutic, exerting pleiotropic effects through diverse cellular and molecular mechanisms. With the rapid evolution of antibody engineering, an important question arises: can engineered antibodies can replace or restrict clinical usage IVIG?

Diverse Cellular and Molecular Mechanisms of IVIG: The therapeutic efficacy of IVIG is rooted in its polyclonal nature, derived from pooled immunoglobulin G (IgG) from thousands of healthy donors. This diversity allows IVIG to target multiple immune pathways, both cellular and molecular, simultaneously, which is particularly advantageous in multifactorial autoimmune diseases (Figure 1).

> *IVIG is not a single drug with a single target, it is a complex orchestra of antibodies that restores immune balance through many pathways at once.*

At the cellular level, IVIG modulates both innate and adaptive immune responses. One of the best-characterized mechanisms involves Fc gamma receptors (FcγRs). IVIG can saturate activating FcγRs on macrophages, thereby inhibiting phagocytosis of opsonized cells, as seen in immune thrombocytopenia. Concurrently, IVIG upregulates the inhibitory receptor FcγRIIB, contributing to a shift toward an anti-inflammatory phenotype. However, Fc-mediated functions do not explain entirely the therapeutic benefits of IVIG and various F(ab')2-dependent mechanisms have been reported.

IVIG also profoundly affects dendritic cells (DCs), promoting a tolerogenic phenotype characterized by reduced expression of co-stimulatory molecules and increased secretion of anti-inflammatory cytokines such as IL-10. These tolerogenic DCs, in turn, facilitate the expansion of regulatory T cells (Tregs), which are central to maintaining immune tolerance.

At the molecular level, several mechanisms have been proposed. Anti-idiotypic antibodies within IVIG can neutralize pathogenic autoantibodies. IVIG can satura-

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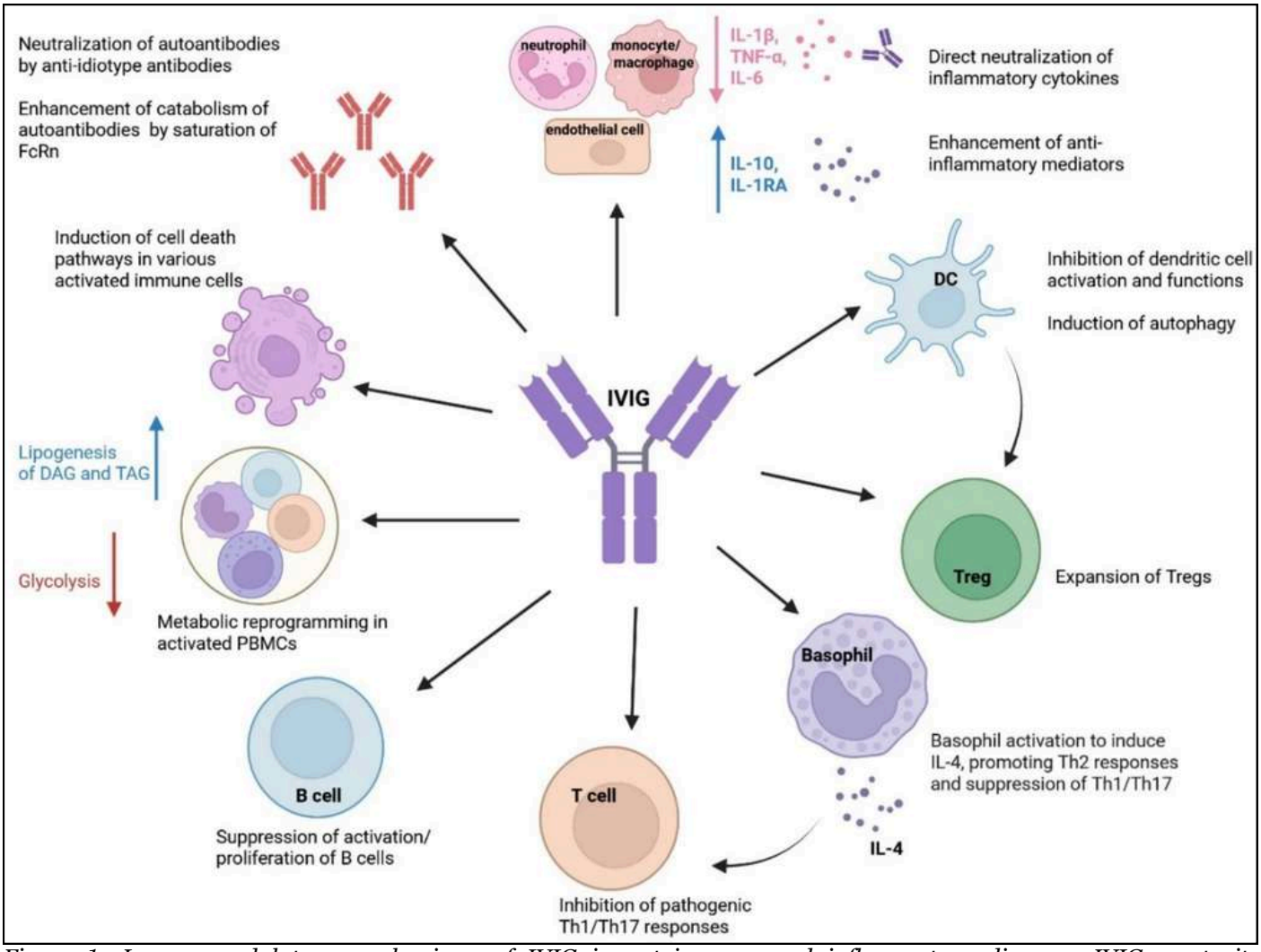

Figure 1: Immunomodulatory mechanisms of IVIG in autoimmune and inflammatory diseases. IVIG exerts its immunoregulatory effects on both innate and adaptive immune compartments. Reproduced with permission from Nature-Springer. https://link.springer.com/article/10.1007/s12016-025-09110-w

te neonatal Fc receptors and hence promote the degradation of pathogenic autoantibodies. IVIG also interferes with complement activation by binding to C3b and C4b, thereby preventing the formation of membrane attack complexes. Additionally, sialylated Fc fragments of IgG have been implicated in anti-inflammatory effects via interactions with lectin receptors such as DC-SIGN.

Emerging evidence highlights the role of IVIG in modulating cytokine networks and intracellular signaling pathways. For instance, IVIG can inhibit pro-inflammatory cytokines such as IL-17 and IFN-γ while enhancing IL-10 production. By signaling through basophil bound IgE and Syk-pathway, IVIG promotes type 2 cytokines in IL-3-primed basophils. It also influences signaling pathways like NF-κB and MAPK, thereby altering gene expression profiles in immune cells. Recent data demonstrates that IVIG triggers distinct autophagy pathways in innate immune cells and modulates metabolism of immune cells by promoting the synthesis of anti-inflammatory lipid synthesis.

Limitations of IVIG Therapy: While IVIG is highly effective, it has several limitations. The requirement for high doses (typically 1–2 g/kg) imposes significant costs and logistical challenges. Supply constraints, given its reliance on human plasma, further complicate accessibility. Adverse effects, although generally mild, can include infusion reactions, thromboembolic events, and renal dysfunction.

Moreover, the non-specific nature of IVIG, while advantag-

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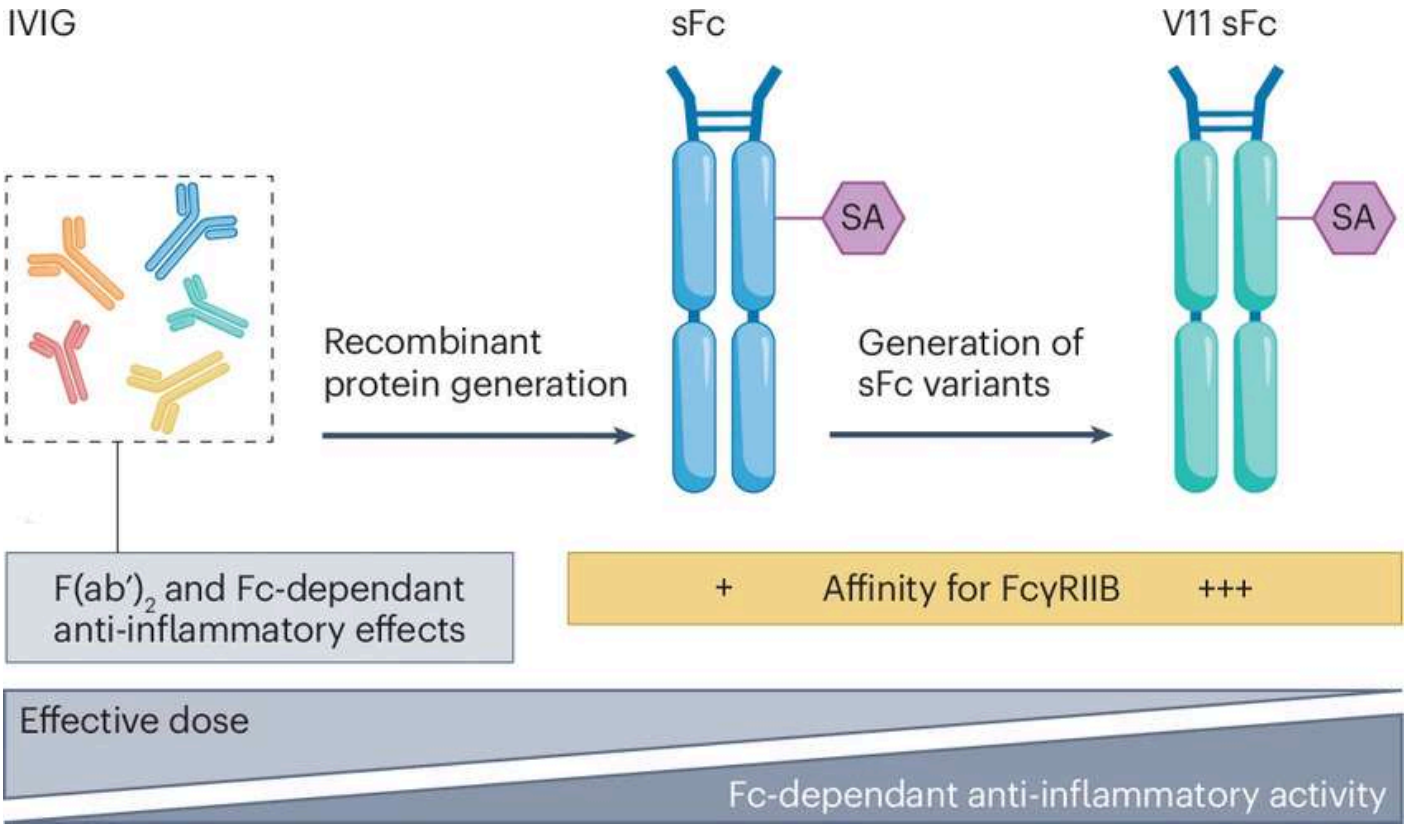

Figure 2: Engineered sialylated IgG1 Fc as a dose-sparing alternative to IVIG. Recombinant sialylated IgG1 Fc fragments (sFc), engineered by mutagenesis to have increased affinity for the inhibitory receptor FcγRIIB, reproduce the anti-inflammatory effects of intravenous immunoglobulin (IVIG) at substantially lower doses in FcγR-humanized mouse models of autoimmune diseases. SA, sialic acid. Reproduced with permission from Nature-Springer. https://www.nature.com/articles/s41584-025-01347-1

eous in some contexts, can also be a drawback. It may lead to variability in therapeutic outcomes and unintended modulation of immune responses.

Can Engineered Antibodies Replace IVIG? Advances in antibody engineering have opened new avenues for designing targeted therapies that could potentially replicate or even improve upon the effects of IVIG. These include monoclonal antibodies, Fc-engineered antibodies, bispecific antibodies, and antibody fragments.

Fc engineering, in particular, holds promise for mimicking key immunomodulatory functions of IVIG. By modifying Fc regions to enhance binding to inhibitory FcγRIIB or reduce affinity for activating FcγRs, engineered antibodies can achieve more precise immunomodulation. Similarly, glycoengineering approaches aim to increase Fc sialylation, thereby enhancing anti-inflammatory activity. In fact, recombinant sialylated IgG1 Fc fragments (sFc) were recently evaluated in FcγR-humanized mice to delineate the roles of Fc sialylation and type I FcγR engagement in mediating the anti-inflammatory effects of IVIG (Figure 2). Prophylactic administration of sFc conferred protection in a serum transfer–induced arthritis model at a 25-fold lower dose than IVIG, whereas non-sialylated Fc or an IgG1 Fc mutant incapable of engaging type I FcγRs failed to protect against arthritis. This work provides compelling preclinical evidence that increasing the affinity of sFc for the inhibitory receptor FcγRIIB markedly enhances its anti-inflammatory efficacy, highlighting its potential as a candidate for clinical development in autoimmune diseases.

Monoclonal antibodies targeting specific cytokines or immune checkpoints have already transformed the treatment landscape for several autoimmune diseases. For example, anti-TNF, anti-IL-6 receptor, and anti-CD20 therapies provide targeted suppression of pathogenic pathways. However, these therapies lack the broad-spectrum immunomodulatory capacity of IVIG.

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Another promising approach involves recombinant polyclonal or oligoclonal antibody preparations designed to mimic the diversity of IVIG. These engineered mixtures could theoretically retain the multifunctionality of IVIG while offering improved consistency and scalability.

Despite these advances, several challenges remain. Replicating the full spectrum of IVIG's mechanisms in a single engineered product is exceedingly complex. IVIG's efficacy arises from the synergistic action of numerous antibodies with diverse specificities and functions, a feature that is difficult to reproduce synthetically.

Furthermore, the safety and long-term effects of engineered antibodies require careful evaluation. While targeted therapies may reduce off-target effects, they may also lack the regulatory balance provided by IVIG's polyclonal nature.

Future Perspectives: Rather than a complete replacement, a more realistic scenario may involve complementarity between IVIG and engineered antibody therapies. Engineered antibodies could be used to target specific pathways in well-defined patient subsets, guided by biomarker-driven precision medicine. IVIG, with its broad immunomodulatory effects, may remain indispensable in complex or refractory cases.

Innovations such as recombinant Fc multimers and advanced glycoengineering could bridge the gap between IVIG and engineered antibodies. Additionally, improved understanding of IVIG's mechanisms will unravel the rational design of next-generation immunomodulators.

Conclusion: IVIG remains a unique and versatile therapeutic in autoimmune diseases, owing to its multifaceted mechanisms and broad immunomodulatory capacity. While engineered antibodies offer exciting opportunities for targeted and potentially more efficient therapies, they are unlikely to fully replace IVIG in the near future. Instead, the integration of IVIG with advanced antibody engineering, guided by robust biomarkers, represents the most promising path forward in the evolving landscape of autoimmune therapy.

> *Engineered antibodies may sharpen precision, but IVIG remains unmatched when broad, system-wide immune regulation is needed.*

Prof. Bayry's contributions to this field are reflected in his publication in Nature Reviews Rheumatology, "Engineered Sialylated IgG1 Fc as a Dose-Sparing Alternative to IVIG" (2026). This article describe how engineered antibody fragments may provide the benefits of IVIG while requiring much lower doses. https://doi.org/10.1038/s41584-025-01347-1

| EXPERT OPINION |

From Molecules to Materials: How Metal Complexes Are Shaping the Next Generation of Sulfide Nanostructures

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Areas of expertise: Metal Sulfides | Organometallic chemistry and catalysis | iClick Reactions

The synthesis of functional materials has traditionally relied on methods that are often energy-intensive and empirically driven. High temperatures, prolonged heating cycles, and repeated optimization steps are common in conventional solid-state routes. Although such approaches have produced technologically important materials for decades, they frequently offer limited control over composition and morphology, particularly in multicomponent systems.

Over the last several years, however, a different philosophy of materials synthesis has begun to attract increasing attention. Instead of assembling materials under harsh conditions from simple inorganic salts or oxides, researchers are now designing molecular precursors in which many of the essential structural and compositional features are already encoded at the molecular level. Among the various approaches explored in this direction, the use of metal complexes as precursors for metal sulfide materials (a class of compounds that underpin technologies ranging from energy conversion to electronics) has emerged as especially promising.

> *"In single-source precursors, the blueprint for the final material is built directly into the molecule, allowing chemists to design advanced sulfides with remarkable precision."*

This strategy is appealing not merely because it simplifies synthesis, but because it offers an unusual degree of chemical control. The precursor is no longer just a reagent; in many cases, it behaves like a molecular template that predetermines how the final material will evolve during decomposition.

Why Sulfides Matter: Metal sulfides occupy an important position in materials chemistry because of the diversity of their electronic and optical properties. Binary sulfides such as ZnS, CdS, CuS, and NiS have long been investigated for semiconducting, catalytic, and photochemical applications. More recently, ternary and quaternary sulfides have attracted considerable attention owing to their tunable band structures and improved functional performance in areas such as photovoltaics, photocatalysis, sensing, and electrochemical energy conversion.

At the same time, sulfide materials are not always easy to prepare reproducibly. Small variations in temperature, precursor ratio, sintering time, or reaction environment can produce substantial differences in phase purity and particle morphology. The problem becomes even more complicated in

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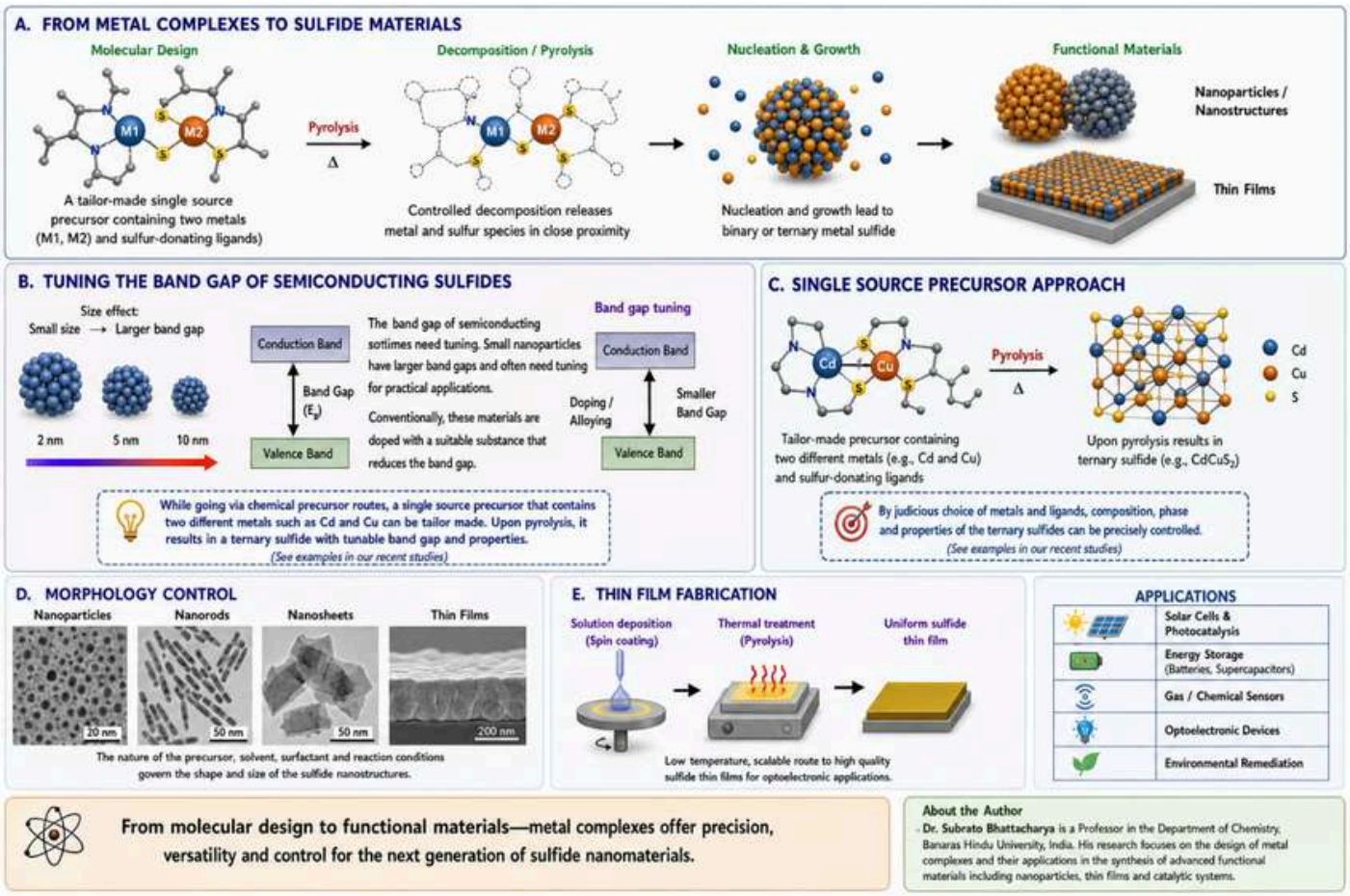

multimetallic systems where maintaining homogeneous elemental distribution is often difficult. Therefore, conventional synthetic approaches are considered somewhat unpredictable, particularly when targeting nanoscale materials. This is one reason why molecular precursor routes have become increasingly attractive.

Metal Complexes as Single-Source Precursors: The use of metal complexes introduces a fundamentally different way of thinking about materials synthesis. In coordination chemistry, ligands are selected to stabilize metals in well-defined chemical environments. When metal complexes having sulfur donor ligands are thermally decomposed, the metal and sulfur components are released in close proximity to one another, thus facilitating the direct formation of metal sulfide phases without requiring separate sulfidizing agents. Since all the components are being obtained from the same molecule, the word single-source precursor (SSP) is commonly usedy used for such molecules.

This idea of molecular-level mixing is one of the major strengths of the precursor approach. Since the constituent elements are already associated within a single molecular framework, diffusion-related problems that are common in conventional solid-state methods are significantly minimized when a single-source molecular precursor is used. Particularly important in this context are sulfur-containing ligands such as thiocarboxylates, dithiocarbamates, xanthates, and related donor systems. These ligands serve not only as stabilizing groups for the metal center but also as internal sulfur reservoirs during decomposition. As a result, the synthesis can often proceed under comparatively milder conditions while still yielding crystalline sulfide materials.

In many cases, the decomposition behavior of the precursor itself strongly influences the morphology of the final nanostructure. Slight modifications in ligand architecture, coordination geometry, or metal-to-ligand ratio can alter nucleation and growth pathways quite dramatically. This sensitivity, although challenging at times, also provides opportunities for rational materials design.

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Toward Multicomponent Sulfide Systems: The advantages of molecular precursor methods become even more evident in ternary compounds and related multicomponent systems. Achieving precise stoichiometric control using conventional approaches is frequently difficult because different metal ions may react or diffuse at different rates. Molecular precursors partly overcome this issue by incorporating multiple metal centers within the same molecule. This aspect is especially relevant for tuning the electronic properties of semiconducting sulfides. At the nanoscale, quantum confinement effects often lead to widening of the band gap as particle dimensions decrease. While this phenomenon can be scientifically interesting, it is not always desirable for practical device applications. Traditionally, band-gap tuning has relied heavily on post-synthetic doping strategies. However, molecularly designed precursors provide a more integrated alternative. By incorporating two or more metals directly into a single-source precursor, it becomes possible to generate ternary sulfides with modified electronic structures in a more controlled manner. Systems containing combinations such as Cu–Cd, Cu–Zn, Ag-Zn, or Ag-Cd have shown how precursor design can influence morphology and property simultaneously. An important consequence of this approach is that compositional tuning occurs during material formation itself rather than through a secondary modification step. This often improves reproducibility and reduces synthetic complexity.

From Nanoparticles to Thin Films: One of the most exciting aspects of the molecular precursor approach is its versatility in shaping materials at different scales. By varying reaction conditions such as temperature, solvent, and deposition method, chemists can direct the formation of nanoparticles, nanostructures, or thin films.

> *By using metal complexes as molecular templates, scientists can create high-performance nanomaterials and thin films under milder, more efficient, and more controllable conditions.*

Nanoparticles derived from metal complexes often exhibit narrow size distributions and well-defined shapes. Their high surface area and unique electronic properties make them ideal for catalysis and sensing applications. Moreover, because their formation is guided by molecular precursors, it is possible to achieve a level of reproducibility that is difficult with conventional methods.

On the other hand, thin films are central to many technologies, including photovoltaics and microelectronics. Using techniques such as solution deposition or spray coating, metal complexes can be transformed into uniform sulfide films on various substrates. In addition, volatile metal complexes have also been extensively explored as precursors in metal–organic chemical vapor deposition (MOCVD), where controlled decomposition in the vapor phase enables the growth of high-quality sulfide thin films with excellent compositional uniformity. These films can be engineered to have specific thicknesses, crystallinity, and surface characteristics, enabling their integration into functional devices.

Advantages Beyond Control : While reproducibility is a major advantage, the benefits of using metal complexes extend further. Thermal decomposition of single-source precursors operates under relatively mild conditions compared to traditional high-temperature sintering routes. Additionally, the ability to design complexes at the molecular level allows for greater flexibility and creativity. Chemists can introduce functional groups, tailor decomposition pathways, and even incorporate additional elements to create hybrid or doped materials, thus providing solutions to the demands of modern technology.

The Road Ahead :Despite the considerable promise of molecular precursor routes, several challenges remain. The design of sui-

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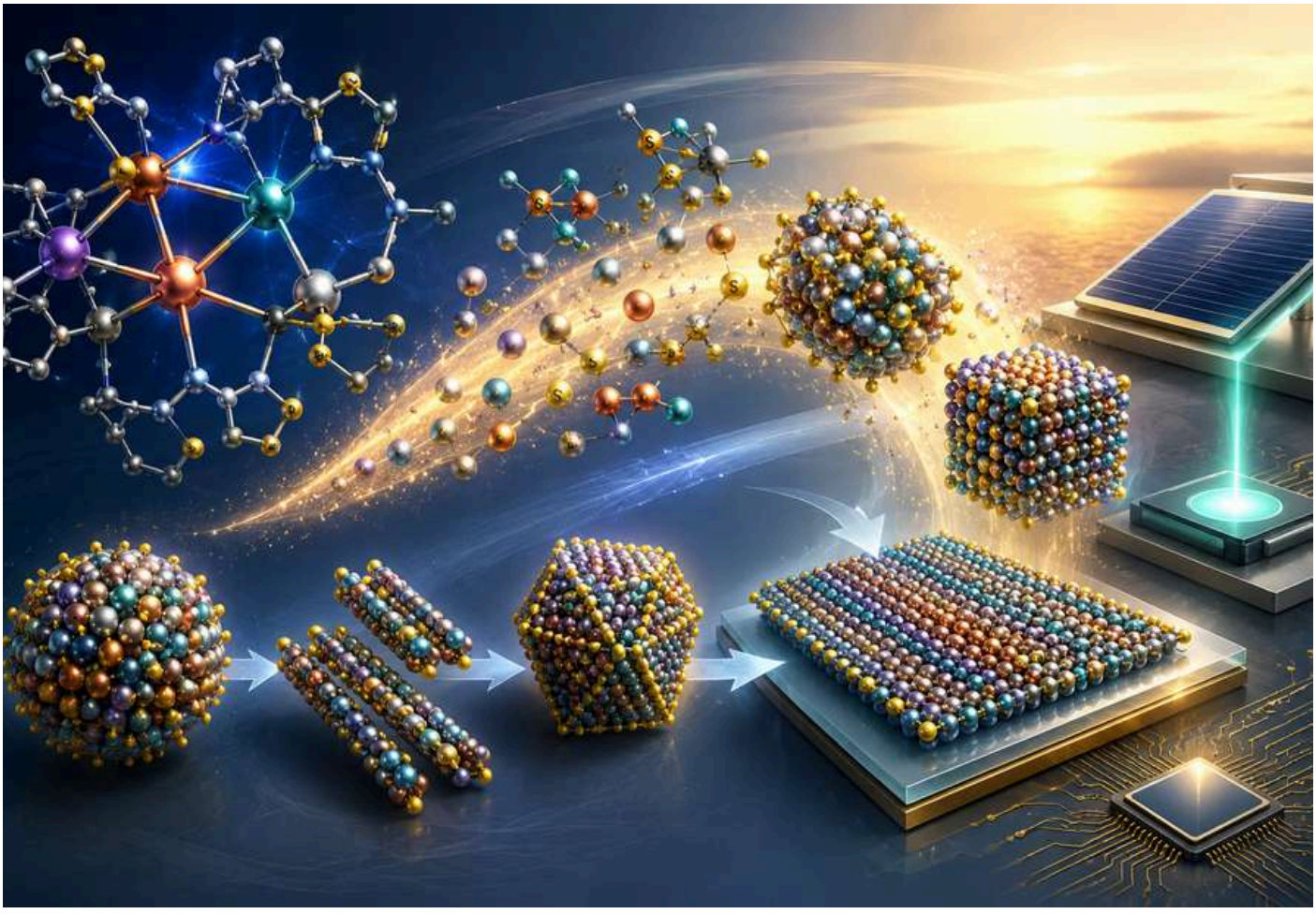
table metal complexes requires careful control over the coordination environment and decomposition pathways. However, advances in spectral and imaging characterization and computational modeling are steadily improving our understanding of these transformations and enabling more rational precursor design.

Nevertheless, the single-source precursor approach has already emerged as a versatile strategy for the synthesis of compositionally controlled sulfide nanomaterials under comparatively mild conditions. As interest in sustainable and tunable functional materials continues to grow, further developments in coordination chemistry and precursor engineering are likely to expand the role of this methodology in areas ranging from catalysis and energy conversion to electronic and optoelectronic applications.

> *In single-source precursors, the blueprint for the final material is built directly into the molecule, allowing chemists to design advanced sulfides with remarkable precision.*

Prof. Chaturvedi's contributions to this field are reflected in his publications in Inorganic Chemistry (https://pubs.acs.org/doi/10.1021/ic200927w), RSC Advances (https://doi.org/10.1039/C3RA48025A) and the European Journal of Inorganic Chemistry(https://doi.org/10.1002/ejic.202400297). His research focuses on the design of single-source molecular precursors for the synthesis of ternary metal sulfides and semiconductor thin films with applications in advanced materials and energy technologies.



| EXPERT OPINION |

How Tiny Materials Can Control Light

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

Areas of Expertise: Colloidal synthesis | quantum dots | 2D nanoplatelets | optoelectronic devices

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Areas of Expertise: Colloidal synthesis | quantum dots | 2D nanoplatelets | optoelectronic devices

Over the past few decades, scientists have extensively explored ways to manipulate the optical properties of semiconductor nanocrystals, which are tiny crystalline materials whose behaviour is governed by quantum mechanics because of their nanoscale dimensions. Doping in nanocrystals is an intriguing and powerful strategy to further tailor their light absorption and emission behaviour. In this process, impurity atoms are intentionally introduced into the nanocrystal lattice in a controlled manner to modify its electronic structure. Through this approach, both homovalent and heterovalent p-type dopants have demonstrated a wide range of useful functionalities and promising applications in tunable solid-state lighting, fluorescence upconversion, biomedical imaging, photoinduced magnetism, luminescent solar concentrators, and many other optoelectronic technologies.

> *For many years, scientists believed that certain impurity atoms could not emit light. In our study, we show that these 'silent' atoms can, in fact, produce a distinct and stable glow.*

Despite these advances, one fundamental question remained unresolved: can n-type heterovalent dopants actively participate in light emission in semiconductor nanocrystals? For many years, the answer appeared to be no.

In semiconductor physics, doping is a powerful way to engineer new electronic states within the band gap. In II-VI semiconductors such as CdSe, p-type dopants like copper or silver are known to create localized acceptor states near the valence band. These states can trap photoexcited holes, leading to the formation of acceptor-bound excitons, quasiparticles that radiatively recombine to produce broad, tunable light emission. This phenomenon has been extensively studied and underpins many important optoelectronic applications. n-type dopants (e.g. indium), however, have traditionally behaved very differently. Indium, as a dopant, generally donates electrons directly to the conduction band, thereby enhancing electrical conductivity without substantially affecting radiative rec-

ombination processes. Thus, donor-bound excitons, the n-type analogue of acceptor-bound excitons, remained elusive in semiconductor nanocrystals for a long time.

This raised a deeper scientific curiosity: are donor states truly optically inactive, or have they simply remained hidden because of experimental limitations?

To address this question, we turned to a unique class of host nanostructures: two-dimensional CdSe nanoplatelets. Unlike conventional quantum dots, which often exhibit size and shape heterogeneity that lead to broad emission spectra, whereas nanoplatelets possess atomically precise thickness and exceptional structural uniformity. As a result, they exhibit extremely narrow emission linewidths, making them an ideal platform for resolving subtle spectral features that would otherwise remain obscured. Using a colloidal growth-doping strategy, indium atoms were introduced into the CdSe lattice during nanoplatelet formation. Precise control over precursor chemistry proved crucial, as only specific reaction conditions allowed indium ions to substitute cadmium sites without disrupting the crystal structure. Under these optimized conditions, the nanoplatelets retained their two-dimensional morphology while incorporating indium atoms in a controlled manner.

Following indium doping, the absorption spectra remained largely unchanged, and the characteristic band-edge emission of CdSe nanoplatelets was preserved. However, a new and well-separated emission peak emerged alongside the original band-edge signal. The photoluminescence excitation (PLE) spectrum of the new emission peak closely matches the absorption profile of CdSe nanoplatelets, with no evidence of thicker nanoplatelets or quantum dots subpopulations. This confirmed that the new feature originated from the indium-doped n-anoplatelets themselves rather than from secondary nanostructures. Detailed spectroscopic analysis confirmed that the new feature originated from a donor-bound exciton, formed when a localized electron associated with the indium donor state recombined with a photo-generated hole. Unlike acceptor-bound excitons, which typically exhibit broad and strongly Stokes-shifted emission, the donor-bound exciton displayed a remarkably narrow emission linewidth and only a small Stokes shift. Even more intriguingly, its emission energy remained nearly unchanged across different dopant concentrations. In p-type-doped systems, increasing the dopant concentration alters the emission energy because of valence band dispersion; here, however, the donor emission remained essentially fixed, indicating an intrinsically stable electronic state.

> *Our findings open a new way to design nanomaterials with precisely controlled optical properties for applications ranging from advanced displays to next-generation photonic devices.*

To understand this unusual stability, we corroborated experimental observations with density functional theory (DFT) calculations. The results revealed a three-level electronic structure in which indium doping creates donor states just below the conduction band edge. Importantly, these midgap states remain unaffected by increasing dopant concentration, as further doping brings higher sub-bands closer to the initial midgap state, demonstrating the robustness of the system. Upon photoexcitation, electrons and holes are generated in the conduction and valence bands, respectively, and radiative recombination can occur either directly via the band-edge state or via the donor state, giving rise to dual emission pathways. Time-resolved photoluminescence studies provided further insight into the recombination dynamics. The donor-bound exciton emission exhibited a lifetime comparable to the intrinsic band-edge emission and nearly two orders of magnitude shorter than typical acceptor-bound excitons. The emission was also signi-

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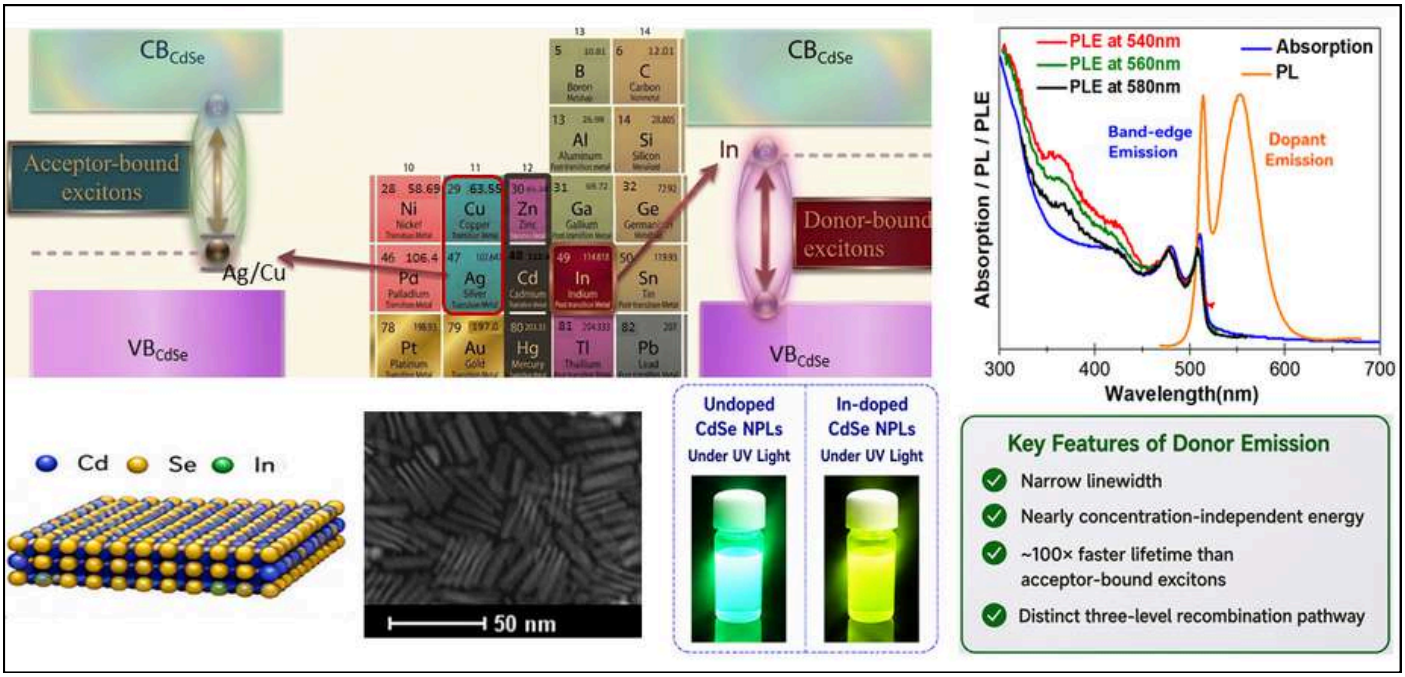

ficantly faster than defect-mediated recombination commonly observed in semiconductor nanocrystals. This rapid recombination likely originates from the lower effective mass and higher mobility of donor electrons, whereas the slower hole dynamics in acceptor-bound systems generally lead to much longer lifetimes. At the same time, the donor emission linewidth was nearly twice as narrow, reflecting a more ordered and well-defined electronic environment.

These findings point to a fundamentally different photophysical mechanism. While acceptor-bound excitons rely on hole localization and often involve complex interactions with the surrounding lattice, donor-bound excitons provide a cleaner and more direct recombination pathway. This results in faster emission dynamics and enhanced spectral stability, two properties highly desirable for optoelectronic applications. The significance of this discovery extends far beyond the specific In:CdSe system. By demonstrating that n-type dopants can g-

> *For many years, scientists believed that certain impurity atoms could not emit light. In our study, we show that these 'silent' atoms can, in fact, produce a distinct and stable glow.*

enerate stable and efficient light emission, this work challenges a long-standing assumption in nanoscience. It suggests that donor states are not inherently optically inactive, but instead require the right material platform and experimental conditions to become observable. In this case, the unique properties of CdSe nanoplatelets, particularly their strong quantum confinement and ultranarrow emission linewidths, played a crucial role in revealing the hidden optical activity of donor states.

The technological implications are substantial. Optoelectronic devices such as light-emitting diodes, lasers, and photodetectors rely heavily on precise control over absorption and emission properties. The ability to engineer donor-bound excitons introduces a new degree of freedom in device design. Fast recombination dynamics may enable high-speed optical communication, while narrow emission linewidths could improve colour purity in display technologies. Moreover, the inherent stability of the donor emission could lead

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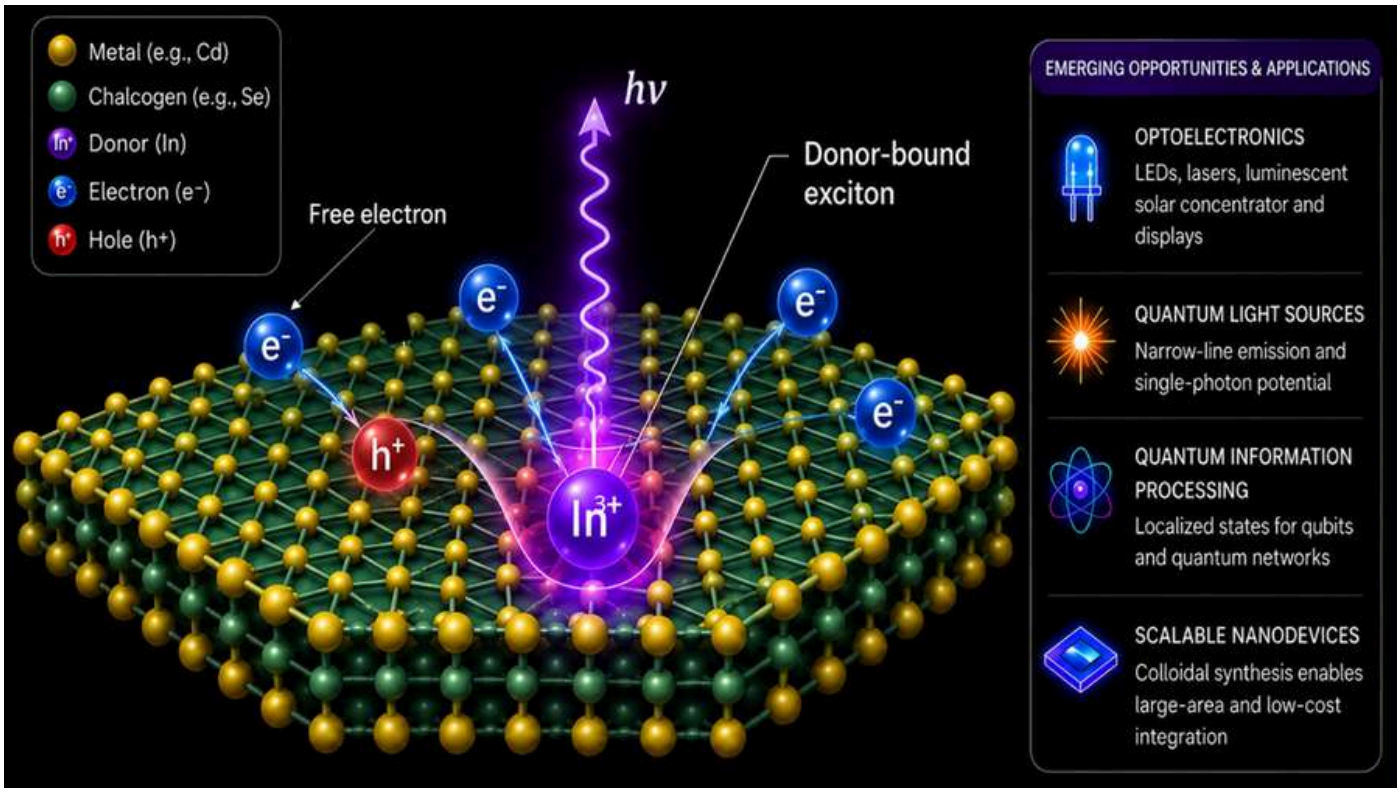

to more robust and reliable devices. They also have potential applications in emerging fields such as quantum photonics, where fast, spectrally stable, and well-defined emission is essential for quantum light sources and single-photon technologies. Ultimately, this work demonstrates that the nanoscale world is far more intricate than it appears. Hidden within these tiny structures are electronic states that quietly govern how materials interact with light. With the right materials, experimental tools, and scientific questions, these hidden states can finally be brought into view.

Dr. Khan and Mr. Dutta's contributions to this field are reflected in their publication in ACS Nano, "Observation of Donor-Bound Excitons in n-Type-Doped Two-Dimensional Semiconductor Nanocrystals" (2026) https://doi.org/10.1021/acsnano.6c01679. In this study, they demonstrate that impurity atoms previously thought to be optically inactive can generate a distinct and stable light signal in semiconductor nanocrystals.

Acknowledgment

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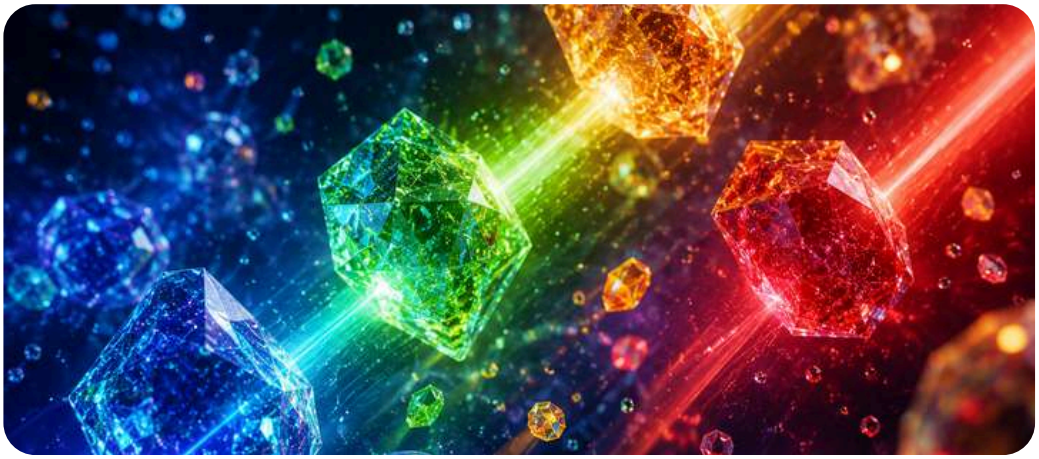

| EXPERT OPINION |

The Body's Billboard: When Skin Reveals Hidden Toxicity

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

Areas of expertise: Interstitial lung disease | Lung cancer | Chronic Lung disease | Intervention Pulmonology

Skin is the largest sense organ helping us interact with external world and maintain a constant internal milieu within the physiological boundaries. Science increasingly recognizes the intimate connection between gut health, hormones, immunity, emotions, and the skin's appearance. The complexion we wear is often an autobiography written by our habits, environment, and inner wellness. Care for the skin, therefore, is not merely to apply creams or conceal imperfections, but to listen deeply. For the skin does not betray us — it informs us. It is both shield and storyteller, manifesting the hidden toxicities of the body while inviting us toward healing, balance, and renewal from the inside out. We try to bring out one such uncommon skin manifestation of a chronic toxicity.

Mercury is a volatile metal with applications in industries and traditional medicinal systems around the globe. It is used for treating fever, convulsions, skin ailments and as an aphrodisiac and immunity booster. Since the recognition of toxic effects, the use of mercury has been banned in medical equipments. Use in industries has been strictly regulated. Acute or chronic exposure to mercury leads to multisystem manifestations and presents a diagnostic dilemma without a forthcoming history. Delay in management can lead to irreversible multi organ dysfunction and death due to central nervous system complications.

> *"The skin is often the body's first warning system, revealing hidden toxic exposures long before the underlying cause is recognized."*

A middle aged teacher came to us with, cough, breathlessness, loss of weight from past six months. She was developing multiple dark skin patches over the arm extending to abdomen, back and lately over the tongue. They are gradually increasing from past three years, these lesions over the arm form small nodules and rupture into surface discharging rounded metallic globules mixed with blood and pus. Lately had been experiencing inability to concentrate while teaching and frequent mood changes. She had been developing these lesions following multiple intravenous injections She had received these injections from a traditional medicine practitioner for an acute febrile illness three years back. After about seven days, she started developing these skin lesions over the arm near the injection site and later becoming widespread. She had consulted dermatologist for the same on multiple occasions, skin biopsy performed twice gave no definitive diagnosis. The common diseases that considered with this presentation are Pulmonary tuberculosis due to here chronic cough, Systemic parasit-

ic infections, chronic kidney disease and least likely chronic heavy metal poisoning including silver, arsenic, lead and lastly mercury.

Chest X ray done three years back shows multiple, nodular/spine shaped, radiopaque shadows in subcutaneous planes and lungs giving a starry sky like appearance over chest wall, which was dismissed as artifacts. X ray of upper limb also shows metallic deposits in the subcutaneous planes. CT of thorax shows metallic attenuation noted in bilateral axillary regions, pericardium, bilateral lung fields, liver, gall bladder, bilateral kidneys, pelvic region, uterus, right gluteal region. Urine routine microscopy showing 2+ proteinuria and nephrotic range protein urea in 24 hour urinary protein estimation. The serum mercury levels were normal but her 24 hour urinary mercury levels were high; she also had to undergo three sessions of dialysis due to renal dysfunction. Patient was started on D penicillamine 250mg 6th hourly for ten days with improvement in her mental and renal function over ten days duration, her repeat serum mercury level and now high with fall in urinary levels, and patient is still being treated with chelation.

Mercury or Hydragyrum, abbreviated "Hg" derived from Greek terms "Hydr" and "Argyros" meaning silver-water, due to dense silvery liquid globule appearance at room temperature and vaporizes at 356.7 0C to a colourless, odourless gas. Mercury is used in dental amalgams, vaccine preservative; thiomersal (ethylmercury), antiseptics and disinfectants (mercuric chloride), laxatives: mercurous chloride (calomel). Mercury oxide was used in skin ointments and skin lightening creams. Mercury is used in Ayurveda, Siddha and Unani as Bhasma (incinerating mercury along with herbs) and topical preparations.
Only 7-15% of ingested inorganic mercury is absorbed, mercuric salts due to greater solubility and corrosive effects are absorbed easily and reach highest levels in kidneys. Metallic mercury outgassed from amalgams is 80% inhaled and reaches brain, heart, liver, kidneys, thyroid, sweat glands. The excretory half-life of metallic mercury is several day to months, but persists in brain for years. Organic mercury is absorbed through lungs and accumulates in brain especially foetal brain, placenta, bone marrow. Overtime organic mercury gets demethylated to inorganic forms and leads to toxic effects5. Exposure by injection mercury can occur only by suicidal intent or in traditional systems of medicine or spiritual purpose.

> *In mercury poisoning, timely diagnosis is critical early treatment can reverse symptoms, while delays may lead to irreversible multi-organ damage.*

Acute manifestations following inhalation can mimic metal fume fever, later manifest as lung fibrosis, emphysema and air leak syndromes of lung. Large Volume exposure can lead to fatal acute respiratory distress syndrome. Chronic exposure presents with classical triad of gingivitis, tremors and erethism along with central nervous system symptoms and also lead to chronic immunosuppressive state. Small fraction of patients develop "Pink disease" characterized by redness of palms and soles, skin peeling, itching and loss of appetite with muscle flabbiness. Injections lead to local site accumulation and wide spread patchy skin lesion, embolization of vascular beds and vital organs. Blood levels of mercury are temporarily elevated and normalize soon, hence measurements are not recommended. Urinary levels remain elevated as it is the main route of excretion, twenty four hour urinary levels is a preferred test, as described in our patient. Mercury can get deposited in various soft tissues planes and visceral planes and on CXR PA view this can mimic artifacts to untrained eyes.

Treatment includes removal of source following ingestion or injection. Chelation with D penicillamine, meso 2,3-dimercapto-

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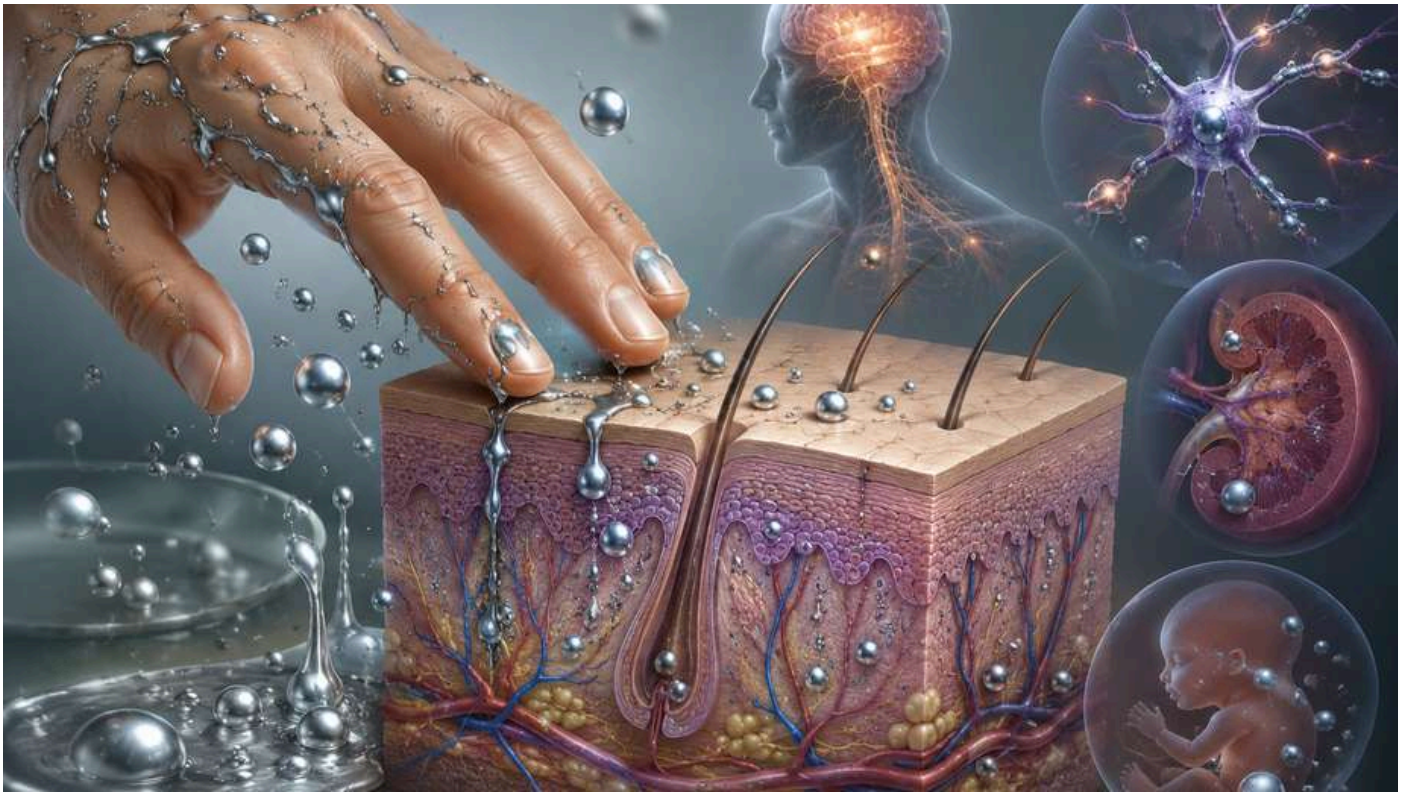
succinic acid (DMSA), sodium 2,3-dimercapto-1-propanesulfonate (DMPS), N-acetyl-d,l-penicillamine (NAP) and calcium disodium ethylenediaminetetraacetic acid (EDTA) increases urinary excretion and relieve symptom.

Conclusion: Mercury is still being in alternative systems of medicine but is toxic in all its forms, manifestations depend on volume, type and routes of exposure and biomagnification. Mercury toxicity can mimic multi system disorders including pulmonary tuberculosis and present a diagnostic dilemma, delay in diagnosis can leads to irreversible organ damage and poor outcome. Timely can result in rapid improvement of symptoms when implemented timely and always listen to your skin, as it's the mirror of your inner self.

Figure: A&B: Multiple dark patches seen in hands and over the abdomen (red circles). C&D: Mercury deposits in muscle, heart, inferior venacava and liver (red arrows).

Dr. Ganga's contributions to this field are reflected in his publication in The Journal of Dermatology, "Cutaneous and Chest X-Ray Manifestation in a Patient With Chronic Systemic Mercury Poisoning With Embolism" (2026). In this report, the authors describe the skin and chest imaging findings associated with chronic mercury poisoning. https://doi.org/10.1111/1346-8138.70271



| EXPERT OPINION |

How lifestyle choices influence male reproductive health

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Areas of expertise: Metabolic Diseases – Obesity | Insulin resistance & Type 2 diabetes | Male Reproduction, Reproductive Toxicology | Adipose Biology | Metainflammation

Reproductive wellness in humans is multifactorial. Apart from genetic and physiological factors, environmental factors, substance abuse etc., the modifiable lifestyle habits have profound influence upon male reproductive health. This has assumed greater importance as we progress through the 21st century with conscious modern lifestyle choices oblivious of the fact that some of these habits can be potential deterrents of fertility. The past few decades have witnessed an alarming rise in infertility worldwide leading to, in parallel, increased dependence on assisted reproductive technologies (ART). According to the latest estimates, approximately one in every six persons in the global adult reproductive population face fertility issues during their lifetime, and male factors contribute to almost 50% of the infertility cases.

Dietary patterns can have significant impact upon the male reproductive system. Traditional heathy dietary patterns e.g., Mediterranean diet and others that recommend balanced intake of carbohydrates, proteins, fats, vitamins and minerals, are associated with healthy male reproductive outcomes. Nevertheless, in the hectic fast-paced modern-day living, these traditional diets have fallen into oblivion. These are increasingly being replaced by more convenient, canned/tinned ultra-processed food laced with high content of saturated fat, refined carbohydrates, refined sugar, preservatives and other chemicals. Long-term intake of such energy-rich high-fat food leads to obesity which poses major risks for myriad health problems including diabetes, hypertension, cardiovascular diseases, metabolic dysfunction, and infertility. There seems a close connection between obesity and reproductive capacity. Our laboratory has been engaged in exploring the molecular mechanisms implicated in metabolic and testicular dysfunction in obese males. Using the laboratory mice model of diet-induced obesity, we have investigated in-depth how obese condition modulates reproductive hormonal titres in males, induces hypogonadism, alters testicular histoarchitecture, and compromises reproductive function.

> *Healthy lifestyle choices today can safeguard fertility and reproductive health for the future.*

In condition of obesity, the prime hormonal hypothalamic-pituitary-gonadal axis is disturbed leading to lower testosterone levels. This is accompanied by drastic changes in testicular tissue structure with marked disorganization of seminiferous tubules, inter-tubular vacuolization, loss of cellularity, and partial to complete tubular atrophy. This ultimately manifests in the fo-

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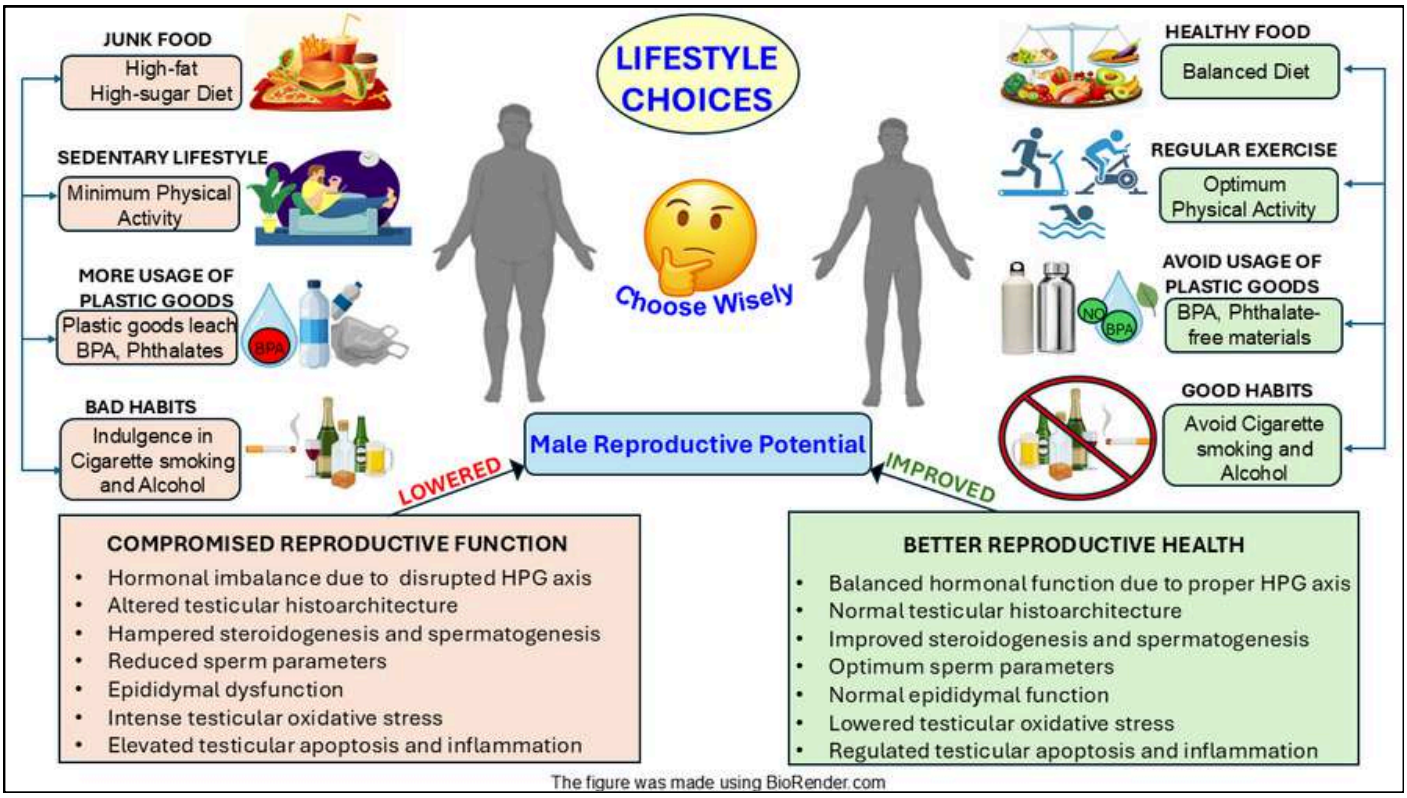

rms of oligospermia (lower sperm count), asthenospermia (low sperm motility due to which sperm fail to swim or show effective movements), teratospermia (sperm with morphological anomalies in head, mid-piece and/or tail), and in extreme cases, azoospermia (lack of sperm altogether). Such sperm pathologies in obesity-induced male infertility arise from hormone-mediated effects as well as non-hormonal mechanisms. These are mainly accounted by the prevalence of intense oxidative stress, inflammation, excessive testicular apoptosis and high rate of sperm DNA fragmentation. Testis being poor in antioxidant defences and rich in highly unsaturated fatty acids in germ cell membranes, is vulnerable to oxidative damage. With the alarming rise in obesity among adolescents and young adults, the deterioration in sperm quality could have significant consequences in the coming years. It becomes pertinent to generate public awareness, especially among the adolescents and young population, not only about healthy nutritional choices but also about the ill-effects of wrong dietary habits. Other than high fat diet, infertility can also be induced by several environmental chemicals. Prominent among these are bisphenol A, plasticizers such as phthalate esters, pesticides, heavy metals etc. These ubiquitous environmental chemicals can serve as potent endocrine disruptors playing havoc with the hormonal milieu. Modern-day lifestyle is excessively dependent on a host of manufacturing items, consumer products, personal day care items, pharmaceutical tubings and coatings, dental sealants, paints etc. with rampant usage of such endocrine disrupting chemicals. Our laboratory has particularly, studied the adverse fertility outcomes of long-term exposure to low levels of diethyl phthalate ester. There should be conscious effort to reduce usage of such compounds in our daily life. Moreover, excessive indulgence in alcohol and smoking can elicit serious fertility issues yet these remain as fully preventable factors.

Apart from diet and environmental chemicals, physical activity plays an important role in protecting male reproductive health. Sedentary men have greater chances of having defective sperm than men who remain physically active. While an active lifestyle would alleviate fat deposition and insulin resistance, the actual consequences of exercise upon testicular function have been inconsistent. Moreover, the effects have been two-sided. While moderate-intensity exercise had beneficial effects upon erectile dysfunction, intense exercise had negative outcomes. Exercise in excess, be it either vigorously intense or for prolonged durations, rather can cause poor fertility. This clearly implied that the intensity of exercise is a critical determinant. We envisaged a complex interplay be-

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tween diet and physical activity in the context of male reproduction. In order to address the existing knowledge gaps in this field, our laboratory established mice models of diet-induced obesity with/without moderate-intensity exercise intervention. The molecular mechanisms were examined using relevant markers in the testicular germ cells and spermatozoa. It was interesting to note that the recovery of reproductive function in exercise-trained obese mice was remarkable when compared to their sedentary obese male counterparts. Taken together, the data revealed significant ameliorative effect of moderate-intensity exercise in obesity.

In the recent times, nationwide campaigns have been launched in India to promote public awareness about the importance of physical activity. The Government of India initiative 'Khelo India programme' aims to boost excellence in sports and encourage mass participation. The 'Fit India Movement' has been running successfully with the core objective of encouraging citizens to make sports, exercise and physical activity an essential part of daily life. The immense health benefits from the ancient practices of Yoga have been accepted worldwide. The concepts and practices as various asanas of Yoga have been rooted in Indian spiritual and cultural heritage. In addition to physical movements, Yoga involves focused breathing exercises - pranayama, and regular meditative practices which bring in mental peace and emotional stability, thereby assuring holistic well-being. By mitigating stress, restoring hormonal balance and improving sperm parameters, Yoga can exert significant beneficial effects in the male reproductive system. Together with psychological wellness, this could pave way for better reproductive health.

Thus, lifestyle habits can influence male reproductive potential to a significant extent.

> *Balanced nutrition, regular exercise, and reduced exposure to toxins are key to preserving male reproductive wellness.*

Increased public awareness about healthy dietary patterns, negative effects of smoking and alcohol consumption, avoiding indiscriminate usage of plasticizers and other environmental toxins, and regular sports activities, moderate-intensity exercises and yoga practices will definitely improve overall health and, in particular, the reproductive health of populations. Government policies and initiatives in this regard would create proper sports ecosystem and emphasize upon holistic wellness. Self-discipline and self-motivation in individuals which will drive appropriate lifestyle choices is the need of the hour.

Dr. Sutapa Mukherjee's contributions to this field are reflected in her recent publication in Cell Biochemistry and Biophysics, (2026)titled "Effects of Diet-Induced Obesity and Exercise Intervention on Testicular Germ Cell Health: Modulation of SIRT1/FoxO1 and SIRT1/PGC-1α Signaling Axes" https://doi.org/10.1007/s12013-026-02076-2. In this study, she and her colleagues demonstrated how exercise can mitigate the adverse effects of obesity on testicular germ cell health by restoring key molecular pathways involved in oxidative stress regulation, mitochondrial function, and cellular survival.

Acknowledgement: We are grateful to the Science and Engineering Research Board (SERB), Govt. of India for funding this work.

| EXPERT OPINION |

How Vitamins and Hidden RNA molecules Shape Our Health and Aging

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Areas of Expertise: Molecular Biology of aging | Non-coding RNAs | Stem cells | Cytokines-transcription factors-cell signaling & disease

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Areas of Expertise: Non-coding RNAs | Molecular Biology | Cell differentiation

Aging is a universal process characterized by a gradual decline in cellular and physiological functions across all organ systems. Apart from genetic composition, nutrition and hidden RNA molecules, including non-coding RNAs, also contribute to health and lifespan. Among these, long non-coding RNAs (lncRNAs) and microRNAs (miRNAs) are the critical regulators of health, metabolism, inflammation and longevity. LncRNAs are typically longer than 200 nucleotides and can regulate chromatin remodeling, DNA methylation, cellular signaling pathways, transcription, RNA stability, alternative splicing and miRNA activity through RNA-DNA, RNA-RNA and RNA-protein interactions. Aging-associated changes in lncRNA expression have been identified in several tissues, including the brain and testes. Many lncRNAs regulate pathways associated with cellular senescence, oxidative stress, mitochondrial dysfunction and genomic instability, all of which are hallmarks of aging. miRNAs are short non-coding RNAs typically 18-25 nucleotides, that can interact with specific mRNAs to negatively influence their stability and translation.

On the other hand, vitamins are essential micronutrients required for normal cellular functions. They function as molecular regulators of metabolism, antioxidants, epigenetic control and immune response, thereby influencing cellular health and aging process. Vitamin B, vitamin C, and vitamin E act as antioxidants, combat oxidative stress and inflammation, and decline with age. The vitamin B group also acts as cofactors for enzymes which control metabolism. Vitamin C facilitates collagen function and stabilization by acting as a cofactor for hydroxylase enzymes involved in collagen maturation. Excessive reactive oxygen species damage DNA, proteins, and lipids, thereby accelerating cellular aging. Interestingly, ncRNAs also regulate oxidative stress pathways by modulating the activity of antioxidant enzymes and mitochondrial metabolism. Vitamin A and vitamin D are well-studied examples of the nutrient-mediated ncRNA regulation. The interplay between vitamins and ncRNAs reveals a new layer of molecular regulation that shapes health and lifespan.

In our laboratory, two long noncoding RNAs were cloned,

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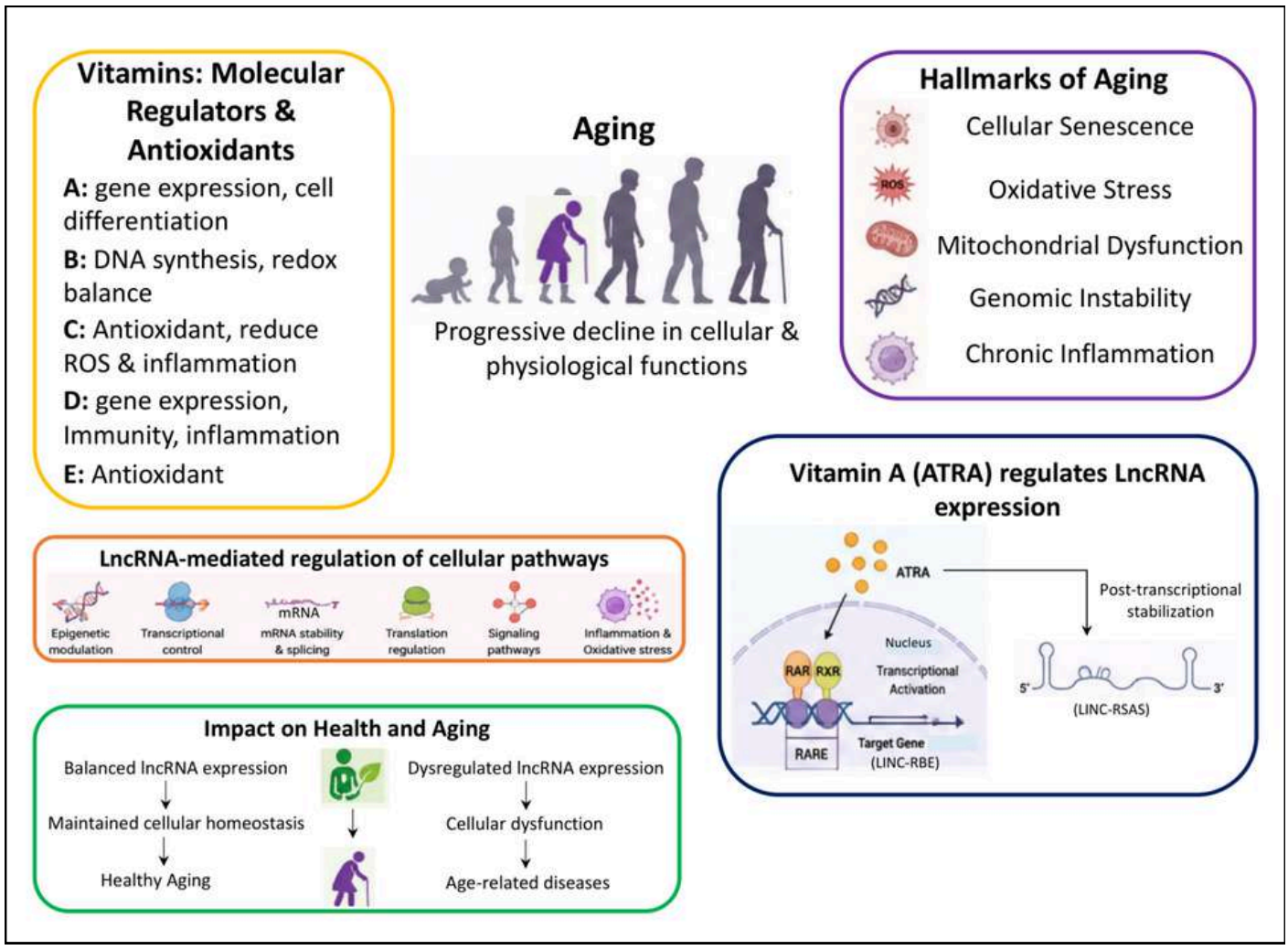

characterized, namely LINC-RBE (long intergenic noncoding-rat brain expressed) and LINC-RSAS (long intergenic noncoding-repeat rich sense antisense) from the rat genome. The lncRNAs exhibit a distinct age-related expression pattern in the brain and testes of the rat. Their expression increased during maturation from young to adult and decreased during aging from adult to near-old rats. These lncRNAs are possibly processed into small noncoding RNAs, including piwi-interacting RNAs and miRNAs, in the immunological tissues of the rat. Vitamin A serves as a key metabolic regulator of cell differentiation, gene expression and embryonic development in vertebrates. All-trans retinoic acid (ATRA) is an active metabolite of vitamin A, which regulates gene expression at transcriptional and post-transcriptional levels through nuclear retinoic acid receptor heterodimers. The expression of LINC-RBE and LINC-RSAS is upregulated by ATRA in the cultured primary hippocampal neurons of the adult rat at transcriptional and post-transcriptional levels,

> *Vitamins do more than just nourishing the body, they also help control hidden RNA molecules that influence how our cells function and how we age.*

respectively. This study provided the first evidence that ATRA upregulated lncRNA expression in the rat hippocampal neurons.

Further analysis showed that the cloned-RBE promoter was upregulated by ATRA and LINC-RSAS was post-transcriptionally stabilized by ATRA in the human neuroblastoma cells. ATRA induced differentiation of these cells into neuronal cells. Moreover, LINC-RBE and LINC-RSAS overexpression in these cells influenced cell proliferation/growth, cell cycle, caused DNA breakage/damage and cell death. Also, lncRNA expression + ATRA differentially regulated the expression of genes involved in adult neurogenesis and learning & memory. These two functions are regulated by the hippocampus in the mammalian brain and typically decline with aging and in neurological disorders. These findings highlight the functional significance of these two lncRNAs in neuronal cells and in the rat hippocampus during aging.

In our recent review article, we represented that retinoic acid (vitamin A) regulates the expression of lncRNAs. Several lncRNAs, including HOTAIRM1, NEAT1, MEG3, LINC-RBE and LINC-RSAS, are regulated by retinoic acid through multiple direct and indirect mechanisms in different cellular systems. These lncRNAs participate in various biological functions including neuronal differentiation, apoptosis, chromatin remodeling, inflammatory signaling and aging. Thus, the interplay between retinoic acid and lncRNAs constitutes a network that may control cell fate, differentiation and aging. Further study on the precise mechanisms by which vitamins regulate lncRNA networks during aging will enrich our knowledge in this field.

In conclusion, the interplay between vitamins and hidden RNA molecules has increased our understanding of biology of aging. Vitamins are not solely utilized as nutritional supplements but may act as molecular regulators to influence epigenetic and transcriptomic networks. In parallel, lncRNAs have emerged as critical regulators of neuronal function, cellular senescence, inflammation and age-related diseases. Together, vitamins and lncRNAs may influence development, tissue homeostasis and longevity. More knowledge about this interaction may pave the way for novel therapeutic strategies to promote healthy aging and prevent metabolic disorders and age-related diseases.

> *By understanding how vitamins and non-coding RNAs work together, we may uncover new strategies to promote healthy aging and prevent age-related diseases.*

Contributions of Prof. Pramod C. Rath, Dr. Anita Kumari and their other lab members to this field are reflected in their extensive research on the molecular biology of aging, non-coding RNAs, and neurobiology.

Their work have been published in leading journals including Kour et al. International Journal of Developmental Neuroscience (https://doi.org/10.1016/j.ijdevneu.2015.07.011), Molecular Neurobiology (https://doi.org/10.1007/s12035-015-9634-z), Danga et al., Biogerontology (https://doi.org/10.1007/s10522-023-10088-1; https://doi.org/10.1007/s10522-024-10119-5), Kour et al., Journal of Molecular Neuroscience (https://doi.org/10.1007/s12031-015-0671-x), and Kumari et al., Neurotoxicity Research (https://doi.org/10.1007/s12640-025-00760-4) and “Expression and functional characterization of candidate-cDNAs isolated by a simple repeat DNA probe” by Mishra. R.R. 2009, Ph.D. Thesis, Jawaharlal Nehru University. Their recent research focused on how vitamin A and long non-coding RNAs regulated brain function, cellular aging, and age-related disorders.

| EXPERT OPINION |

Fighting Eye Infections with Stem Cell-based Therapies: When Antibiotics Fail!

Dr. Sachin Shukla
Centre for Ocular Regeneration, Prof. Brien Holden Eye Research Centre, L V Prasad Eye Institute, Hyderabad, India

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

Areas of expertise: Mesenchymal Stem cells | Ocular Surface Infection and Inflammation | Extracellular Vesicles | Cell and Molecular Biology

Microbes are opportunistic and notorious! They somehow find the way to grow as and when they find the suitable conditions. One may notice their presence virtually everywhere, irrespective of living and non-living. While they are fundamental to life, once they grow within living organisms including plants, animals, and humans, and that too in a harmful way, they are recognized as 'pathogens' which cause infections. This demands immediate care and attention to prevent them from causing further harm and to avoid worsening the situation.

In such scenarios, antibiotics are the first and probably the most sought-after treatment to prevent further worsening of bacterial infections and, same is true with the antifungal and antiviral drugs. However, once the microbes become familiar with the antimicrobial drugs being used against them repeatedly, they gradually evolve resistance mechanisms to attenuate or nullify the effects of these drugs. This phenomenon, known as antimicrobial resistance (AMR), poses global challenges to the use of traditional antimicrobial drugs and demands for the novel/unconventional alternate therapies to treat infections. It is in this context that our team (including Mr. Sairam Abbireddy: an enthusiastic young postgraduate, Dr. Joveeta Joseph: a microbiologist, Dr. Bhupesh Bagga, a clinician ophthalmologist with specializations in treating ocular infections, and myself, Dr. Sachin Shukla: a Scientist with focus on the applications of Mesenchymal Stem/Stromal Cells (MSCs)) at L V Prasad Eye Institute, Hyderabad, India, started exploring MSC-based alternatives for eye infections.

> *"Mesenchymal stem/stromal cell (MSC)-derived conditioned medium (MSC-CM) derived from human adipose-tissue, bone marrow, dental pulp, and umbilical cord, demonstrates novel antibacterial effects against ocular bacterial infections in laboratory-based studies."*

Eyes, being in direct contact with the external environment, like skin, are prone to microbial infections. When the immune homeostasis at the ocular surface is compromised due to injury, infection, or allergic conditions, it may lead to ocular infections causing blindness and vision impairment in their most severe forms. Bacterial keratitis, affecting cornea, is the most common and serious form of ocular infections which may be caused by unhygienic and long-term use of contact lens, corneal injury, and corneal transplantation. *Pseudomonas aeruginosa* and *Staphylococcus aureus*, the Gram-negative and -positive bacteria, respectively, are among the most predominant causal microorganisms causing bacterial keratitis; and at the same time they are increasingly developing resistance to a wide spectrum of antibiotics, including quinolones (e.g., ciprofloxacin and moxifloxacin) and aminoglycosides (e.g., gentamicin, strepto-

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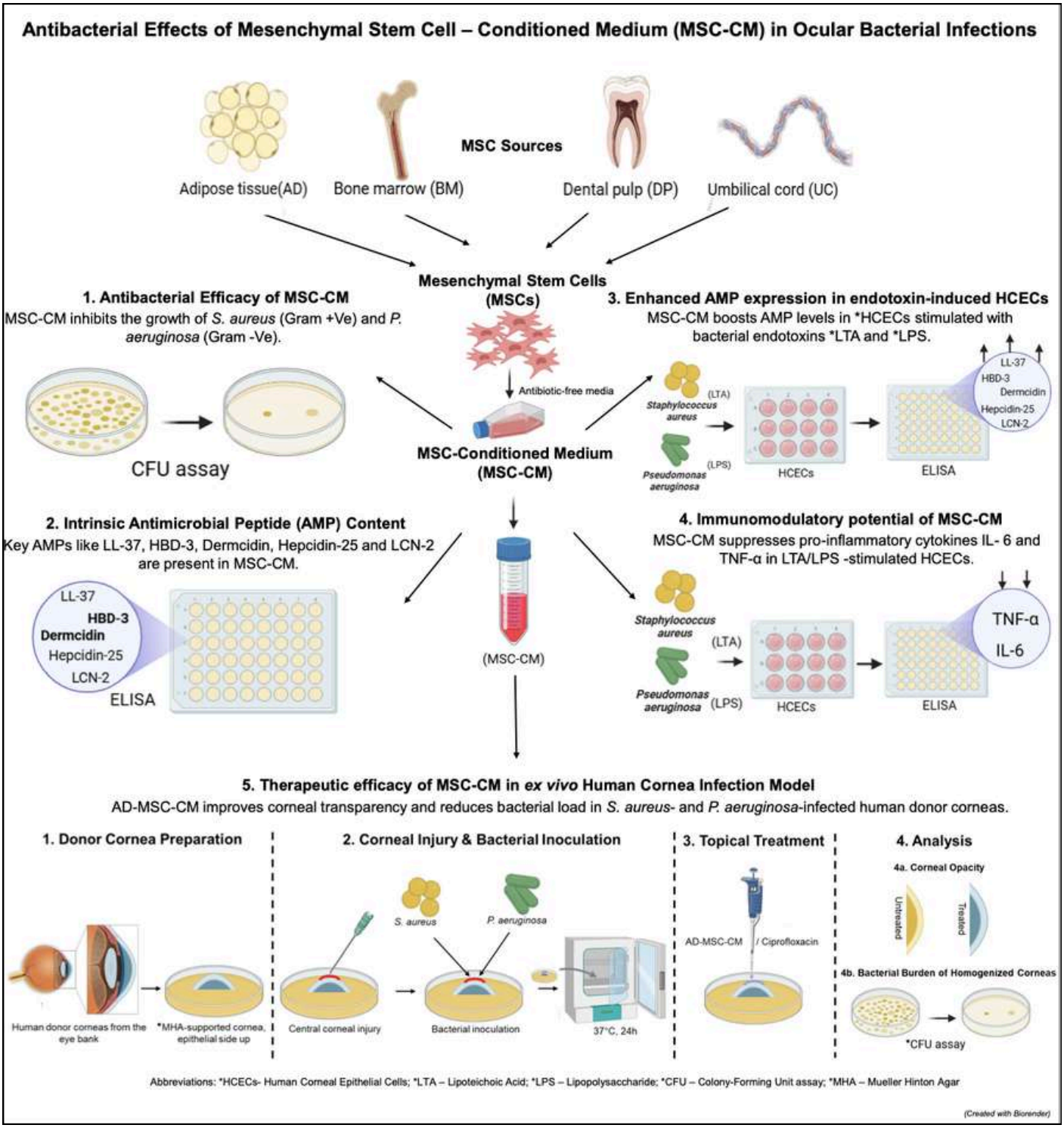

mycin). Moreover, these pathogens are classified within the ESKAPE (Enterococcus faecium, S. aureus, Klebsiella pneumoniae, Acinetobacter baumannii, P. aeruginosa, and Enterobacter species) group of World Health Organization (WHO) as significant multidrug-resistant bacteria for which effective therapies are urgently needed.

Stem Cells, being multipotent, are popularly known for their tissue repair and regenerative potential. Additionally, tissue-specific adult MSCs, among the different types of stem cells (e.g., embryonic stem cells, induced pluripotent stem cells, MSCs), are largely known for their immunoregulatory properties. Rather, hematopoietic stem cell transplantation is the only U.S. Food and Drug Administration approved stem cell-based therapy in the w-

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orld till date. Consequently, MSCs have been widely used in clinical trials, particularly for immune-mediated disorders (e.g., Rheumatoid arthritis, Graft versus Host Disease). However, their abilities to fight ocular infections have not been sufficiently explored with no such report available, to the best of our knowledge, until our recent publication entitled 'Mesenchymal stem cell-derived conditioned medium demonstrates novel antibacterial effects in ocular bacterial infections' (https://pubmed.ncbi.nlm.nih.gov/42060691/).

Our hypothesis that MSC-based therapies would be effective for treating eye infections and underlying inflammation was based upon the previous observations by different investigators across the globe (including ours) that MSCs derived from different tissue sources including adipose tissue, bone marrow, dental pulp, and umbilical cord produce antimicrobial peptides (AMPs: e.g., LL-37, Hepcidin, Dermcidin, and Lipcalin-2) which effectively disrupt bacterial cell membranes and inhibit biofilm formation and thus exhibit antibacterial effects against pathogens like S. aureus, P. aeruginosa, and E. coli. The MSCs have been reported to be therapeutically effective in preclinical models of sepsis, chronic wound infections, and cystic fibrosis and more recently in urinary tract infections by different investigators. Further, their tissue repair and immunomodulatory properties have been investigated in Rheumatoid arthritis, Alzheimer's disease, and myocardial infarction. Instead, their role in ocular infections remains largely unexplored.

MSCs exhibit antibacterial effects in ocular bacterial infections. To study their antibacterial properties, we procured the human MSCs derived from different tissue sources, namely, adipose tissue, dental pulp, bone marrow, and umbilical cord; cultured them under laboratory conditions, and collected their secretions under defined conditions (called as 'conditioned medium', hereafter referred as 'MSC-CM'). To check the effect of MSC-CM on bacterial growth, the standard ATCC strains and clinical isolates (isolated from the infected eyes of patients) of a Gram-positive (S. aureus) and a Gram-negative bacteria (P. aeruginosa) were cultured, further incubated with MSC-CM and plated on Mueller-Hinton agar plates. Number of bacterial colonies were counted through colony-forming unit assay. Treatment with MSC-CM further induced structural deformations in bacteria as observed through scanning electron microscopy.

> *"MSC-derived conditioned medium has the therapeutic potential to be used as an effective alternate antibiotic drug to tackle with the increasing burden of antimicrobial resistance. However, this needs to be further validated through pre-clinical animal studies and clinical trials."*

MSC-secreted Antimicrobial peptides (AMPs) help in execution of antibacterial properties. Having observed the antibacterial effects of MSC-CM on the growth and morphology of S. aureus and P. aeruginosa, the next step before us was to find out what in MSC-CM contributes to their antibacterial effects. We checked the presence of AMPs and quantified their levels of expression through Enzyme-linked immunosorbent assay (ELISA). Our results show the presence of cathelicidin (LL-37), hepcidin-25, dermcidin, human beta defensin-3, and lipocalin-2 in MSC-CM. To see how these AMPs are modulated upon bacterial infection and inflammation, we treated the laboratory cultured human corneal epithelial cells with the bacterial cell wall components: Lipopolysaccharide (LPS, in Gram-negative bacteria) and Lipoteichoic acid (LTA, Gram-positive bacteria) and observed changes in expression of AMPs and pro-inflammatory cytokines (IL-6 and TNF-alpha). While the expression of AMPs was increased, that of pro-inflammatory cytokines was decreased. This suggests that MSC-CM plays dual role: resolution of infection and suppression of inflammation. This combined effect of MSC-CM can be more useful in clinical settings to treat ocular infection and underlying inflammati-

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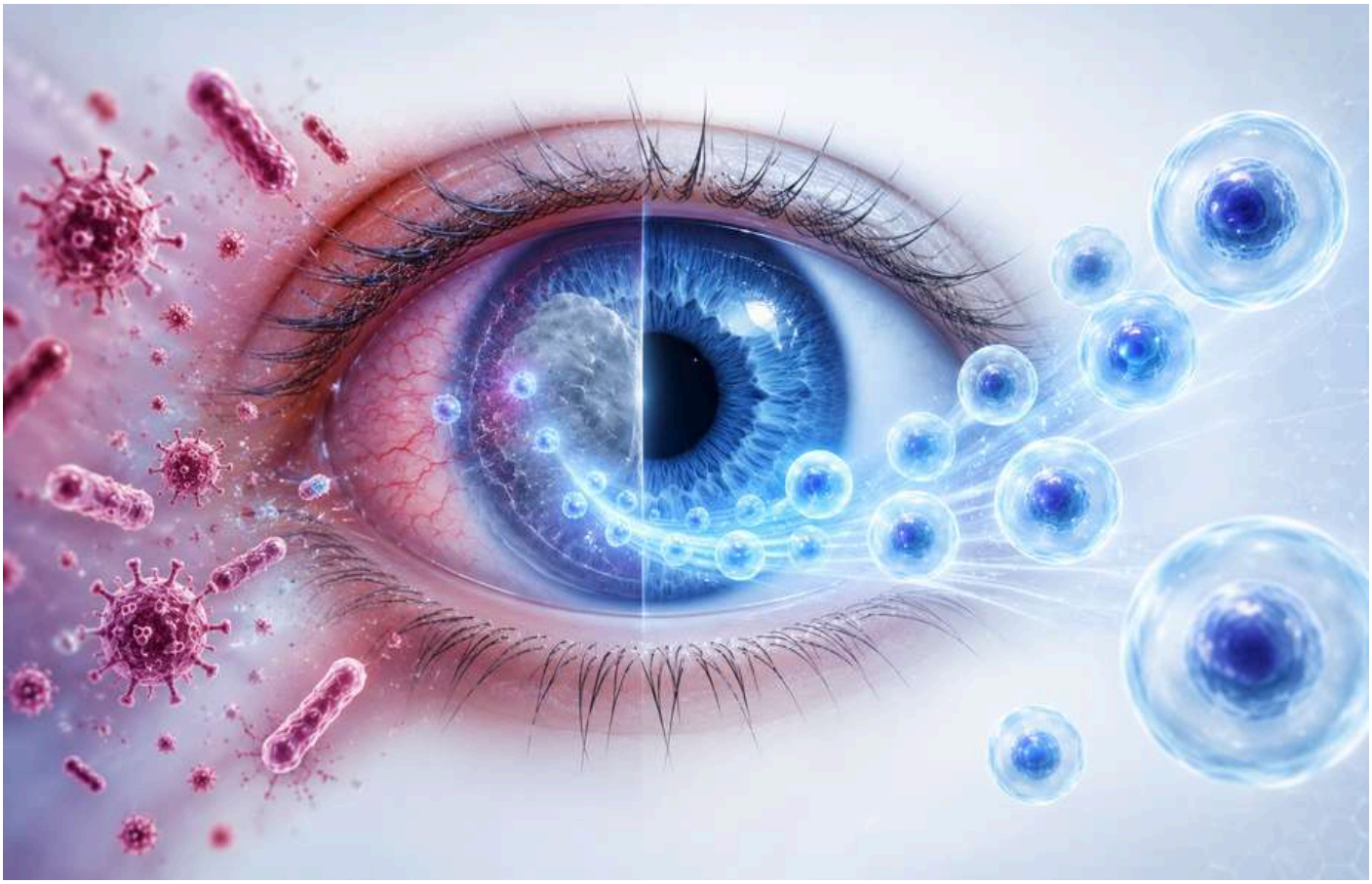
on. Further animal studies and clinical trials are required to validate our findings for clinical applications.

Therapeutic Efficacy of MSC-CM: Following the confirmation of antibacterial properties of MSC-derived conditioned medium, the next step was to test the efficacy. For this purpose, we chose the cadaveric corneas as an ex-vivo model system. The cadaveric corneas, with no reported history of infection at the time of death, were infected with the clinical isolates of bacteria (P. aeruginosa and S. aureus) for 24 hours and were then subjected to treatment with adipose tissue-derived MSC-CM as eye drops for next 24 hours. We observed that the treatment resulted in reduced bacterial load and improved corneal transparency ex vivo. To validate our results and compare our outcomes with an established antibiotic, we used ciprofloxacin in all experiments as control and observed comparable results.

> *Mesenchymal stem/stromal cell (MSC)-derived conditioned medium (MSC-CM) derived from human adipose-tissue, bone marrow, dental pulp, and umbilical cord, demonstrates novel antibacterial effects against ocular bacterial infections in laboratory-based studies.*

Dr. Shukla's contributions to this field are reflected in his recent publication in Infection and Immunity, a journal of the American Society for Microbiology, titled "Mesenchymal Stem Cell-Derived Conditioned Medium Demonstrates Novel Antibacterial Effects in Ocular Bacterial Infections https://doi.org/10.1128/iai.00697-25". In this study, the authors show that factors released by mesenchymal stem cells can inhibit bacteria associated with eye infections, highlighting a promising alternative approach to antibiotic therapy.



| EXPERT OPINION |

How Smart Packaging Can Keep Cut Apples Fresh for Longer

Dr. Ankit Tyagi
Department of Chemical Engineering, Indian Institute of Technology Jammu, Jammu & Kashmir, India

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

Areas of expertise: Food Packaging | Electrospinning | Nanomaterials | Energy storage and conversion

Fresh-cut fruits have become more popular in modern lifestyles for their convenience, health benefits, and easy consumption as ready-to-eat snacks, whether packed in school lunch boxes, sold in supermarkets, or in restaurants. However, anyone who has sliced an apple notices one common problem: browning. Within minutes, the fresh white surface slowly turns brown. Along with color change, the fruit gradually loses moisture, texture, nutritional quality, and freshness.

Browning in fresh-cut apples is mainly caused by enzymatic oxidation reactions, which are triggered when the tissue of the fruit is exposed to air. The enzymes, such as polyphenol oxidase, mediate the development of brown colors. In addition, moisture condensation and microbiological contamination accelerate the deterioration of quality.

Each year, tons of fruit are discarded due to spoilage during transportation and storage, and the ubiquitous conventional plastic wrap commonly used to cover food items also accounts for a large share of non-biodegradable waste. These two global concerns, food waste and plastic waste, have encouraged scientists to search for smarter and more sustainable packaging solutions. A possible answer is the development of smart, eco-friendly packaging films, which can extend the shelf life of food items. Unlike conventional plastic wraps, smart packaging films not only wrap the food but also interact with it and its environment; they can reduce spoilage, inhibit microbial growth, maintain the food's nutritional value, and even indicate how fresh the food is. Over the last few years, scientists and researchers have been developing active packaging materials using novel nanomaterials and natural compounds.

> *"Smart packaging does more than wrap food, it actively protects freshness, slows spoilage, and helps reduce both food waste and plastic pollution."*

Natural antioxidants, antibacterial compounds such as plant extracts, essential oils, and bio-derived carbon-based nanomaterials can be incorporated as active materials in the fibrous films to enhance the food preservation efficacy. Carbon dots, a zero-dimensional material, have attracted significant attention due to their small size, fluorescence properties, low toxicity, and excellent biocompatibility. They can improve the physicochemical, mechanical, antioxidant, and antimicrobial properties, as well as the UV-blocking characteristics, of packaging films.

Electrospinning can produce fibrous films with diameters ranging from microns to na-

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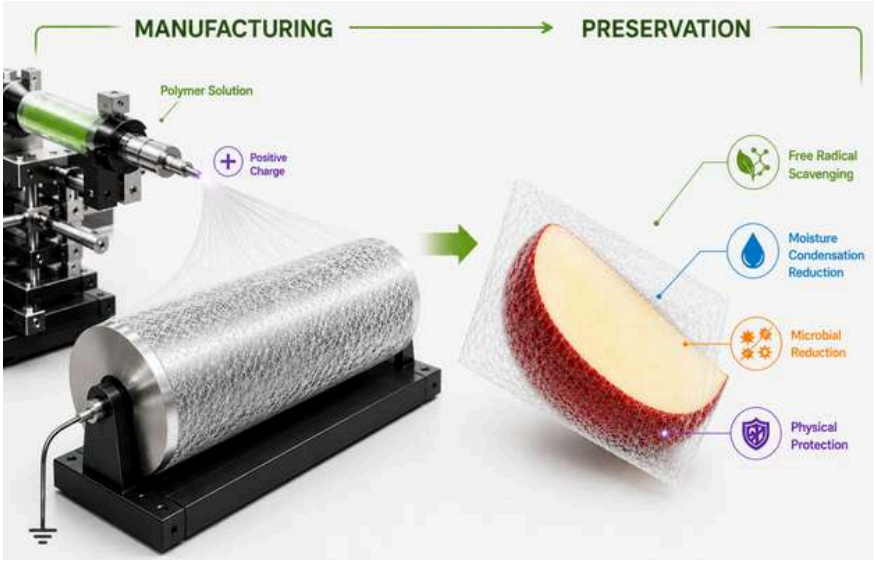

nometers and offers distinct advantages over conventional films, including higher surface area, interconnected pores, a lightweight structure, and excellent flexibility. These features make electrospun fibrous films very attractive for food packaging.

The fibrous structure functions as a permeable protective barrier that maintains the flow of oxygen and moisture, unlike conventional plastic films. This helps preserve texture and reduces water vapor condensation. Furthermore, owing to the presence of functional groups, including hydroxyl, carbonyl, and nitrogen groups, on the carbon dots, the films exhibited excellent antioxidant and UV-blocking properties.

When these films were used as a practical, standalone packaging material, they reduced browning index by ~26% and visible decay in fresh-cut apples during the 5-day storage study, compare to conventional films. The potential impact of these packaging systems can be further applied to a wide range of fresh produce, including climacteric and non-climacteric fruits.

Although smart packaging technologies are still emerging, progress in this field has been remarkably rapid. Efforts are underway globally to enhance scalability, affordability, and material robustness. Looking ahead, packaging will no longer serve merely as a protective layer. It will function as an active system capable of maintaining freshness, communicating food quality to consumers, minimizing waste, and contributing significantly to mitigating global food loss and environmental issues. Such innovations represent a shift from passive packaging to intelligent systems that actively govern food quality and sustainability.

> *By combining biodegradable electrospun fibers with carbon dots, scientists are transforming food packaging into an intelligent system that keeps fresh-cut fruits fresher for longer.*

Dr. Tyagi's contributions to this field are reflected in his publication in the International Journal of Biological Macromolecules, "Sustainable ethyl cellulose fibrous films with nitrogen-carbon dots for fresh-cut apple preservation" (DOI: 10.1016/j.ijbiomac.2026.151195). In this research, Neem-derived carbon dots were incorporated into ethyl cellulose electrospun fibrous films and evaluated for extending the shelf life of fresh-cut apples.

| EXPERT OPINION |

From Superconductors to Nanosheets: An Unexpected Research Journey

Prof. Kabeer Jasuja
Dr. Dinesh O. Shah Chair Professor in Surface Science and Nanotechnology, Department of Chemical Engineering, Indian Institute of Technology Gandhinagar, India

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

Areas of expertise: Boron-Rich Nanosheets | 2D Nanomaterials | Nanocomposites | Surface Chemistry

My research at the Indian Institute of Technology Gandhinagar revolves around the chemical science of nanosheets - a class of nanomaterials whose thickness is equivalent to only a few atoms. When I joined IIT Gandhinagar, one of the scientific questions that intrigued me was: Can we design a material that is analogous to graphene, but rich in boron instead of carbon?

This question emerged from the fascinating chemistry of boron. Although boron is carbon's neighbor in the periodic table, it differs fundamentally because of its electron-deficient nature. Unlike carbon, boron cannot independently constitute stable honeycomb networks similar to graphene. We thus began revisiting layered metal diborides such as MgB_2 from an entirely different perspective. While MgB_2 had been extensively researched for superconductivity, we wondered whether its layered arrangement, where magnesium atoms are sandwiched between boron planes, could provide access to boron-rich nanosheets.

In our initial studies, we demonstrated that MgB_2 can indeed be exfoliated into ultrathin boron-rich nanosheets. This formed the first foundational step toward developing a new family of two-dimensional nanomaterials, which we termed "XBenes" where we showed that layered metal borides beyond MgB_2, such as TiB_2, AlB_2, and TaB_2 can also be exfoliated into sheet like nanostructures." What made this journey particularly exciting was that every stage opened new scientific questions. For example, while establishing scalable methods for synthesizing these nanosheets, we discovered that MgB_2 crystals undergo dissolution followed by non-classical recrystallization through oriented attachment. This enabled us to develop high-yield synthesis approaches using simple shear mixing methods.

> *"Boron-rich nanosheets can turn familiar materials into entirely new scientific possibilities."*

As we continued probing deeper into the chemistry of these nanosheets, we realized that their surfaces were not chemically passive. Detailed characterization revealed the presence of borohydride-like functionalities. We were curious to examine whether these could impart reducing behavior to the nanosheets. To our surprise, the nanosheets indeed displayed chemically reducing action, allowing us to assemble heterostructures with graphene oxide directly in solution. This was a fundamentally new way of viewing nanosheets not merely as substrates or fillers, but as chemically active entities the-

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mselves.

Gradually, our research started moving from fundamental science toward technological possibilities. We found that boron-rich nanosheets could impart exceptional flame retardancy to polymers, enhance hydrogen storage characteristics, improve ultrafast charging in battery electrodes, and catalyze reactions relevant to energy conversion. More recently, we observed that pristine defect-rich nanosheets derived from metal diborides exhibit the ability to chemisorb nitrogen under ambient conditions without external energy input. Such findings continue to reinforce our anticipation that boron-based nanosheets may provide access to several unconventional material properties.

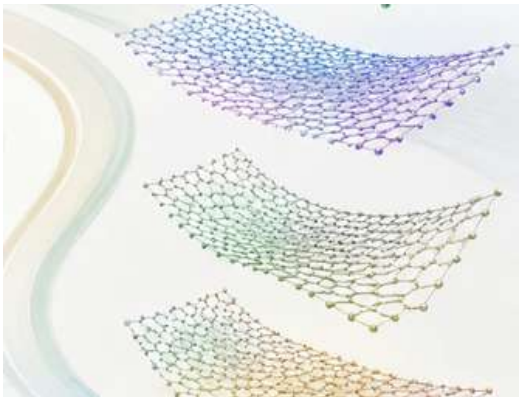
Interestingly, some of our important insights emerged while investigating results that initially appeared anomalous. During studies involving ultrasonication-assisted exfoliation, we discovered that the organic solvents themselves could transform into photoluminescent carbon quantum dots. Similarly, we found that freeze-drying protocols commonly used for recovering nanomaterials can induce spontaneous nanosheet assembly of organic species. These observations reminded us that scientific protocols often contain hidden physical phenomena that remain unnoticed until one begins to question long-standing assumptions.

In my opinion, the future of nanomaterials research will depend not only on discovering new materials, but also on developing deeper mechanistic understanding of how chemistry evolves at atomically thin interfaces. Many emerging technologies in energy, sustainability, catalysis, and advanced manufacturing will likely require multifunctional materials whose properties can be tuned through controlled defects, surface chemistry, and nanoscale architecture. Two-dimensional boron-rich nanomaterials provide a particularly exciting playground in this direction because they combine unusual electronic structure with rich chemical versatility.

> *"Understanding materials at atomically thin scales can open doors to future technologies."*

Looking back, I realize that our work on boron-rich nanosheets continuously evolved through scientific curiosity. In many instances, the most meaningful directions emerged unexpectedly while pursuing something entirely different. While we are continuing to uncover several such phenomena, we are also gradually moving toward translating this science into people-serving technologies by developing scalable approaches to synthesize these nanomaterials. I believe that this interplay between curiosity-driven science and purposeful application is what makes research deeply rewarding. Every new material teaches us not only about its own behavior, but also about how much remains unexplored in the natural world.

Dr. Jsuja's contribution to this field is reflected in his recent publication in ChemComm (Cambridge, 2026), titled "Composition-Dependent Hydrogen Oxidation Activity of Pt–Cu Nanoparticles Prepared Using Boron-Rich Nanosheets" https://doi.org/10.1039/D6CC00243A. This work highlights the emerging potential of boron-rich nanosheets in designing advanced catalytic nanomaterials for energy-related applications.



| EXPERT OPINION |

Why Molecules Move Differently Inside Cells: The Hidden Role of Charge and Interactions?

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

Areas of expertise: Cellular Biophysics & Cell Biology | Protein Biology & Biochemistry | Drug off-targets Identification | Confocal & Super resolution Microscopy | Physical Chemistry of macromolecules

Imagine you want to catch a local train at a busy Indian railway station during peak hours. The platform is packed, people are everywhere, and boarding the train becomes a real struggle during peak office hours. You need to leave home early, keep extra time in hand, and carefully move through the crowd. Even reaching the train door can take effort because there are simply too many people in a small space. Now compare this with a quiet railway station in the European countryside during a vacation. The station is mostly empty, there is very little crowd, and you can easily walk to your train and board comfortably without stress. Everything moves more smoothly because there is plenty of free space around you.

A very similar situation exists when scientists compare the movement of molecules inside a living cell with their movement in a simple test tube experiment. Most biochemical experiments involving proteins, nucleic acids, or small bio-active molecules are usually performed in dilute buffer solutions under standard laboratory conditions. These experiments are extremely important because they provide the first level of understanding about how biomolecules behave. However, these conditions are far from the real environment inside a living cell.

> *"Inside living cells, molecular movement is shaped not only by crowding, but also by countless hidden interactions."*

The interior of a cell, especially the cytoplasm, is incredibly crowded —even more severe packed than busiest Indian railway station, one can think of. Inside cells, the concentration of biomolecules can reach nearly 200–300 mg/mL. In such an environment, molecules constantly collide, compete for space, and struggle to move freely. Their behaviour, reaction speed, folding, and interactions can become very different from what we observe in a dilute test tube experiment. Scientists, including me, have tried to mimic this crowded cellular environment in the laboratory by adding artificial "crowder" molecules into buffer solutions, previously. But recreating the true complexity of a living cell is extremely challenging. Even with these efforts, the results often remain incomplete compared with what is observed directly inside living cells. Therefore, experiments performed directly in living cells are critically important for obtaining physiologically relevant insights into molecular behaviour and intracellular transport.

Measuring Diffusion coefficients serves a

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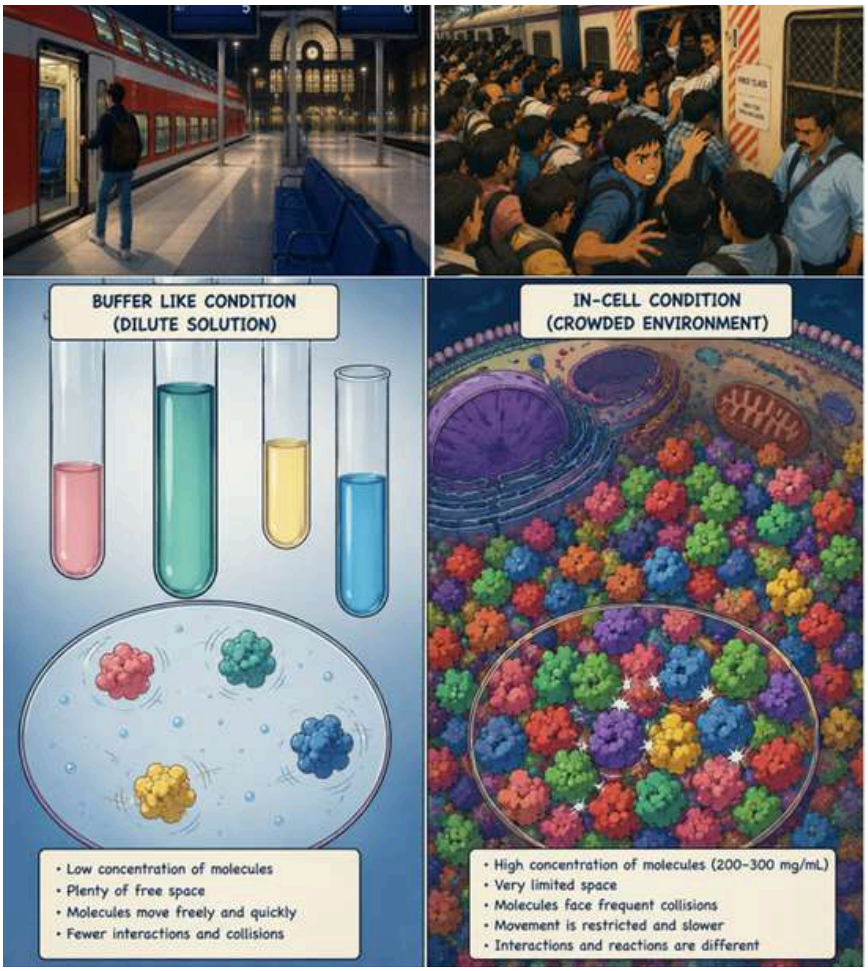
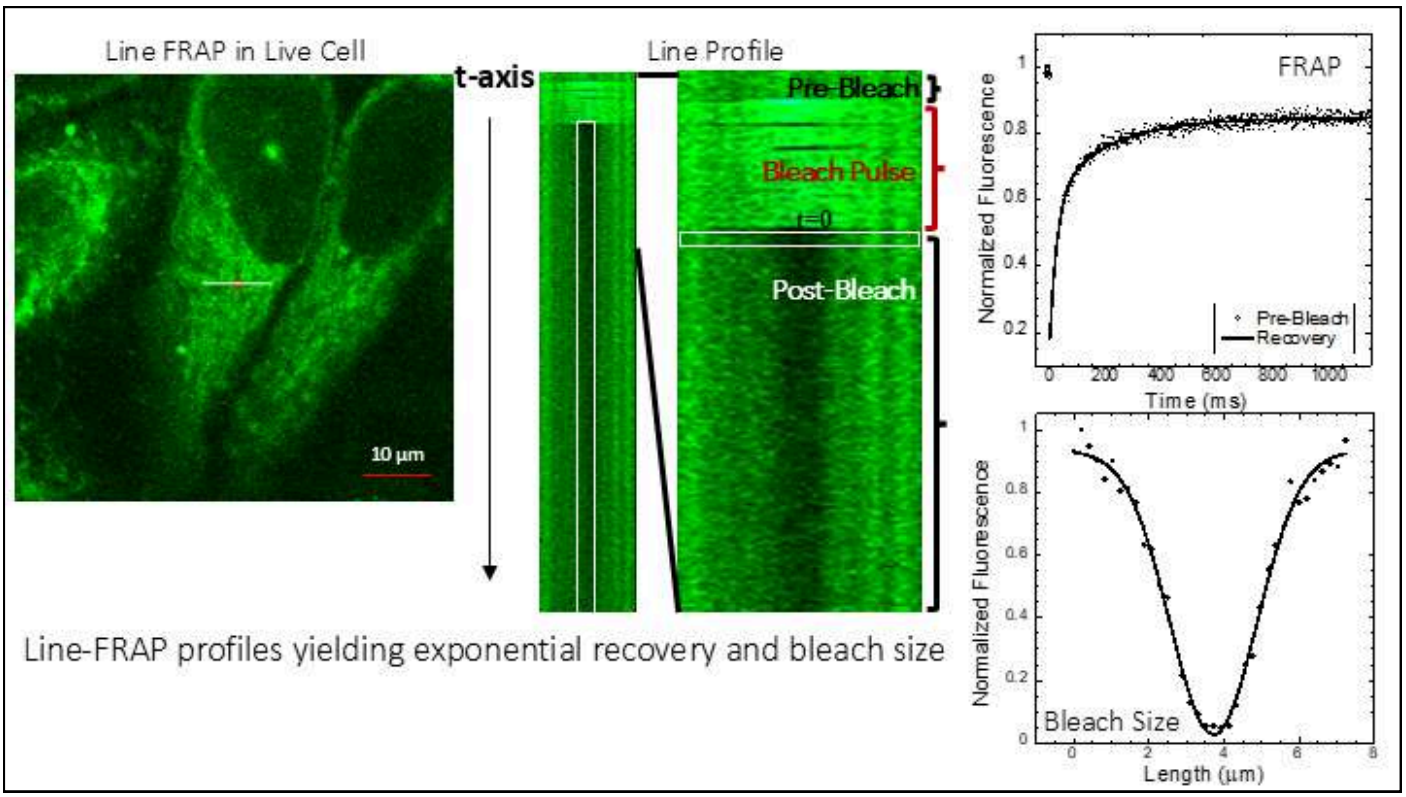


good proxy to understand the molecular motion in any media including their binding, interactions with the surrounding environments. The classical Stokes-Einstein theory of particle diffusion in ideal solution states that the translational diffusion constant of a particle A (DA) is a function of its dimensions and the solution viscosity.

$$DA = kBT/6\pi\eta rA \qquad (1)$$

where η is the solvent viscosity, kBT is the product of the Boltzmann constant and the absolute temperature, rA is the hydrodynamic radius of the diffusing particle, and DA is a measure of the mean squared displacement per unit time. Interactions with other molecules that lower the mobility will be reflected by lower DA values. Alternatively, if the motion of the molecule is increased due to the presence of another faster moving molecule or the surrounding environment, higher DA values will be recorded. Moreover, inside the complex environment of a cell (presence of lipid microdomains/small organelles may constrain the molecular diffusion), the mean square displacement (MSD) may deviate from linearity with respect to time. This is known as anomalous diffusion. Smaller molecules usually move faster, whereas larger molecules or molecules interacting with surrounding components show slower movement.

A number of experimental approaches are available to study molecular diffusion both in vitro and inside living cells, although each technique comes with specific advantages and limitations. Fluorescence correlation microscopy (FCS) is considered the gold standard for this purpose; however, its application can be challenging. It requires highly fluorescent molecules (moderate to high quantum yields) and works best at very low concentrations, which may not accurately represent physiological conditions. In addition, immobile or strongly bound molecular populations are often not detected efficiently by this method. Therefore, FRAP is the technique most widely used by experimental biologists. FRAP is relatively simple, minimally invasive, and suitable for studying molecules over a wide concentration range, including biologically relevant conditions. It is particularly useful for molecules that exhibit weak fluorescence signals. Nevertheless, conventional FRAP has limitations, especially when studying rapidly diffusing molecules because of its relatively slow acquisition speed. To address these challenges, I developed an improved high-speed version of FRAP, known as “Line FRAP,” during my postdoctoral research. By using rapid line-scanning instead of conventional imaging modes, the method significantly improves temporal resolution and allows more reliable measurements of fast molecular motion. The use of Line mode greatly improves time resolution of FRAP data acquisition, from 20-100 Hz in the classical mode to 800 Hz in the line mode. This improves data analysis, as intensity and radius of the bleach at the first post-bleach frame is critical. Using this technique, we investigated the diffusion of fluorescently labelled bacterial proteins inside both mammalian and bacterial cells.



Line-FRAP profiles yielding exponential recovery and bleach size

Using fluorescently labelled bacterial proteins (molecular weight ~20–100 kDa, bacterial proteins are mostly acidic in nature), we observed that diffusion coefficients in HeLa cells and in E. coli were approximately 2.5-fold and 15-fold lower, respectively, compared with measurements in buffer. This trend is consistent with the progressively increasing degree of cellular crowding from dilute buffer systems to mammalian cytoplasm and finally to the highly compact bacterial cytoplasm, where the available free space for molecular motion becomes substantially reduced. Such crowded intracellular environments influence diffusion through both hard interactions arising from excluded volume effects and soft interactions involving weak, nonspecific molecular associations.

A particularly intriguing finding was that several small molecules (molecular weight <1 kDa) diffused even more slowly than considerably larger proteins within mammalian cells. These results cannot be explained solely by cytoplasmic crowding or occluded volume effects. Although bacterial cytosol is generally more crowded than eukaryotic cytoplasm, mammalian cells possess a much more structurally and chemically heterogeneous intracellular environment due to the presence of multiple membrane-bound organelles, including acidic compartments such as lysosomes.

Importantly, weakly basic, amine-containing small molecule drugs (pKa >7) displayed pronounced intracellular “stickiness,” reflected by progressively lower diffusion coefficients with increasing pKa values. This behaviour is consistent with widespread nonspecific electrostatic interactions between positively charged molecules and anionic cellular constituents distributed throughout the cytoplasm. Notably, even after pharmacologically inhibiting lysosomal acidification, the overall diffusion behaviour changed only marginally, suggesting that these nonspecific electrostatic interactions are not restricted to acidic organelles alone but occur broadly across the intracellular environment.

Collectively, these findings indicate that simplified theoretical descriptions such as porous-medium models may adequately describe the diffusion of electronegative larger proteins but are insufficient for explaining the intracellular transport behaviour of positively charged signalling molecules, drugs, peptides, and proteins. For such systems, electrostatic effects and other nonspecific intracellular interactions appear to play a dominant role and therefore need to be incorporated into future models of intracellular diffusion.

Overall, our research is focused on combining advanced

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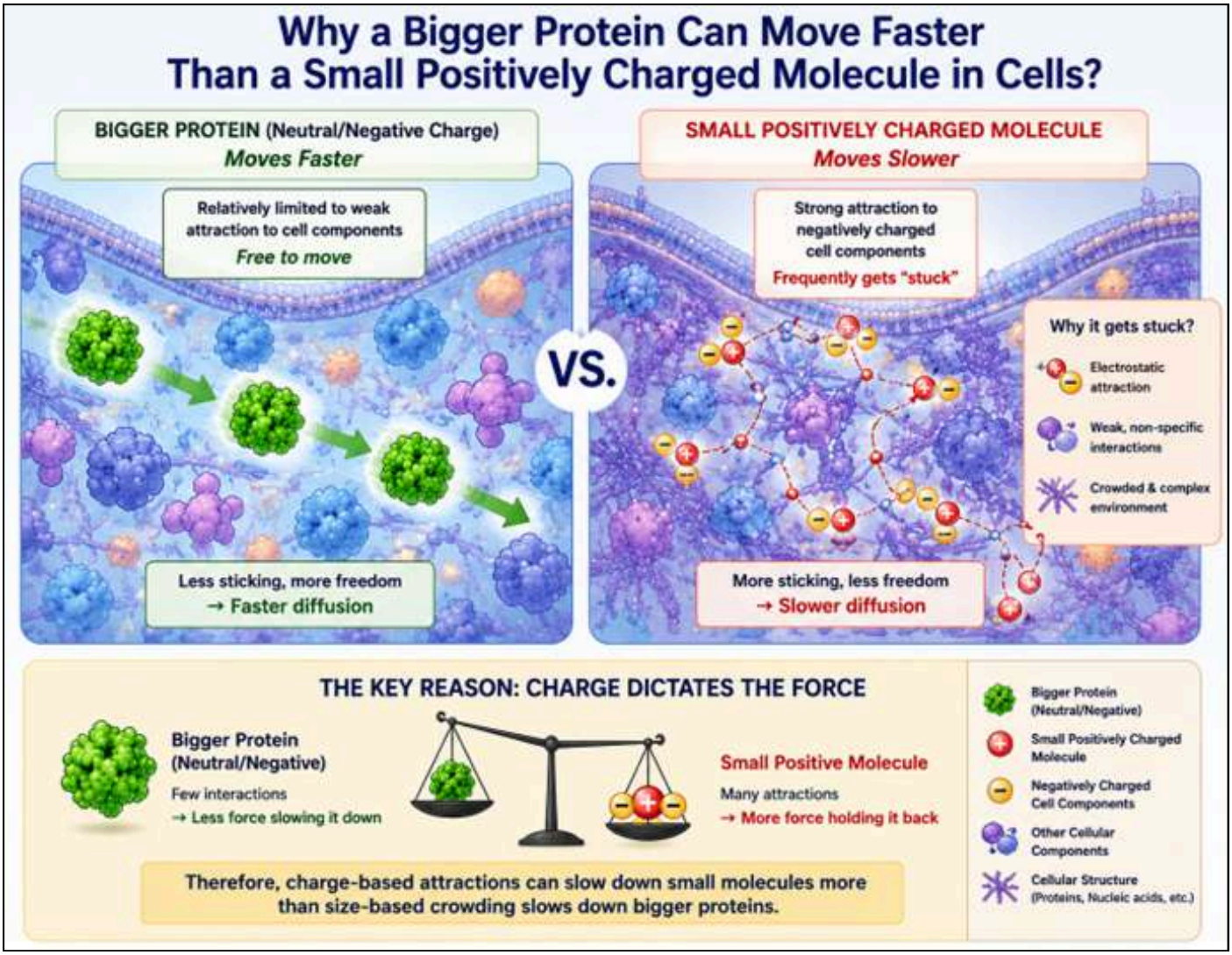


optical microscopy and super-resolution imaging approaches to directly visualize small-molecule drugs, their cellular targets, and hidden off-target interactions inside living cells. By uncovering how drugs navigate the complex intracellular environment, we aim to design next-generation precision therapeutic strategies that minimize off-target effects and enable more selective and effective cancer treatments.

Acknowledgements:
Dr. Dey acknowledges support from the Department of Biotechnology (DBT), Ministry of Science & Technology, Government of India, through the Ramalingaswami Re-entry Fellowship. ChatGPT (OpenAI) was used for language refinement and generation of selected illustrative graphics. The author reviewed and edited all content and takes full responsibility for the article.

> *Understanding how molecules diffuse inside cells is essential for designing more precise and effective medicines.*

Dr. Dey's contributions to the field are reflects in his publications in PNAS (2026), https://doi.org/10.1073/pnas.2605166123 ; eLife (2024), https://doi.org/10.7554/eLife.97255.3 ; Journal of Molecular Biology (2021), https://doi.org/10.1016/j.jmb.2021.166898; These studies provide important insights into intracellular diffusion dynamics, molecular transport, and drug behavior within living cells, advancing our understanding of how molecules move and interact within complex cellular environments.

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. Sivan Friedman

WHO WRITES THE WORLD'S POLICIES?

Amina adjusted her glasses and looked at the long list of references at the end of her report. Sitting in her office at the Ministry of Agriculture in Nairobi, she was preparing a policy to help Kenyan farmers cope with severe drought. The stakes were high. Millions of people depended on agriculture, and another failed season could push many families into hunger. As she reviewed the document, something caught her attention. Most of the references were not from Kenya. There were reports from the United States Department of Agriculture, studies from universities in the United Kingdom, and recommendations from the World Bank and the United Nations. Amina leaned back in her chair and wondered, "Why am I writing a policy for Kenya using so much knowledge from other countries?"

Later that day, her colleague David stopped by. "You look deep in thought," he said. Amina turned her screen toward him. "I just noticed that most of the evidence in this report comes from the US and Europe." David smiled. "That's actually how policymaking works in much of the world." He explained that a recent study analyzed more than 1.2 million government policy documents from 185 countries. The researchers examined which reports and scientific papers governments cited when drafting their policies. They found that, across the globe, policymakers rely heavily on evidence produced in a small group of wealthy countries, especially the United States and the United Kingdom. Amina was surprised. "So governments in Africa, Asia, and Latin America are all looking to the same countries for answers?" "Exactly," David said.

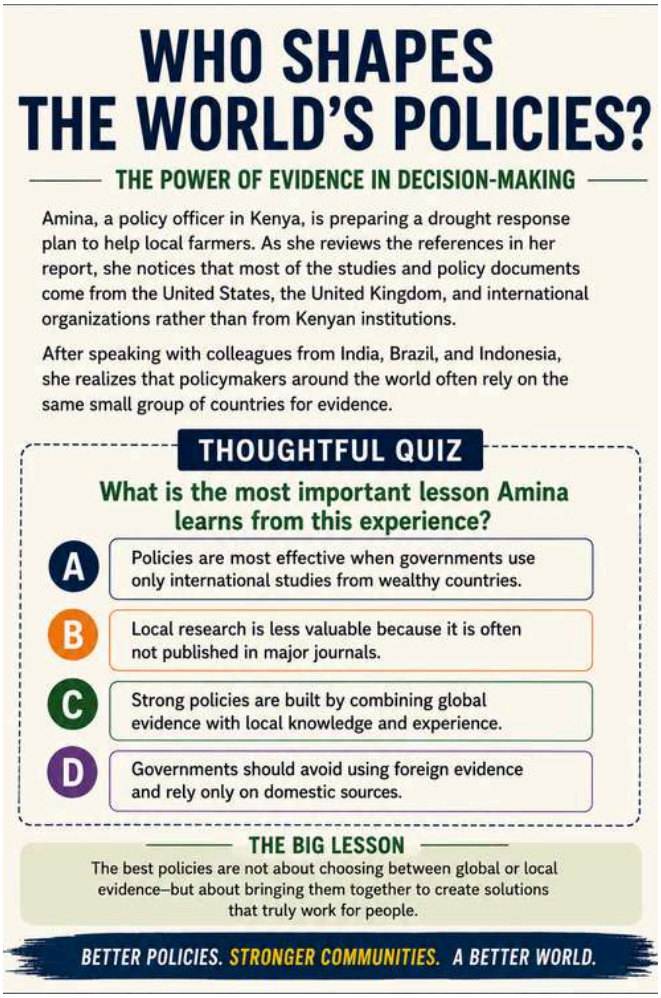
The study showed that governments in wealthy nations mostly cite their own domestic sources. In contrast, governments in the Global South cite foreign sources far more often. In African countries, only about 13% of policy references came from domestic documents, while in Western Europe, around 73% were domestic. Amina thought about the many talented scientists working in Kenya. Their research on drought-tolerant crops and sustainable farming was valuable, but much of it was not a-

| By Dr. Sivan Friedman

s visible as studies from larger institutions overseas. The next week, Amina joined an international workshop with policymakers from India, Brazil, and Indonesia. As they shared their experiences, she realized they all faced the same situation. Priya from India was drafting a health policy and relied heavily on studies from the United States. Carlos from Brazil used climate reports from Europe. Sari from Indonesia cited fisheries research from Australia and the UK. Different countries. Different problems. But the same sources of knowledge.

The researchers found that the United States was the single most influential contributor to global policymaking. In fact, 43% of all academic papers cited in policy documents worldwide included at least one author affiliated with a US institution. This dominance is not accidental. Countries like the United States and the United Kingdom invest enormous amounts in research and development. They produce large numbers of scientific papers, policy reports, and public databases. Their institutions make information easy to access online, so policymakers everywhere can find and cite it. By contrast, many countries in the Global South have fewer resources to publish and distribute their own research. Important local studies may exist, but they are often harder to discover. The study also showed that some policy areas depend more on scientific research than others. Health, agriculture, environment, and technology policies frequently cite academic studies, while housing and government administration rely more on reports and internal documents. But regardless of the topic, one trend remained clear: when governments used foreign evidence, it almost always came from developed countries.

That evening, Amina visited her father, who had farmed the same land for over forty years. After listening to her explanation, he said, “It is good to learn from others. But no one understands our soil better than the people who work on it every day.” His words stayed with her. The next morning, Amina revised her report. She kept the international studies, but she also added research from Kenyan universities, reports from local agricultural institutes, and insights from extension officers who worked directly with farmers. Her final policy was stronger because it combined global knowledge with local experience. The study’s authors argue that this is the future of better policymaking. Governments should invest in their own research systems, make local evidence more accessible, and strengthen collaboration among countries in the Global South. When Amina submitted her report, she felt a renewed sense of purpose. She had learned that policymaking is not just about finding evidence. It is about deciding whose knowledge matters. Today, a small number of wealthy countries help shape policies around the world. But as more nations share their own research and experiences, the global conversation can become richer, more balanced, and more relevant to the people those policies are meant to serve.



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| By Dr. Dhanashree Mundhe

NICKEL, NATURE, AND THE PRICE OF A GREENER FUTURE

Rina stood on a hill overlooking a dense tropical forest in Sulawesi, Indonesia. She was an environmental scientist, and below her, the forest stretched like a green ocean toward the coast, where coral reefs shimmered beneath clear blue water. Hornbills flew overhead, and in the villages below, fishermen prepared their boats while farmers tended coconut trees. But the peaceful landscape was changing. Surveyors had arrived, and rumors spread that a large nickel mine would soon be built. Rina knew why. Around the world, electric cars, solar panels, and battery factories were expanding rapidly, and all of them needed nickel. This metal was becoming one of the most important ingredients in the fight against climate change. Yet the forest before her was also one of the richest places for biodiversity on Earth. “Are we saving the planet,” she wondered, “by destroying some of its most precious ecosystems?”

A few days later, Rina met Daniel, a mining engineer working with an international energy company. He explained that global demand for nickel was expected to rise sharply between 2025 and 2050. Most of that supply nearly 80% would come from laterite deposits, which lie close to the surface beneath tropical forests in countries such as Indonesia, the Philippines, and New Caledonia. Extracting these deposits required clearing vegetation and removing enormous amounts of soil and rock. Daniel showed Rina maps from a recent study revealing that nearly half of all future nickel production may overlap with the top 10% of global land areas most critical for biodiversity and carbon storage. “These forests hold thou-

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sands of species and vast stores of carbon," Rina said. "If we cut them down, we release the carbon we are trying to keep out of the atmosphere." Daniel nodded. "That is the dilemma. We need nickel to build a cleaner world, but much of it lies beneath ecosystems that are irreplaceable."

Rina's concern deepened when she traveled to the coast. Red-brown sediment from existing mines stained the water near mangroves and coral reefs. Fishermen told her that catches had declined, and some reefs were struggling to recover. The study estimated that more than half of future nickel supply could come from mines located within 50 kilometers of the world's most important marine ecosystems. Rainfall in tropical regions washes loose soil and heavy metals from mine sites into rivers and coastal waters, threatening fish, corals, and seagrass beds. In places such as Raja Ampat and the Coral Triangle, some of the planet's most diverse marine habitats sit dangerously close to nickel deposits. "One mine can damage both the forest and the sea," Rina thought as she watched children playing near the shore. "And when nature suffers, local communities suffer too."

At an international conference, Rina joined scientists, policymakers, and industry leaders to discuss solutions. Some argued for declaring "no-go zones" where mining would be prohibited in the most sensitive ecosystems. Others proposed expanding recycling, but experts explained that recycled nickel would supply only a small fraction of demand in the coming decades because most nickel remains locked in long-lived products like buildings and machinery. Another controversial option was deep-sea mining in the Pacific Ocean, where metal-rich nodules lie on the ocean floor. The study suggested that these nodules could provide up to a quarter of future nickel demand and reduce pressure on tropical forests. But many scientists warned that deep-sea ecosystems are poorly understood, and disturbing them could have lasting consequences. Rina realized there was no perfect solution. Every path involved trade-offs between climate goals, biodiversity, and social impacts.

Months later, as the sun set over Sulawesi, Rina prepared her report. Her message was clear: a low-carbon future must also be a nature-positive future. Governments and companies should avoid mining in the most critical conservation areas, strengthen environmental safeguards, rehabilitate damaged land, improve supply chain transparency, invest in recycling, and develop battery technologies that use less nickel. Climate change and biodiversity loss are two sides of the same global challenge. If humanity solves one while worsening the other, the victory will be incomplete. As Rina looked once more at the forest meeting the sea, she felt both concern and hope. Nickel may help power a cleaner future, but only wise choices will ensure that the journey to a greener world does not come at the expense of the natural wonders we are trying to protect.

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| By Dr. Sudha Shankar

PLASTIC IN THE SKY: THE HIDDEN HEAT ABOVE US

Dr. Li Wen had spent her career studying the air above Shanghai. She was used to seeing particles of soot, dust, and smoke under her microscope. These were familiar pollutants, and scientists had studied their effects on climate for decades. But one spring morning, while examining samples collected from the roof of her laboratory at Fudan University, she noticed something she did not expect. Tiny blue, red, yellow, black, and white fragments were scattered among the other particles. They were pieces of plastic—some as small as bacteria, others even smaller. Her graduate student, Mei, looked through the microscope and asked, "How did plastic get into the air?" Dr. Li explained that plastic waste breaks into microscopic fragments that can be lifted by wind from roads, landfills, oceans, and even clothing fibers released during washing. These particles are called microplastics and nanoplastics. They had already been found in rain, mountain snow, and polar ice. But Dr. Li had a new question: "If these particles are floating in the sky and interacting with sunlight, could they also be affecting Earth's climate?"

To answer that question, Dr. Li and Mei began a series of careful experiments. They collected common plastics such as polyethylene, polystyrene, and PET from everyday products and ground them into tiny particles. They separated the particles by color and studied how each one interacted with light. What they found surprised them. White plastic reflected much of the sunlight, but colored particles—especially black, yellow, red, and blue—absorbed large amounts of energy. Black plastic was particularly powerful, behaving almost like black carbon, the soot produced by engines and fires. On average, colored particles absorbed sunlight about 75 times more strongly than clean, transparent plastic. The team also simulated atmospheric ageing by exposing the particles to ultraviolet light, oxygen, and humidity. Some particles yellowed, while others faded, but overall their warming ability changed very little. "That means these particles can continue absorbing sunlight for days or weeks as they travel through the atmosphere," Mei said. Dr. Li nodded. "Color matters more than the type of plastic itself."

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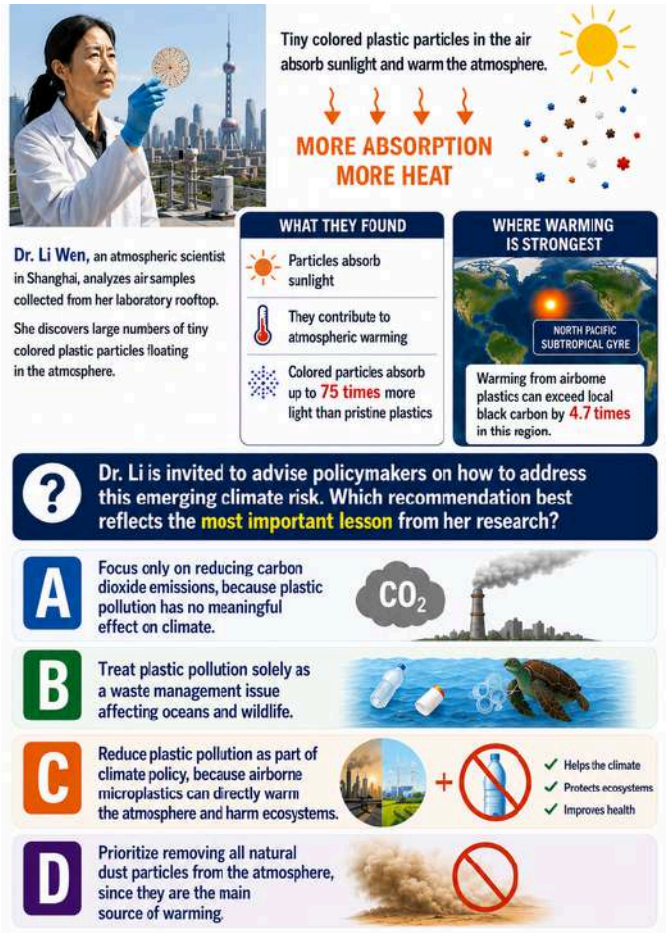
The next step was to estimate how much plastic was floating in the atmosphere. Using global transport models, the researchers calculated that the air near Earth's surface contains on average about 4.18 microplastic particles per cubic meter, along with 3.67 nanograms of nanoplastics per cubic meter. These particles were not confined to polluted cities. They were found over remote oceans, high mountains, and even Antarctica. Nanoplastics were especially concerning because their tiny size allows them to remain suspended in the air much longer than larger particles and travel enormous distances. The highest concentrations were predicted over East Asia, Europe, North America, and the North Pacific Subtropical Gyre, where plastic waste accumulates in the Great Pacific Garbage Patch. During storms and strong winds, plastic fragments are lifted into the atmosphere and carried thousands of kilometers. Looking at the colorful global maps, Mei was astonished. "Plastic pollution has become part of the atmosphere itself," she said. Dr. Li agreed. "And if it is everywhere, its climate effect could be global."

When the researchers incorporated these data into a radiative transfer model, the results were startling. Airborne microplastics and nanoplastics were estimated to produce a global warming effect of 0.039 watts per square meter. Although that number is much smaller than the effect of carbon dioxide, it is remarkably large for a pollutant that had never been included in climate models. In fact, it represents about 16.2% of the warming caused by black carbon, one of the most important short-lived climate pollutants. In some regions, especially over the North Pacific Subtropical Gyre, the warming effect of airborne plastics reached 1.34 watts per square meter—more than four times greater than the warming caused by local black carbon. "We always thought of plastics as a pollution problem for oceans and wildlife," Mei said. "Now we know they are also trapping heat in the atmosphere." The study showed that plastics are a previously unrecognized climate forcing agent, meaning they directly alter Earth's energy balance by absorbing sunlight.

One evening, after the paper had been accepted for publication, Dr. Li stood by the window of her office and looked at the Shanghai skyline. She thought about the journey of a plastic bottle. It might be used for a few minutes, discarded carelessly, broken into microscopic fragments by sunlight and waves, lifted into the atmosphere by wind, and eventually become part of the invisible haze that warms the planet. Plastic pollution, she realized, was connected to climate change in more ways than anyone had imagined. Plastics already contribute to greenhouse gas emissions during manufacturing and disposal. Now there was evidence that the particles themselves also trap heat after they are released into the environment. Dr. Li hoped this discovery would change how society views plastic waste. Reducing single-use plastics, improving waste management, expanding recycling, and designing sustainable materials could protect ecosystems, improve human health, and also help cool the planet. As she closed her notebook, she wrote one final thought: "The plastic we throw away does not disappear. Some of it rises into the sky and quietly changes the climate of the Earth."



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| By Dr. Priyangana Deb

THE OCEAN'S HIDDEN PHARMACY

Dr. Maya Chen stood on the deck of a research ship as it drifted across the Pacific Ocean. The sun was setting, and the sea stretched endlessly in every direction. Beside her stood Leo, a curious high school student who had won a science contest and earned the chance to join the expedition. Maya lowered a bottle into the seawater and held it up to the light. "It may look like ordinary seawater," she said, "but this bottle contains millions of microbes. Each one carries DNA instructions that could help us discover the next antibiotic or life-saving medicine." Leo looked puzzled. "If these microbes are so important, why haven't we already studied them?" Maya smiled. "Because most of them refuse to grow in the laboratory. It's like having millions of books written in a language no one can read." She pointed to her laptop. "That's why we built DeepSeMS, an artificial intelligence system that can read those hidden instructions and predict the molecules the microbes are capable of making."

Later that evening, Maya showed Leo a colorful diagram on her screen. "Inside microbial DNA," she explained, "there are special groups of genes called biosynthetic gene clusters, or BGCs. These are like recipe cards. Each recipe tells the microbe how to build a chemical compound." Some of these compounds become famous medicines, such as penicillin, which has saved millions of lives. Leo leaned closer. "So DeepSeMS reads the recipe and predicts what the final molecule looks like?" "Exactly," Maya said. "It works much like a language translator. If you enter a sentence in English, ChatGPT can translate it into French. DeepSeMS translates a genetic language into a chemical language." Instead of reading every letter of DNA, the AI focuses on the most important sections—the functional domains of enzymes, which are like the active tools in a molecular factory. "One domain may add a carbon ring, another may attach a sugar, and another may modify the structure," Maya explained. "By learning how these tools work together, the AI can imagine the final molecule."

Back in the ship's laboratory, Maya described how they taught the AI. "We used more than 3,000 gene clusters whose products were already known," she said. "Each cluster was paired with the exact chemical structure it produces." To help the AI learn chemistry better, the team

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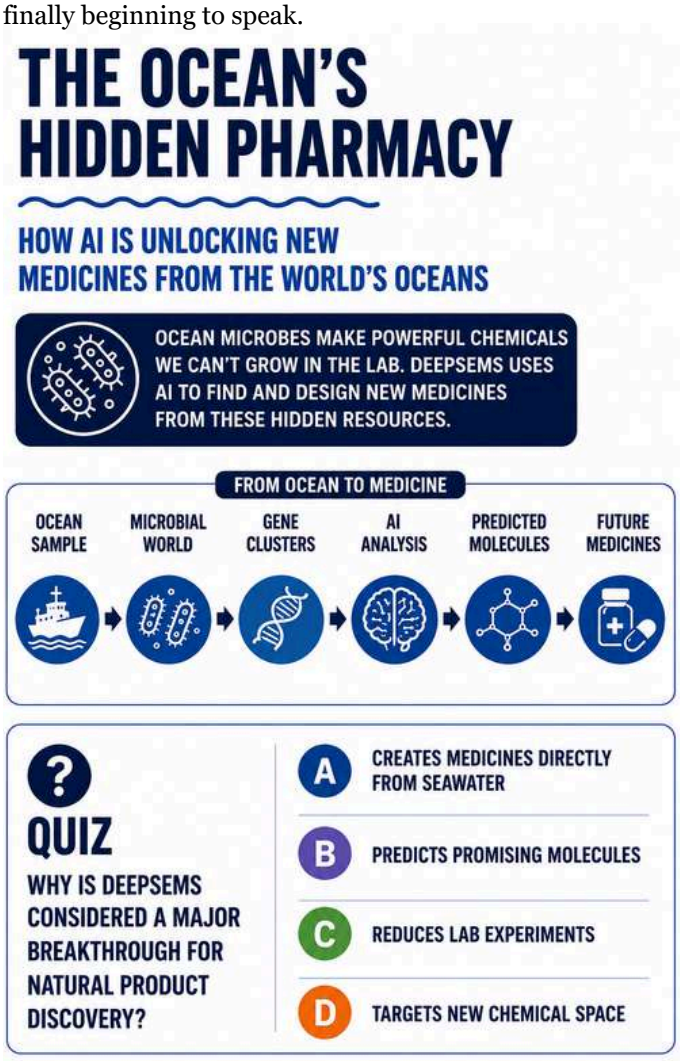
showed it the same molecule written in many different text forms, called SMILES strings. “That’s like teaching a child that ‘water,’ ‘H_2O,’ and a picture of a molecule all mean the same thing,” Leo said. Maya nodded. “Exactly.” After training, they tested DeepSeMS against older tools. On known gene clusters, it predicted the exact molecule in more than 40% of cases—far better than previous methods. On mysterious gene clusters that had never been decoded before, it succeeded in producing valid chemical structures for over 96% of them. Leo’s eyes widened. “So it can make smart guesses about molecules no one has ever seen?” “That’s the exciting part,” Maya replied. “It gives us a glimpse into a hidden chemical universe.”

The next morning, Maya and Leo examined a world map filled with glowing dots. “These dots represent seawater samples collected from every major ocean,” Maya said. The team analyzed over 27,000 microbial genomes and found nearly 47,000 biosynthetic gene clusters. DeepSeMS transformed those genetic recipes into more than 65,000 unique predicted molecules. “And here’s the astonishing part,” Maya said. “About 97% of them are unlike any natural product scientists have ever recorded.” Some of the most unusual molecules came from deep, cold waters where sunlight never reaches. Others carried chemical signatures commonly found in antibiotics. “We identified more than 8,700 molecules that could potentially kill harmful bacteria,” Maya said. They also found thousands of ectoine-like compounds that might protect human cells from stress and be useful in cosmetics and medicine. Leo stared at the screen in amazement. “So the ocean is like a giant pharmacy that we’ve barely explored.” Maya smiled. “Exactly. And AI just handed us the map.”

On the final night of the voyage, Leo stood at the railing and looked across the dark ocean. “It’s incredible to think that invisible microbes could hold the key to future medicines,” he said. Maya joined him. “For decades, scientists had to grow microbes, extract compounds, and spend years figuring out their structures. DeepSeMS changes that. Now we can start with DNA and predict promising molecules in minutes.” She explained that the team had created a free website where researchers around the world can upload a gene cluster and receive predicted structures, novelty scores, and clues about drug potential. “Of course, we still need experiments to confirm what the AI predicts,” she said. “But DeepSeMS tells us where to look.” Leo watched the moonlight shimmer on the waves and imagined countless microbes drifting below, each carrying chemical secrets billions of years in the making. Thanks to artificial intelligence, those hidden recipes were finally beginning to speak.



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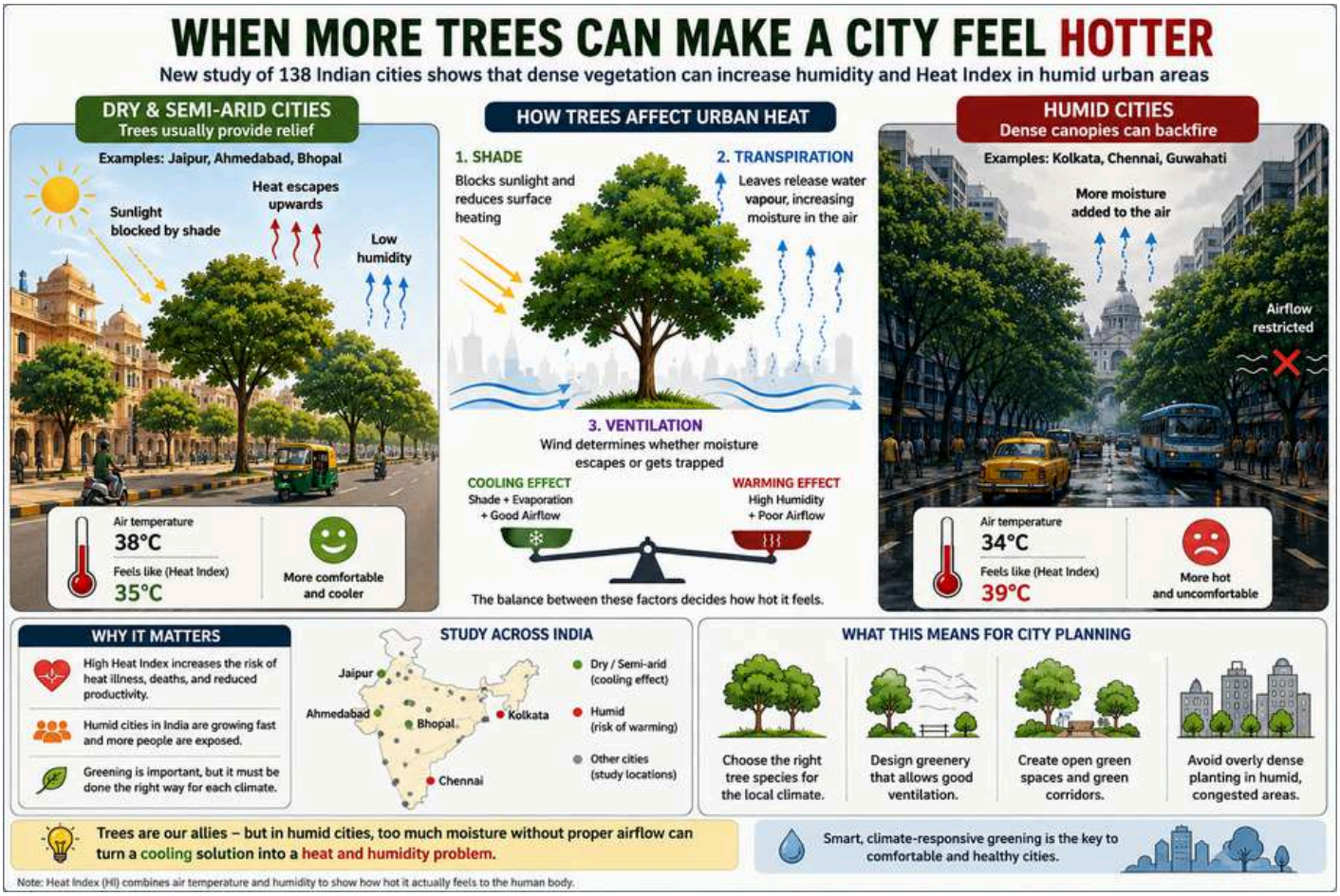
| By Dr. Sourav Kumar

WHEN MORE TREES CAN MAKE A CITY FEEL HOTTER

One summer afternoon in Ahmedabad, twelve-year-old Riya was walking home from school. The sun was blazing, and the road shimmered with heat. As she crossed one neighborhood, she felt the harsh sunlight directly on her face. There were only a few small trees, and the street seemed like an oven. A little farther ahead, she entered another street lined with large neem and banyan trees. Thick branches stretched overhead, casting deep shade on the road. Riya smiled, expecting an instant sense of relief. The sunlight was blocked, birds chirped above, and the street looked much cooler. But after a few minutes, she noticed something strange. The air felt sticky and heavy. Sweat clung to her skin, and she felt almost as uncomfortable as before. “That doesn’t make sense,” she said to herself. “If there are more trees, shouldn’t it feel cooler?” That evening she asked her older brother Arjun, a climate science student. He laughed and said, “You’ve just asked the same question that a team of Indian scientists wanted to answer.”

Arjun explained that researchers studied 138 cities across India, including dry cities such as Jaipur and Ahmedabad and humid cities such as Kolkata and Chennai. They wanted to know how trees affect the way people experience heat. Instead of measuring only temperature, they used something called the Heat Index, which combines temperature and humidity to estimate how hot the weather actually feels to the human body. For example, 35°C on a dry day may feel manageable, but 35°C on a humid day can feel much hotter because sweat evaporates more slowly. The scientists used satellite images to measure how green each city was, how dense the leaves were, and how actively the plants were releasing water into the air. They then used artificial intelligence to analyze how these factors changed the Heat Index. Their goal was simple but important: to understand whether planting more trees always makes cities more comfortable.

The results showed that trees have two powerful and sometimes competing effects. First, they provide shade. By blocking sunlight, trees keep roads, sidewalks, and buildings from heating up as much. This usually makes the surrounding area cooler. Second, trees release water vapor

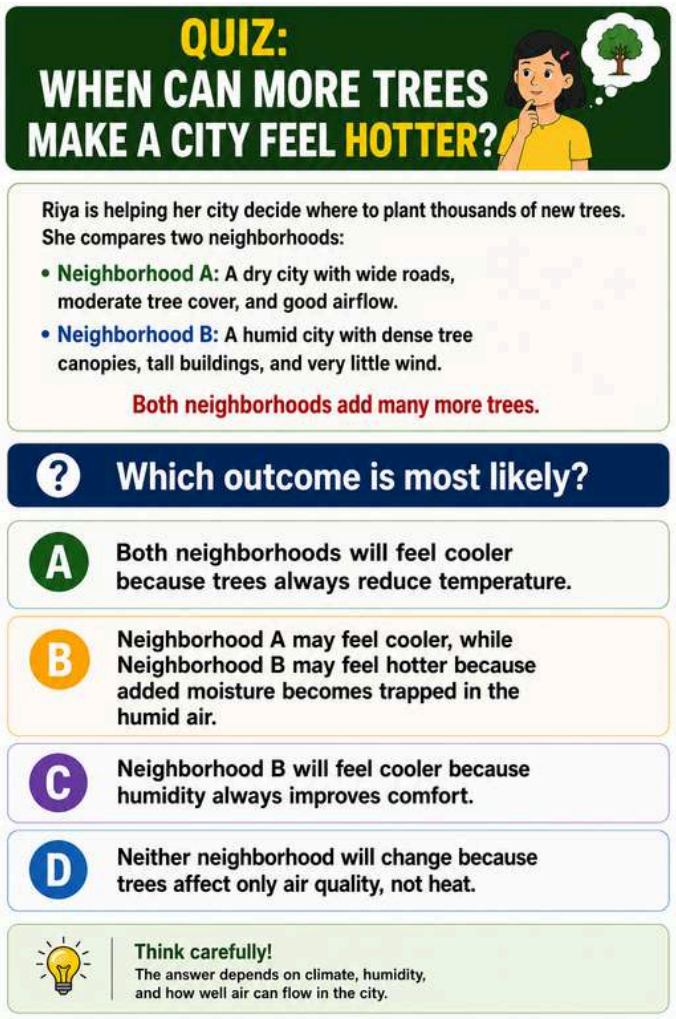


| By Dr. Sourav Kumar

through a natural process called transpiration. Plants absorb water from the soil and release some of it through tiny pores in their leaves. This process can cool the air, much like perspiration cools our skin. In dry climates, both shade and transpiration work together to reduce heat stress. But in humid climates, where the air is already full of moisture, extra water vapor may make conditions feel more uncomfortable. The scientists found that in some dense and humid urban areas, very lush vegetation could increase the Heat Index by 1–2°C. In other words, even though the air temperature might be slightly lower, the added humidity could make the environment feel hotter.

Arjun gave Riya a simple example. “Imagine sitting under a tree in Delhi on a hot, dry afternoon,” he said. “The tree blocks the sun, and the little moisture it releases makes the air feel fresh and cool.” Then he continued, “Now imagine standing under a dense canopy in Kolkata during the monsoon. The tree still provides shade, but it also releases moisture into air that is already humid. If tall buildings block the wind, that moisture stays trapped around you. Your sweat cannot evaporate easily, so you feel sticky and hotter.” Riya immediately understood. It was like wearing a wet raincoat on a hot day. The study showed that this effect was strongest in neighborhoods where buildings were closely packed together and airflow was poor. In more open areas, even in humid cities, trees were more likely to improve comfort because the wind could carry away excess moisture.

This discovery carries an important lesson for urban planners and city leaders. Planting trees remains one of the best ways to improve urban environments. Trees provide shade, absorb carbon dioxide, reduce pollution, support biodiversity, and make cities more attractive and livable. But the study shows that successful greening strategies must be tailored to local climate conditions. In dry and semi-arid cities, increasing tree cover is generally an excellent solution for reducing heat stress. In humid cities, planners should select tree species and planting designs that provide shade while preserving good airflow. Parks, green corridors, and tree-lined streets should be arranged to allow wind to move freely rather than trapping moist air. As Riya looked out the window at the trees swaying gently outside, she realized that nature is powerful but works best when we understand how it interacts with the environment. Sometimes, making a city cooler is not just about planting more trees—it is about planting the right trees in the right places.



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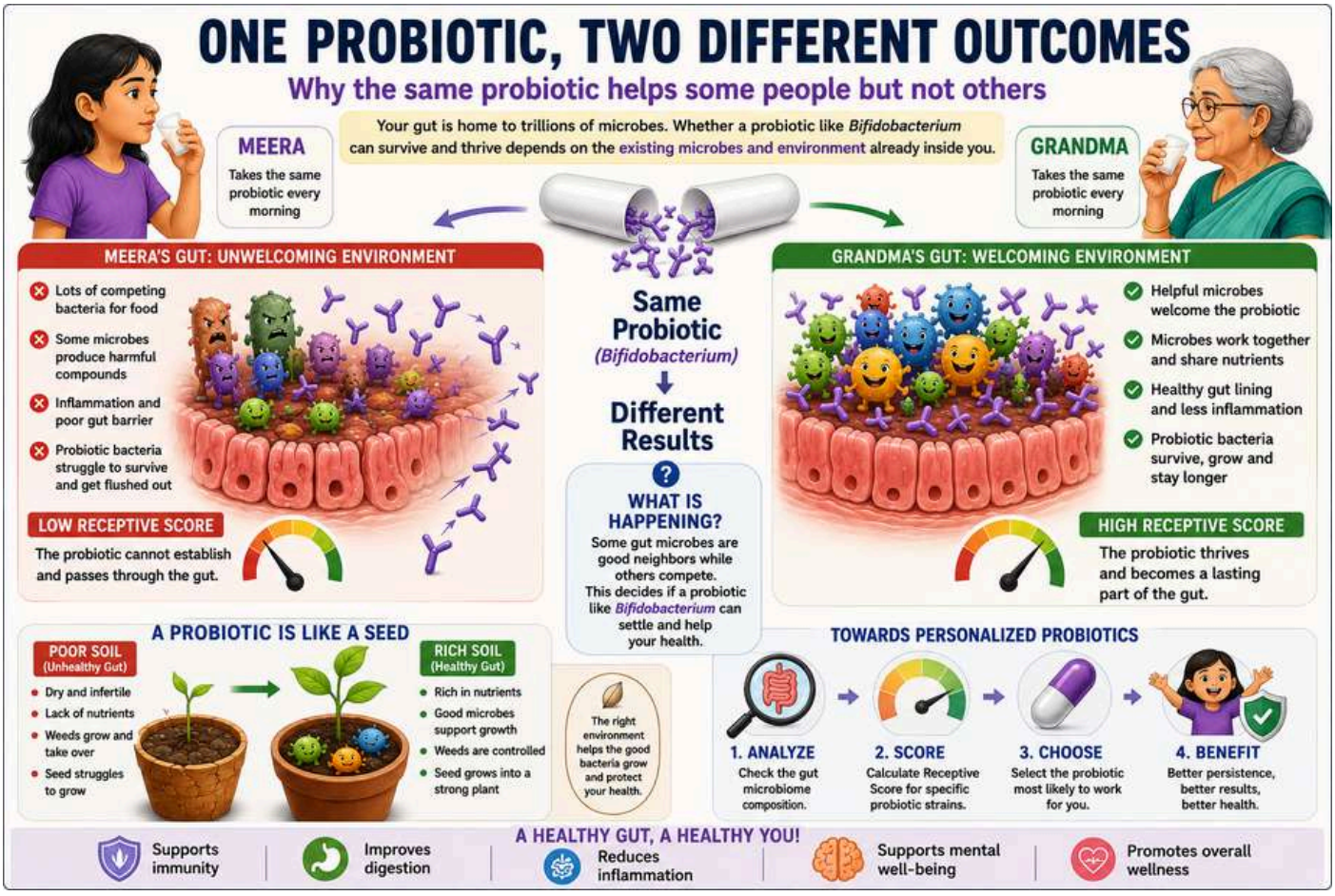
| By **Dr. Poulami Chakraborty**

WHY THE SAME PROBIOTIC HELPS GRANDMA BUT NOT MEERA

Twelve-year-old Meera often felt that her stomach had a personality of its own. Some days she could eat anything and feel perfectly fine. On other days, even a simple meal left her with bloating, cramps, and discomfort. Her grandmother, who trusted traditional remedies and healthy foods, gave her a bottle of probiotic yogurt one morning and said, "Drink this every day. It contains good bacteria that will help your stomach." Meera followed her advice carefully for two weeks. Her grandmother felt lighter, more energetic, and said her digestion had improved. But Meera noticed almost no difference. Her stomach still felt unpredictable. "How can the same probiotic help you so much but do nothing for me?" she asked. Curious to understand, she visited her uncle, Dr. Arjun, a microbiologist at a research institute in Delhi. He smiled and said, "That is one of the most important questions scientists are trying to answer today."

Dr. Arjun explained that Meera's digestive system was home to trillions of microorganisms, collectively called the gut microbiome. These tiny organisms include bacteria, fungi, and viruses, and together they form a bustling community inside the intestines. He compared the gut to a large city. Some microbes are helpful citizens that recycle waste, make vitamins, train the immune system, and keep harmful invaders under control. Others can cause trouble if they become too abundant. Among the most beneficial residents are bacteria known as Bifidobacterium. These microbes help break down food, reduce inflammation, strengthen the immune system, and produce substances that nourish the cells lining the intestine. Many probiotic supplements are made with Bifidobacterium because of these health benefits. But swallowing beneficial bacteria does not guarantee they will survive and settle in the gut.

"To understand why," Dr. Arjun said, "imagine planting a mango seed." If you place the seed in rich, moist soil with enough nutrients, it can sprout and grow into a strong tree. But if you drop the same seed on dry, rocky ground, it may never grow. Probiotics behave in the same way. The bacteria in a probiotic are like seeds, and your gut microbi-



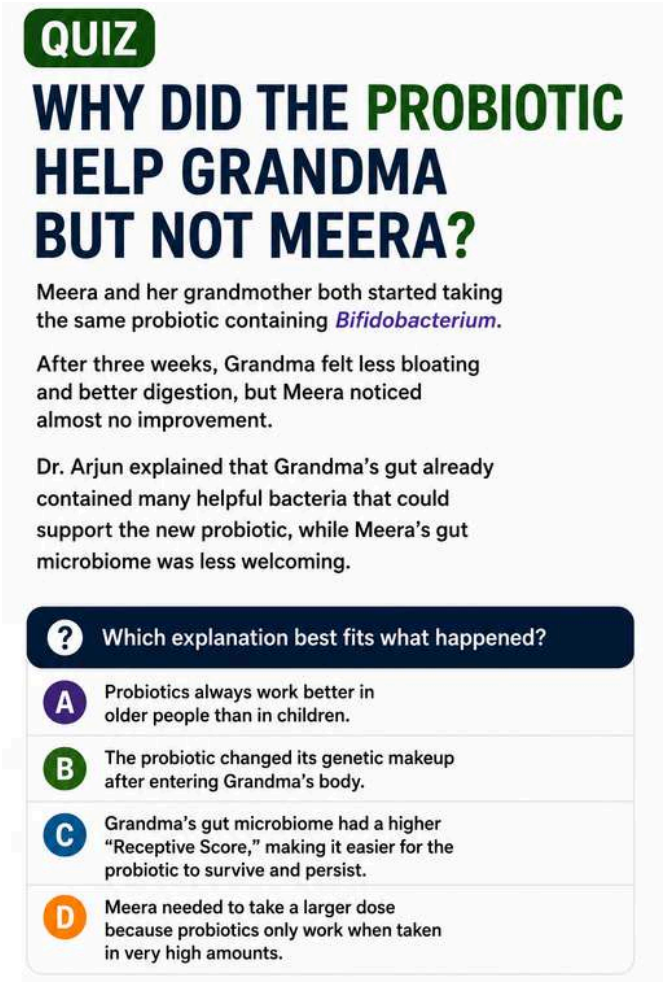
| By Dr. Poulami Chakraborty

ome is the soil. When the probiotic enters the gut, it must find food, compete with existing microbes, and adapt to its new environment. Some resident microbes act like friendly neighbors, sharing nutrients and creating favorable conditions. Others compete for resources or make the environment less welcoming. In a major study led by Indian scientists, researchers analyzed more than 51,000 gut microbiome samples from 45 countries. They found that people whose guts already contained certain supportive bacteria were much more likely to retain probiotic Bifidobacterium. Others, whose microbiomes lacked these partners, often experienced little benefit from the same probiotic.

The researchers discovered that some gut bacteria are especially helpful companions. Many of them produce butyrate, a small molecule that reduces inflammation and keeps the intestinal lining healthy. These bacteria and Bifidobacterium often cooperate through a process called cross-feeding. One species breaks down dietary fiber into smaller molecules, and another species uses those molecules to make compounds that benefit the host. To predict whether a probiotic would succeed, the scientists developed a mathematical tool called the Receptive Score. This score estimates how welcoming a person's gut environment is to a particular probiotic strain. A high score means the gut contains many supportive microbes, increasing the chances that the probiotic will survive and persist. A low score suggests the probiotic may pass through without establishing itself. When the researchers tested this score using data from eight independent probiotic trials involving more than 1,600 microbiome samples, they found that people with higher Receptive Scores were much more likely to experience long-term probiotic colonization.

Meera listened carefully and finally understood. "So probiotics are not one-size-fits-all," she said. "Exactly," Dr. Arjun replied. "Two people can swallow the same probiotic, but their guts may be as different as two gardens." One garden is fertile and ready for new seeds. The other may need different nutrients before anything can grow. This discovery could transform the future of medicine. Instead of recommending the same probiotic to everyone, doctors may first analyze a patient's gut microbiome and choose the strains most likely to thrive in that individual. Personalized probiotics could help treat digestive disorders, inflammatory diseases, and even conditions related to immunity and mental health.

Meera looked again at her probiotic bottle with new appreciation. It was not simply a drink containing "good bacteria." It was a tiny group of travelers searching for a welcoming home. And whether they stayed depended on the invisible world already living inside her.



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| By Dr. Ipsita Mohanty

THE MOSQUITO'S SECRET INTELLIGENCE NETWORK

On a warm evening in Singapore, twelve-year-old Aarav stood beside Dr. Maya Rao in a brightly lit laboratory. On the bench in front of them were dozens of small tubes, each containing Aedes aegypti mosquitoes the same black-and-white striped mosquitoes that spread dengue, Zika, and chikungunya. To most people, mosquitoes are little more than annoying insects. They buzz around our ears, bite our skin, and sometimes carry dangerous diseases. But Dr. Rao saw them differently. "Each mosquito," she told Aarav, "is like a tiny flying world. Inside its body lives a whole community of viruses, and the mosquito is constantly fighting to keep them under control." Aarav looked surprised. "If mosquitoes carry so many viruses," he asked, "why don't they get sick?" Dr. Rao smiled. "That's exactly what scientists around the world have been trying to understand."

To answer this question, researchers collected more than 200 mosquito samples from Asia, Africa, and the Americas. They wanted to know which viruses were hiding inside these insects and how mosquitoes defend themselves. Dr. Rao explained that mosquitoes have a remarkable immune system. "Imagine a burglar enters your house," she said. "Your security cameras take snapshots, and your alarm system uses those pictures to find the intruder." Mosquitoes do something very similar. When a virus infects a mosquito cell, the cell cuts the viral genetic material into tiny pieces called small RNAs. These fragments act like molecular wanted posters. They are loaded into special proteins that search for matching viral RNA and destroy it. This defense system is called RNA interference, or RNAi. By sequencing these tiny RNA fragments, scientists can identify which viruses are present, even if they have never seen those viruses before.

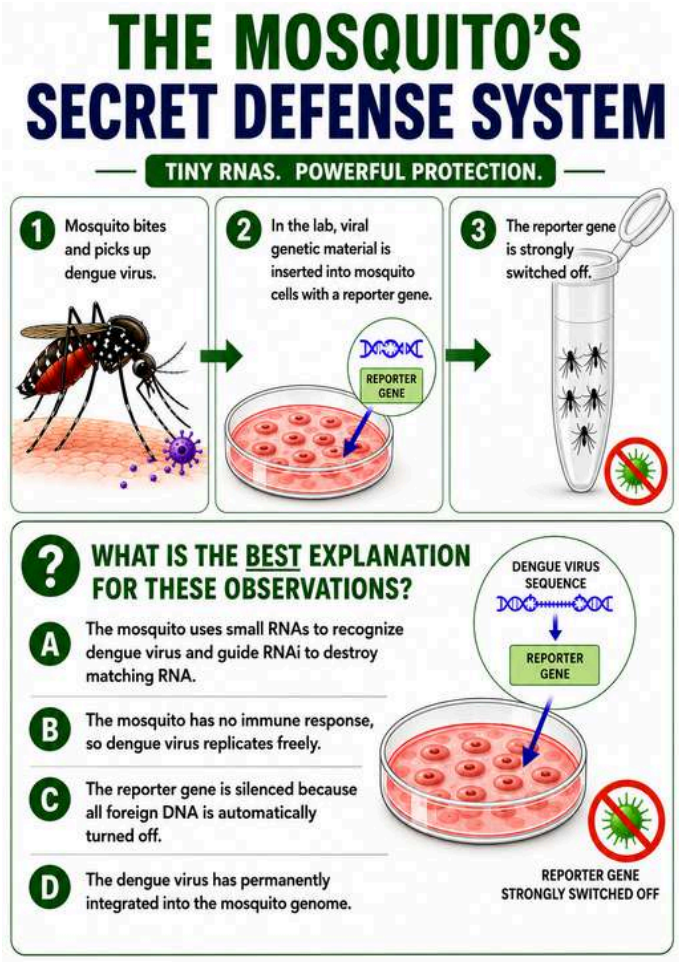
When the researchers analyzed the mosquito samples, they discovered dozens of hidden viruses. Some were known insect-specific viruses that infect only mosquitoes and pose no threat to humans. Others were new and had never been described before. The viral communities differed dramatic-

| By Dr. Ipsita Mohanty

ally from one continent to another. Mosquitoes from South America often carried viruses such as Phasi Charoen-like virus, while African mosquitoes harbored different viral species. One of the most exciting discoveries came from Singapore, where the scientists found strong evidence that a wild mosquito was actively infected with dengue virus. The small RNAs inside that mosquito perfectly matched dengue, showing that its immune system was already responding to the infection. The researchers also noticed an important difference between mosquitoes raised in laboratories and those collected in the wild. Many laboratory strains carried only a few viruses, while wild mosquitoes often hosted a much richer viral community. This suggested that the hidden world inside mosquitoes is more diverse than scientists had imagined.

Aarav was fascinated, but he wanted to know how the scientists proved these viruses were real. Dr. Rao explained that they ground up infected mosquitoes, filtered the material, and added it to mosquito cells growing in laboratory dishes. If the cells became infected and produced the same small RNAs, it would confirm that the viruses were alive and active. That is exactly what happened. Some viruses spread easily in the cells and triggered a strong RNAi response. The team then performed an elegant experiment. They inserted a short viral sequence into a reporter gene that normally glows under special light. If the mosquito's small RNAs recognized the viral sequence, they would switch off the reporter gene and the glow would disappear. When this happened, it proved that the tiny RNA fragments were guiding the immune system with remarkable precision. "So these molecules are like guided missiles," Aarav said. "Exactly," Dr. Rao replied. "They seek out matching viral messages and destroy them before the virus can spread."

As the evening came to an end, Aarav looked at the mosquito on the microscope screen with newfound respect. What seemed like a simple insect was actually a miniature battlefield. Viruses were constantly trying to multiply, while the mosquito's RNAi system cut them into pieces and kept them under control. By decoding these tiny RNA signatures, scientists can uncover hidden viruses, monitor disease threats, and better understand why some mosquito populations spread infections more efficiently than others. This knowledge could improve surveillance for dengue and other mosquito-borne diseases and may even lead to new strategies for controlling them. Aarav smiled as he packed up his notebook. "I used to think mosquitoes were just pests," he said. "Now I see they are carrying out one of nature's most sophisticated defense operations." Dr. Rao nodded. "Sometimes," she said, "the smallest creatures hold the biggest secrets."



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SCIENCE DESK

Smart Materials for Energy and Light Control: The Future of Flexible Electronics and Smart Windows

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

AREAS OF EXPERTISE
Nano materials • Energy materials • Supercapacitors • Batteries • Smart Windows

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AREAS OF EXPERTISE
Liquid Crystals • Organic functional materials • Soft matter • Photoresponsive Materials

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AREAS OF EXPERTISE
Liquid Crystals • Organic functional materials • Soft matter • Photoresponsive Materials

Q *What inspired your team to work on multifunctional materials that combine energy storage and electrochromic properties?*

A In this era of global energy demand, the need for smart, energy-efficient and sustainable devices is crucial. Smart windows are used to effectively utilize the energy within the building and reduce overall energy consumption. The Smart windows, which work through electrochromism, consist of two electrodes, with one electrode containing an electrochromic layer and an electrolyte sandwiched between them. Generally, upon application of voltage, ion intercalation within the structure changes the device's color. In any energy storage device, the energy storage mechanism primarily relies on charge intercalation/deintercalation. The materials, which are generally used as energy storage materials (such as carbon-based materials or some metal oxides), may not exhibit electrochromism and cannot be used in a smart window. However, if we can use one electrochromic material to make one smart window and utilise its energy storage properties during ion intercalation, it can serve both purposes simultaneously, without any extra energy cost. Additionally, the electrochromic property of a supercapacitor can serve as a real-time charge indicator, which is highly useful for smart displays and self-indicating energy devices. These were the inspiration to utilize a material's multifunctionalities.

Q *In simple terms, what does your material do, and how can it both store energy and change optical properties (like color or transparency)?*

A Our material is an oxygen-deficient bimetallic oxide. The material works as both an electrochromic and an energy-storage material.

A typical electrochromic device comprises two transparent conducting electrodes - one of which is coated with an electrochromic material, and the other is either a complementary electrochromic material or a bare electrode; and an ion-conducting electrolyte is sandwiched between the two electrodes. When a certain voltage is applied to the electrochromic electrode, the electrons move

toward (or away, depending on the voltage bias) the electrode through the external circuit, and to balance the charge, the ions from the electrolyte intercalate into the structure (or de-intercalate, depending on the bias of the voltage). Through the intercalation of ions into the electrochromic material's structure, the oxidation state of the metal changes, which leads to a change in the color or the optical state of the material. Through this ion intercalation, along with the color change, the material stores the charge, hence stores the energy. The ability to store charge is quantified by areal or specific capacitance. After reversing the applied voltage, the charges exit the structure and the material returns to its original optical state.

Q *Your work focuses on a molybdenum–tungsten bimetallic oxide. What makes this combination unique compared to single-metal materials.*

A The material used in this work, oxygen–deficient molybdenum–tungsten bimetallic oxide, has outperformed individual metal oxides. Molybdenum oxide is well known for its strong redox activity and multiple oxidation states, but it exhibits poor electrochromic performance. On the other hand, tungsten oxide exhibits rich electrochromic performance with high optical modulation and high color purity, but shows limited energy storage performance. Therefore, combining these metals to form the metal oxide provides a high density of redox-active sites. Due to the presence of tungsten oxide, the bimetallic oxide can also exhibit electrochromic performance, with higher color contrast than a single metallic oxide, owing to enhanced ion intercalation. In addition, the material formed in this way exhibited a flower-like structure with a high surface area, a large interplanar spacing, and oxygen vacancies, which also contributed to high ion intercalation. Overall, the bimetallic oxide showed better electrochemical performance than the single metallic oxide.

Q *How does your material improve performance in terms of energy storage and smart window applications?*

A The energy storage performance can be explained through the usual parameters – areal capacitance, specific capacitance, and cyclic stability. The material has exhibited a high areal capacitance of 975 mF cm−2 at a 5 mV s−1 scan rate, which is almost 1.5 times that of an individual tungsten oxide electrode and 3 times that of an individual molybdenum oxide electrode. It showed a high specific capacitance of 234 F g-1 at a current density of 5 A g-1, and remained stable for 1000 cycles at 10 A g-1. When integrated into a flexible device, it demonstrated 10,000 cycles of stability at a current density of 1 A g-1. The flexible device, consisting of a flexible electrode and a gel electrolyte, can operate similarly while bending to different radii and at both low and high temperatures.

As an electrochromic electrode, this material showed a good optical modulation with fast switching, with response and recovery times of 1.5 s and 3.5 s, respectively, and a high stability of 2000 cycles. While integrated as a device, it showed a high coloration efficiency of 146.65 cm2 C-1 at 700 nm.

Q *Your study shows flexibility, stability, and fast response. Why are these features important for real-world applications?*

A For use in real-world applications, these features are highly demanding. For a wearable device or a smart window on a curved surface, flexibility is a crucial parameter, and any device should maintain its performance till a certain level of flexibility to support a wide range of applications.

Long-term reliability is also essential for any kind of electronic device. Whether it is in a smart window or an energy storage device, the consistent performance without degradation is what a customer wants for its practical use.

An electrochromic device can tune its color to the user's requirements, and instant feedback is always expected, especially in smart display applications.

Q *How do you see this technology being used in the future (for example, in buildings, wearable devices, or energy systems)?*

A This technology will definitely help build an energy-efficient building, where a user can simultaneously store charge through the window while modulating incoming electromagnetic radiation to reduce energy consumption. The material can also be used as a smart and wearable energy storage device, which can indicate different colors at different charge states. This will give the opportunity to build a compact system using a single material that can perform multiple tasks. This technology could enable smart, flexible, self-indicating energy systems, from buildin-

gs to wearables, where energy storage and functionality are seamlessly integrated into the material itself.

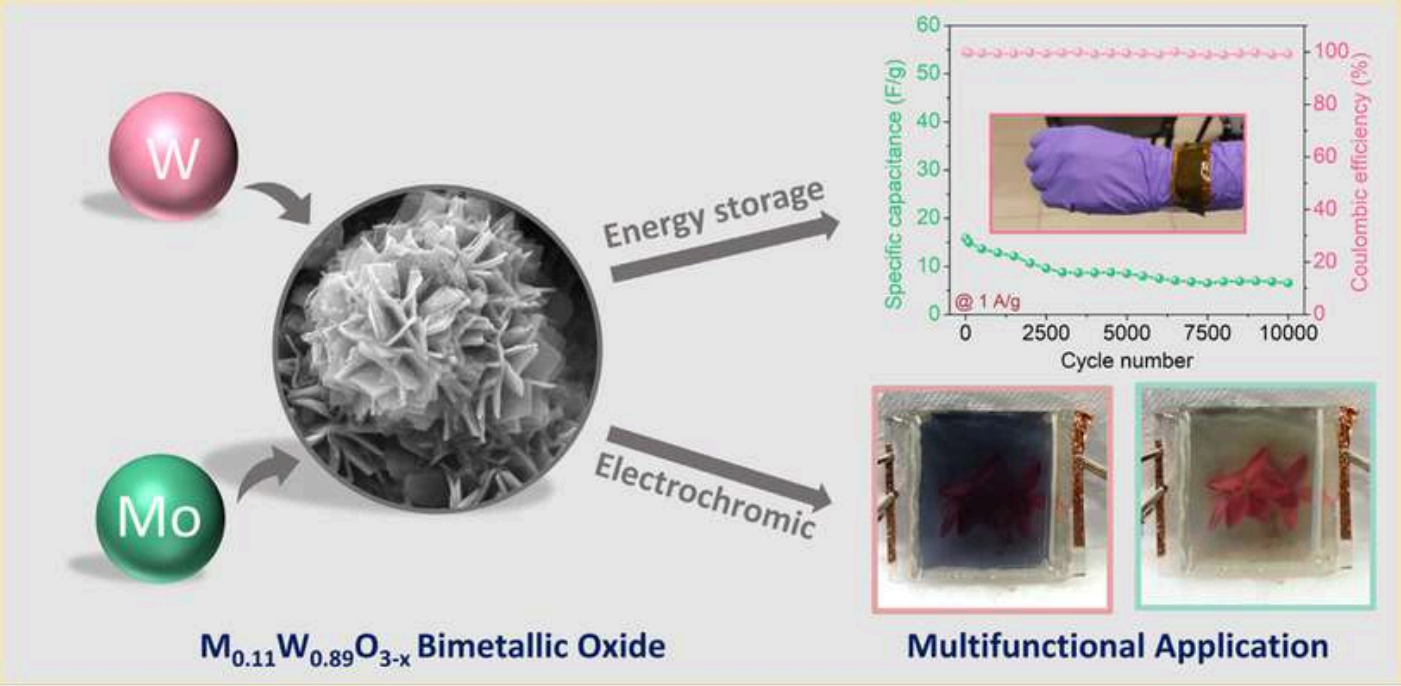

Figure: Morphological microscopic image of bimetallic oxide and demonstration of its performance as a flexible & wearable energy storage device along with an electrochromic smart window.

Reference

Dr. Singh and his team's contributions to this field are reflected in their publication in Journal of Materials Chemistry A (2026), titled "Oxygen-Deficient Bimetallic Oxide M0.11W0.89O3−x for Flexible Energy Storage and Electrochromic Applications," https://doi.org/10.1039/D6TA01049K,which highlights innovative strategies for developing multifunctional materials for next-generation flexible energy storage and smart electrochromic technologies.

SCIENCE DESK

How Poor Posture Alters Shoulder Movement and Stability

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Scientific Profile
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Factors Press

AREAS OF EXPERTISE
Electrochemistry and Electrocatalysis • Fuel cell • Water electrolyzer • Aqueous metal-ion batteries

Q *What inspired you to investigate the relationship between forward head posture and shoulder movement?*

A The inspiration for this study came from a growing concern we observed in today's younger population, particularly students and young professionals who spend long hours using smartphones, laptops, and other digital devices. Poor posture, especially forward head posture (FHP), has become increasingly common due to prolonged sitting and screen-based activities.

In both clinical and academic settings, we frequently encountered young individuals complaining of neck stiffness, shoulder discomfort, fatigue, and reduced mobility despite having no major injury or underlying pathology. This raised an important question: could postural habits alone influence the way the shoulder moves and functions?

While forward head posture is commonly associated with neck pain, its effect on shoulder biomechanics is often overlooked. Since the shoulder depends heavily on coordinated muscular and postural control, we wanted to explore how altered head and spinal alignment could affect scapulohumeral rhythm the coordinated movement between the shoulder blade (scapula) and the upper arm bone (humerus) during arm motion.

Our study aimed to highlight that posture is not merely a cosmetic concern; it has a direct impact on movement quality, joint stability, and long-term musculoskeletal health.

Q *In simple terms, could you explain what scapulohumeral rhythm is and why it is important?*

A Scapulohumeral rhythm refers to the coordinated movement between the shoulder blade (scapula) and the upper arm bone (humerus) during shoulder motion. Whenever we lift our arm to reach, throw, write, exercise, or perform overhead activities, these two structures must move together in a precise and balanced manner.

The shoulder is one of the most mobile joints in the human body, and this mobility depends on proper coordination between multiple muscles and joints. The scapula acts as a stable base, while the humerus moves freely to allow smooth arm movement. If this coordination becomes disrupted, the shoulder may lose efficiency and stability.

One simple way to understand scapulohumeral rhythm is to think of it as a well-synchronized partnership. When both the scapula and humerus move harmoniously, shoulder movement becomes smooth, stable, and pain-free. However, if one part fails to move properly, excessive stress is placed on surrounding muscles and joints, increasing the risk of fatigue, pain, reduced performance, and injury.

Therefore, maintaining a healthy scapulohumeral rhythm is essential not only for athletes and physically active individuals, but also for routine daily activities such as carrying bags, typing, driving, and reaching overhead.

Q *How does poor posture, especially forward head posture, affect shoulder stability and everyday movement?*

A Forward head posture significantly alters the alignment of the head, neck, shoulders, and upper spine. In this posture, the head moves excessively forward relative to the body and is often accompanied by rounded shoulders and a slouched upper back. These changes disturb the body's natural biomechanical balance.

The shoulder complex functions efficiently only when the surrounding muscles maintain proper alignment and coordination. In individuals with poor posture, muscles at the front of the chest and neck often become tight and overactive, while important stabilizing muscles around the scapula become weak or inefficient. This muscular imbalance affects the normal movement of the scapula during arm elevation.

As a result, shoulder stability decreases, movement becomes less efficient, and additional strain is placed on muscles, tendons, and joints. Everyday tasks such as studying, typing, lifting objects, carrying backpacks, or prolonged mobile phone use may gradually become physically stressful.

If these abnormal movement patterns persist, they can contribute to muscle fatigue, reduced mobility, shoulder impingement, neck pain, and long-term musculoskeletal dysfunction. What makes this particularly concerning is that these biomechanical changes can begin silently, often before noticeable pain develops.

Our findings reinforce the idea that poor posture is not simply a visual habit; it can directly influence how the body moves, stabilizes, and performs during daily life.

Q *Your study highlights changes across different movement ranges. Could you explain this in detail?*

A One of the most important aspects of our study was examining scapulohumeral rhythm across different ranges of shoulder movement rather than assessing the shoulder as a single mechanical unit.

We observed that the effects of altered posture were not identical throughout the entire movement. During lower ranges of arm elevation, the body may partially compensate for postural abnormalities using surrounding muscles and alternative movement strategies. However, as the arm moves into higher ranges, particularly during overhead motion, the demand for proper scapular coordination increases significantly.

In participants with forward head posture, the scapula demonstrated altered movement patterns and timing during these higher ranges. In simpler terms, the shoulder blade was not moving as efficiently or effectively as it should to support the arm during elevation.

This finding is clinically important because many daily activities involve repeated overhead movements such as reaching shelves, lifting objects, sports participation, classroom tasks, and prolonged desk work. When abnormal movement patterns continue repeatedly, excessive mechanical stress may gradually develop within the shoulder complex.

Our study suggests that even subtle postural deviations can influence shoulder mechanics long before severe symptoms appear. This highlights the importance of early assessment, postural awareness, and preventive intervention, especially among young adults exposed to prolonged sedentary and screen-based lifestyles.

Q *What was the most important or surprising finding from your study on young adults?*

A One of the most significant findings of our study was that measurable alterations in shoulder movement patterns were present even in young adults who appeared healthy and active. Many participants did not report severe pain or functional limitations, yet their scapulohumeral rhythm was already affected by poor posture.

This was particularly important because it demonstrated that postural dysfunction can silently influence biomechanics before obvious clinical symptoms develop. In other words, the body may begin adapting to poor posture long before an individual becomes aware of discomfort or movement restriction.

Another noteworthy finding was the consistency of altered shoulder coordination across different movement ranges. This reinforced the understanding that forward head posture has a genuine functional impact on shoulder mechanics rather than being merely a cosmetic or visual concern.

In today's digital era, where prolonged screen exposure and sedentary habits are increasingly common, these findings emphasize the urgent need for greater awareness regarding posture and movement health among younger populations.

Q *How can your findings help students and professionals improve posture and prevent long-term musculoskeletal issues?*

A Our findings highlight the importance of maintaining proper posture not only for comfort and appearance, but also for preserving healthy movement patterns and preventing future musculoskeletal problems.

Students and professionals often spend extended hours studying, working on computers, or using handheld devices, which places continuous strain on the neck, shoulders, and upper back. Small but consistent lifestyle modifications can significantly reduce this stress.

Simple strategies such as maintaining an ergonomic workstation, positioning screens at eye level, taking regular movement breaks, and avoiding prolonged slouched sitting can help improve postural alignment. In addition, strengthening exercises for the deep neck flexors and scapular stabilizers, along with stretching of tight chest and neck muscles, can improve shoulder mechanics and overall posture.

From a preventive healthcare perspective, our study also emphasizes the value of early posture screening and awareness programs in schools, colleges, and workplaces. Educating individuals about healthy movement habits at an early stage may help reduce the long-term burden of neck pain, shoulder dysfunction, and related musculoskeletal disorders.

Ultimately, our research reinforces a simple but important message: posture influences movement, stability, and long-term physical health far more than most people realize. In an increasingly digital world, improving posture awareness may play an important role in protecting long-term musculoskeletal health and maintaining efficient movement throughout daily life.

Reference

Dr. Popli's contribution to this field is reflected in her publication in J Man Manip Ther (2026), titled "The Hidden Cost of Slouching: Exploring Scapulohumeral Rhythm Changes in Forward-Headed Students" (DOI: 10.1080/10669817.2026.2663584). This study provides important insights into how poor posture influences shoulder movement, stability, and musculoskeletal health in young adults.

SCIENCE DESK

Stable Nanoarchitectonics of Metal Halide Perovskites for Aqueous Electrocatalysis

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Scientific Profile
Organization Link
Factors Press

AREAS OF EXPERTISE
Electrochemistry and Electrocatalysis • Fuel cell • Water electrolyzer • Aqueous metal-ion batteries

Q *What inspired you to explore metal halide perovskites, particularly their stability challenges in water, and how did this research direction evolve over time?*

A My research has been primarily driven by the need to develop cost-effective, high-performance electrocatalytic materials for electrochemical energy applications such as fuel cells and water electrolyzers. Traditionally, the most efficient catalysts in these systems rely on noble metals like platinum (Pt), iridium (Ir), and ruthenium (Ru), which significantly increase the overall cost of energy devices. This economic limitation motivated me to explore alternative material platforms that could deliver comparable performance at a lower cost. Metal halide perovskites emerged as a compelling candidate due to their simple crystal structure, ease of synthesis, and scalability. Their tunable composition and electronic properties make them particularly attractive for energy-related applications. However, a major bottleneck quickly became evident: their intrinsic instability in aqueous environments, which limits their direct use in water-based electrocatalysis. This challenge shaped the evolution of my research. I began focusing on strategies to enhance the water stability of these materials while preserving their catalytic activity. One approach involved modifying the surface chemistry, such as tuning the A-site cation to introduce hydrophobic character by incorporating long-chain organic molecules. Increasing conjugation within the structure also helped improve stability. More recently, protective coating strategies have gained prominence, where thin layers are applied to control water accessibility while maintaining the structural integrity of the perovskite. This research direction evolved from the broader goal of replacing expensive noble-metal catalysts to the specific challenge of stabilizing promising yet vulnerable materials, ultimately advancing their practical applicability in sustainable energy technologies.

Q *In simple terms, could you explain what metal halide perovskites are and why their instability in water is such a critical issue for real-world applications?*

A Metal halide perovskites (MHPs) are crystalline materials with an ABX_3 structure, where A is a large cation, B is a metal (e.g., lead or tin), and X is a halide (Cl, Br, or I). They form a 3D metal-halide framework with A-site ions in the cavities. MHPs are widely studied for their strong light absorption, efficient charge transport, tunable energy levels, and low-cost synthesis, making them promising for solar cells, LEDs, and electrocatalysis. However, their poor stability in water is a major limitation. Due to their soft, ionic structure, MHPs readily interact with water, leading to hydration, structural changes, and eventual decomposition into simpler compounds or even complete dissolution. This instability is especially problematic for aqueous energy technologies like fuel cells and electrolyzers, where rapid degradation limits their long-term practical use.

Q *How do the electronic structure and material design of these perovskites influence their performance in energy-related applications like electrocatalysis?*

A The electronic structure of metal halide perovskites

(MHPs) is central to their electrocatalytic performance, as it governs charge transport, surface reactivity, and overall catalytic efficiency. Their valence and conduction bands, primarily derived from metal (B-site) and halide (X-site) orbital interactions, enable efficient light absorption, charge generation, and separation, which are critical for driving reactions such as hydrogen evolution (HER), oxygen evolution (OER), and CO_2 reduction. The alignment of these band edges with the reaction potential determines how effectively electrons can be transferred to reactants. A key advantage of MHPs is the high tunability of their electronic structure. By modifying composition (e.g., substituting different metals or halides), introducing dopants, or engineering defects, researchers can precisely adjust the band gap, Fermi level, and adsorption energies of reaction intermediates. This control is crucial for optimizing catalytic pathways and minimizing energy barriers. In particular, defect states such as halide vacancies can act as active sites, enhancing catalytic activity by promoting charge localization and increasing the density of reactive centers. Structural dimensionality further influences electronic behavior. Lower-dimensional MHPs (0D, 1D, 2D) generally exhibit stronger quantum confinement, leading to larger band gaps and improved environmental stability, though often at the cost of reduced charge mobility. In contrast, 3D MHPs offer better charge delocalization, higher conductivity, and faster electron transfer, which are beneficial for catalytic turnover. Therefore, an effective design strategy requires balancing stability and electronic performance by carefully controlling composition, defects, and structure.

Q *During your research, what was the most surprising or challenging finding regarding degradation mechanisms or stability in aqueous environments?*

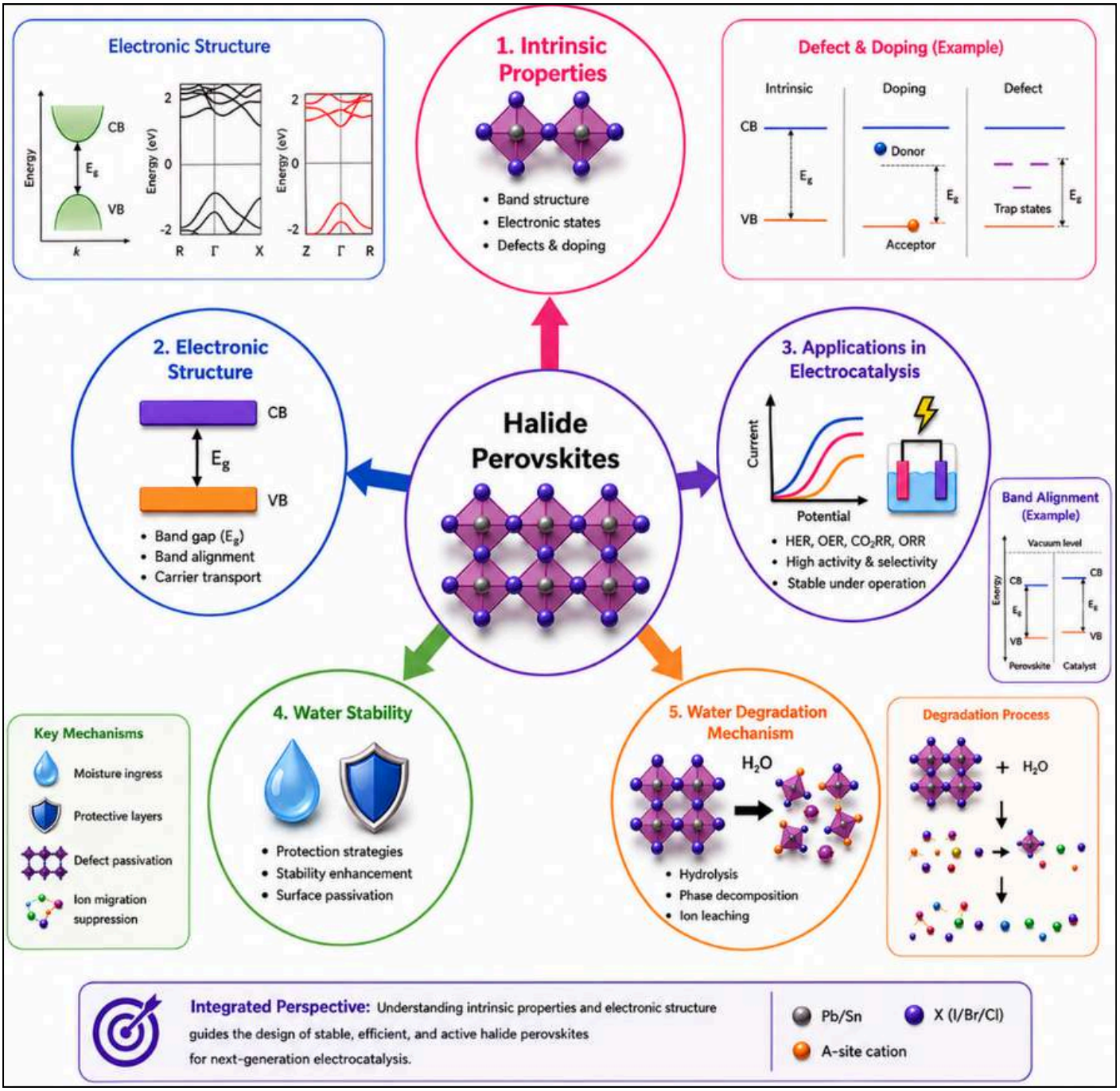
A One of the most challenging yet surprising findings of this research is the complex and poorly understood degradation mechanism of metal halide perovskites (MHPs) in aqueous environments. While their instability in water is well known, the exact pathways, intermediate phases, and energy barriers, especially under realistic electrocatalytic conditions, remain unclear. The study reveals that degradation is not a single-step process but a dynamic, multi-stage transformation involving hydration, phase transitions, decomposition, and eventual dissolution. For instance, materials like $MAPbI_3$ initially form hydrated intermediate phases before gradually breaking down into PbI_2 and organic components, highlighting a stepwise structural evolution from 3D to lower-dimensional phases. A major challenge lies in the intrinsically "soft" ionic crystal structure of MHPs, which allows water molecules to easily penetrate the lattice, disrupt ionic interactions, and trigger phase changes. Additionally, degradation strongly depends on the electrolyte environment: acidic conditions lead to hydrolysis and irreversible breakdown, while alkaline conditions accelerate phase transformations. This environment-dependent behavior complicates the design of universally stable materials. Overall, the key challenge is understanding and controlling this multi-step degradation process, while the most striking insight is the critical role of intermediate hydrated phases and structural transformations in governing stability.

Q *How can your research contribute to future technologies in clean energy, such as hydrogen production, CO_2 reduction, or energy storage?*

A My research advances clean energy technologies by developing efficient, low-cost metal halide perovskite (MHP)-based electrocatalysts for hydrogen production, CO_2 reduction, and energy storage. Their tunable electronic structure, high charge mobility, and favorable surface properties make them promising for key reactions like HER, OER, and CO_2RR. By engineering composition, dimensionality, and defects, the work optimizes charge-transport and adsorption energies, enabling catalytic performance comparable to that of noble metals at lower cost. A major focus is improving water stability by studying degradation mechanisms and applying strategies such as compositional tuning, surface passivation, and encapsulation. Additionally, controlled synthesis enhances surface area, active sites, and charge-transfer kinetics. Overall, this research bridges fundamental design and practical application, enabling the development of stable, efficient, and scalable catalysts for sustainable energy systems.

Q *What are the next big questions in this field, and what still needs to be understood before these materials can be widely used in practical applications?*

A The manuscript highlights that, despite rapid progress

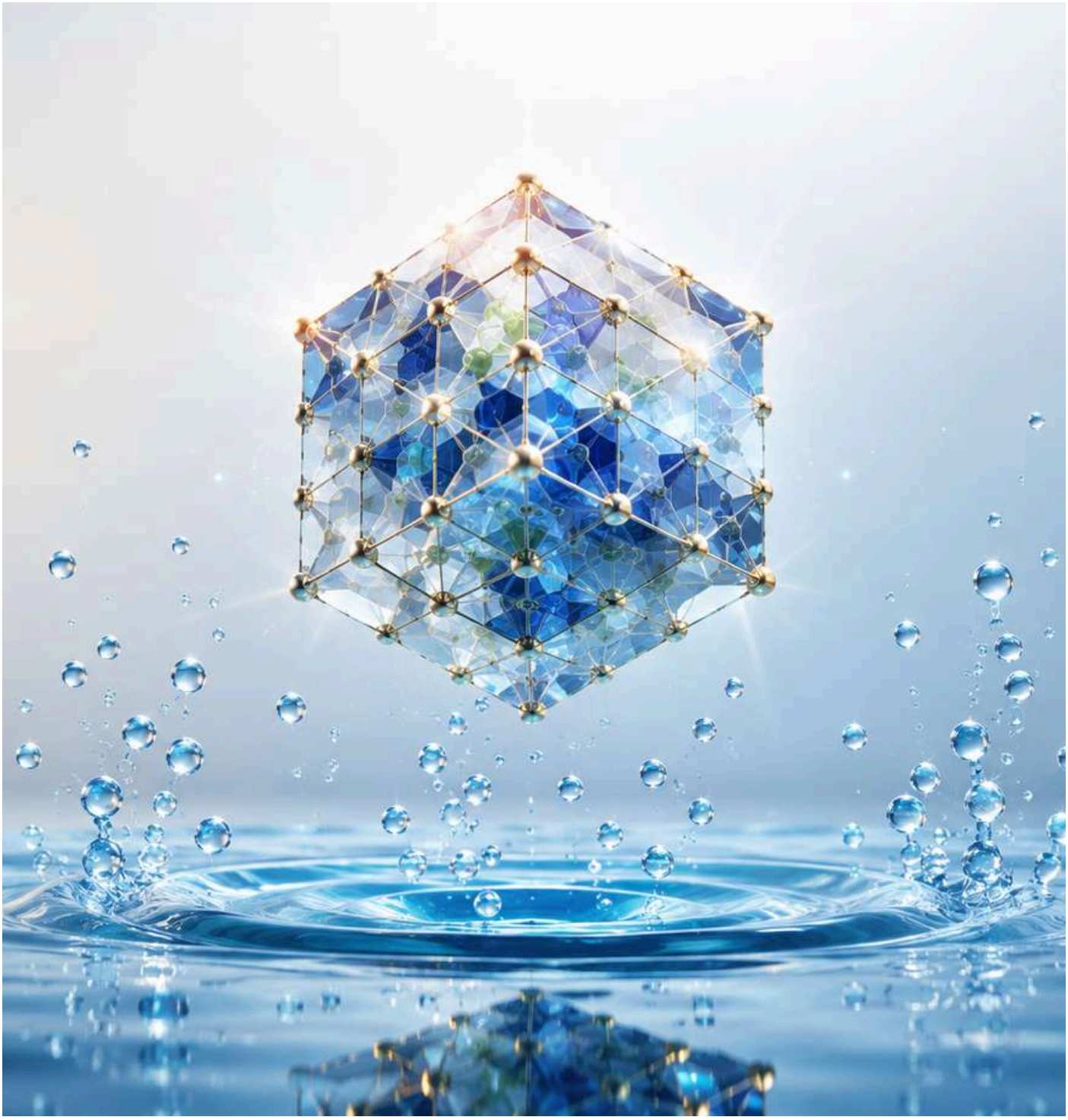


several fundamental challenges must be resolved before metal halide perovskites (MHPs) can be widely used in practical energy applications. A key open question is how the electronic structure and interactions among the A-, B-, and X-site components govern catalytic activity under real electrochemical conditions. Although their tunable band structure is advantageous, a deeper understanding is needed to precisely control charge transfer, adsorption energies, and reaction pathways for processes such as HER, OER, and CO_2 reduction. Another major issue is the incomplete understanding of degradation in aqueous environments, where the exact pathways, intermediate states, and energy barriers, especially across different pH conditions, remain unclear, limiting the rational design of stable materials. A further challenge is achieving durability comparable to conventional electrocatalysts. Existing stabilization strategies, including encapsulation, ligand passivation, and compositional engineering, often introduce trade-offs, such as reduced activity, hindered charge transport, and long-term coating instability. Additionally, the roles of structural dimensionality, defects, and interfaces in determining both stability and

catalytic performance remain poorly understood. For example, lower-dimensional perovskites offer better stability but poorer conductivity, while 3D structures exhibit the opposite trend. Moving toward practical deployment requires a clear understanding of structure-property-stability relationships, along with scalable synthesis methods and long-term operational durability under realistic conditions.

Reference

Dr. Singh's contributions to this field are reflected in publications in Small (https://doi.org/10.1002/smll.202514875) and Chemical Communications (https://doi.org/10.1039/D5TA02493E). His research focuses on developing chemically stable and efficient perovskite materials for electrochemical energy conversion, particularly for oxygen evolution and related catalytic reactions in aqueous environments.



SCIENCE DESK

Invisible Pollutants, Lasting Impact: Understanding Persistent Organic Pollutants in India

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Factors Press

AREAS OF EXPERTISE
Environmental Geochemistry • Hydrogeology • Groundwater Quality Assessment • Emerging Contaminants

Q *What motivated you to study persistent organic pollutants (POPs) in India, and why is this topic important today?*

A The motivation behind this study arose from the growing recognition that environmental sustainability is one of the defining scientific challenges of the 21st century. India is experiencing rapid industrialization, urbanization, energy transition, and agricultural expansion, which are essential for economic development but can also increase the release of persistent organic pollutants (POPs) into the environment. Unlike conventional contaminants, POPs persist for decades, circulate across air, water, soil, sediments, and biota, and can migrate far beyond their original source regions. Their persistence, toxicity, and bioaccumulation potential have made them a major global environmental concern under the Stockholm Convention. This issue is especially relevant for India as the country advances toward sustainable development goals and the vision of Viksit Bharat 2047, emphasizing environmental resilience, cleaner technologies, and ecological security. Our study therefore aimed to understand the environmental distribution, geochemical behavior, and long-term risks of POPs to support science-based environmental management strategies.

Q *In simple terms, what are POPs, and why are they considered dangerous for the environment and human health?*

A POPs are toxic chemical compounds that resist natural degradation and remain in the environment for long periods. They can accumulate in living organisms, move through food chains, and eventually reach humans. Examples include polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and organochlorine pesticides such as DDT. These contaminants originate from combustion processes, chemical usage, waste disposal, and other anthropogenic activities. POPs are particularly dangerous because they remain toxic even at very low concentrations. Long-term exposure has been associated with cancer, endocrine disruption, neurological disorders, reproductive toxicity, and immune system damage. Unlike many conventional contaminants, POPs can also undergo long-range atmospheric and hydrological transport, making them a global environmental and public health concern.

Q *Your study highlights different pollutants like PAHs, PCBs, and pesticides. What makes these particularly concerning?*

A These pollutants are especially concerning because of their persistence, toxicity, and strong bioaccumulative nature. PAHs are mainly produced through incomplete combustion of fossil fuels, biomass, and other carbon-rich materials, and several compounds within this group are recognized carcinogens. PCBs, despite being banned in many countries, continue to persist in sediments and aquatic systems because of their exceptional chemical stability. Similarly, organochlorine pesticides such as DDT and lindane remain detectable in soils and water bodies decades after their application. A major concern is that these contaminants can continuously cycle between environmental compartments and accumulate within food webs over time. Although many developed countries have reported declining trends due to stricter regulations, several developing regions still experience residual contamination and secondary emissions, highlighting the long-term legacy of POP

pollution.

Q *What are the main sources of these pollutants in India, and how do they spread across water, soil, and air?*

A The major sources of POPs in India include thermal power generation, combustion-related emissions, pesticide usage, waste burning, electronic waste processing, transportation activities, and improper disposal practices. Once released, these contaminants continuously interact between atmospheric, terrestrial, and aquatic systems. Semi-volatile POPs compounds can travel through the atmosphere before redepositing onto soils and surface waters. In soils, they strongly bind with organic matter and remain persistent for extended periods. Rainfall runoff, river transport, and sediment movement further redistribute these contaminants into lakes, estuaries, groundwater systems, and coastal environments. India's tropical climate and monsoon-driven hydrological conditions can further accelerate contaminant mobility and redistribution compared with colder regions.

Q *Your work identifies regional hotspots. What does this mean, and why should people be aware of it?*

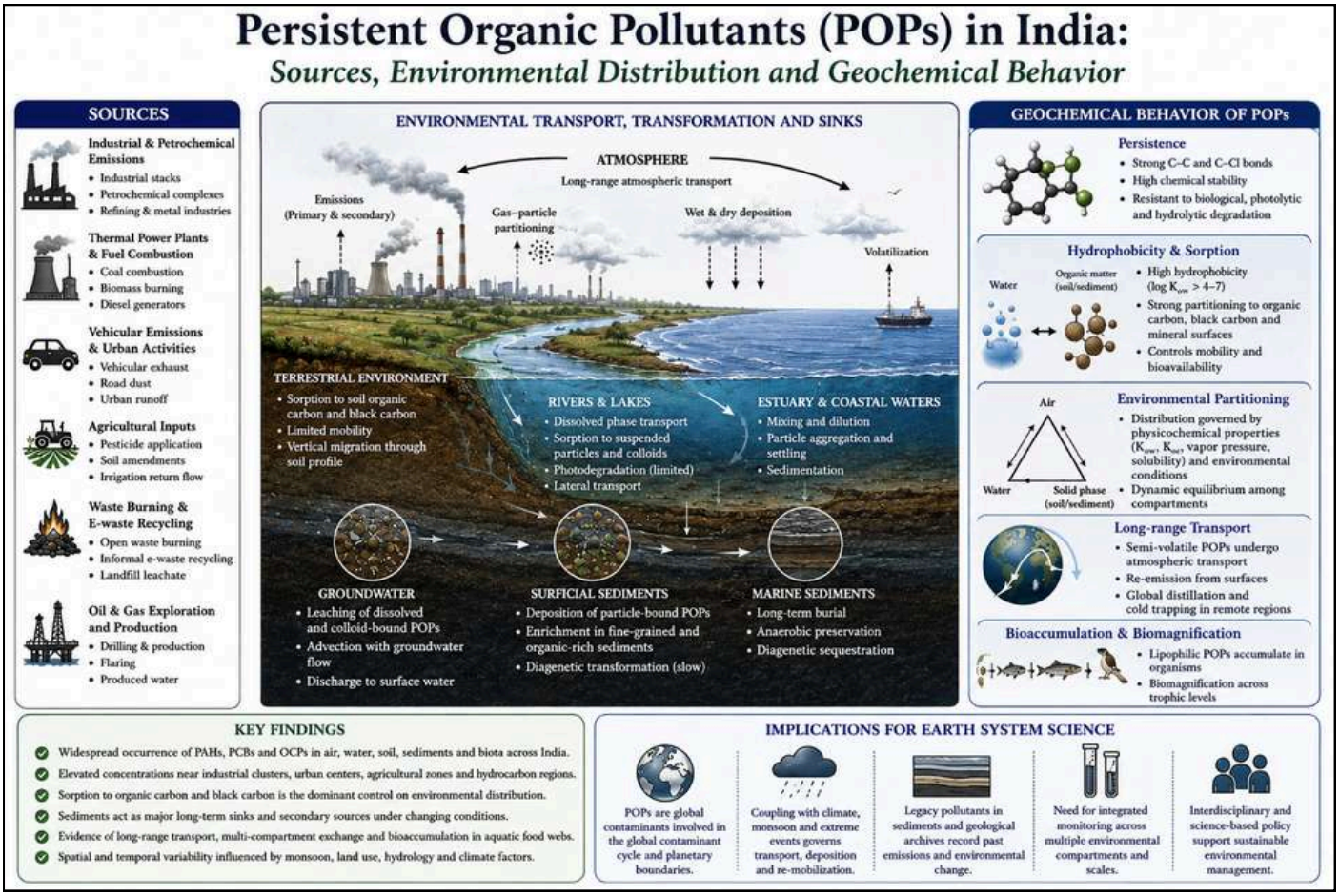
A Regional hotspots are areas where pollutant concentrations are significantly higher than surrounding regions due to intense anthropogenic influence and long-term contaminant accumulation. These hotspots indicate zones of elevated ecological vulnerability and potential human health risk. Our study identified several hotspot regions associated with dense population canters, coastal belts, waste-processing zones, and areas experiencing high environmental stress. Such regions often receive contaminant inputs from multiple pathways simultaneously, resulting in cumulative environmental impacts. Public awareness is important because POP contamination is largely invisible, yet long-term exposure through air, food, soil, and water can significantly affect human health and ecosystem stability. Identifying hotspots also helps policymakers prioritize environmental monitoring, remediation planning, and sustainable resource management.

Q *What are the major risks of these pollutants for ecosystems and human health?*

A POPs can significantly disrupt ecosystem functioning by affecting microbial activity, biodiversity, aquatic organisms, and food-web dynamics. Wetlands, estuaries, and coastal environments are particularly vulnerable because they often act as long-term sinks for contaminant accumulation. In humans, exposure mainly occurs through contaminated food, drinking water, inhalation, and occupational contact. Scientific studies worldwide have linked POPs exposure with cancer, endocrine disorders, neurological diseases, immune suppression, and reproductive abnormalities. An additional concern is that climate change may remobilize contaminants previously stored in soils, sediments, and aquatic systems, potentially increasing future environmental and human exposure risks.

Q *Based on your research, what steps should be taken in the future to monitor and reduce these pollutants?*

A Future POPs management requires stronger environmental monitoring, stricter regulatory frameworks, and cleaner technological practices. India should expand long-term monitoring of air, water, soil, sediments, and biota using advanced approaches such as geospatial analysis, high-resolution analytical techniques, and source-apportionment models. Better management of waste disposal, wastewater discharge, combustion emissions, and informal recycling activities is also essential to reduce contaminant release. Globally, increasing emphasis is being placed on integrated environmental monitoring and sustainable pollution management, particularly under climate resilience and sustainable development frameworks. Effective reduction of POP contamination will ultimately depend on collaborative efforts among scientists, policymakers, industries, and the public to ensure long-term environmental sustainability and protection of ecosystem and human health.



Reference

Dr. Mallesh's contributions to this field are reflected in his publication in Science of the Total Environment (2026), titled "Persistent Organic Pollutants in India: Multi-Compartment Trends, Source Fingerprinting, and Emerging Environmental Challenges (2000–2025)", 10.1016/j.scitotenv.2026.181646, which provides a comprehensive assessment of pollutant distribution, environmental risks, and emerging challenges associated with persistent organic contaminants in India.

SCIENCE DESK

Dietary Fats, Sleep, and Aging

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Scientific Profile
Organization Link
Factors Press

AREAS OF EXPERTISE
Drosophila aging • nutritional geometry • circadian rhythms • Life-history traits • and evolution.

Q *What inspired you to study the effects of dietary fats, particularly unsaturated fatty acids, on behavior and aging?*

A I have been interested in pursuing research that relates to our day-to-day life, such as the health impact of dietary choices. Excessive dietary intake, particularly increased caloric intake, is associated with various metabolic diseases. In recent years, researchers have begun to recognize that fats can influence sleep, metabolism, gut health, and even aging. However, unsaturated fatty acids especially attracted my attention because they are commonly considered "good fats," yet their broader physiological effects are still not fully understood. This inspired me to investigate how these dietary components shape behavior, lifespan, and health during aging.

Q *In simple terms, could you explain what unsaturated fatty acids are and how they differ from other types of fats?*

A Unsaturated fatty acids (USFA) are considered healthy fats and are mainly enriched in food sources such as nuts, seeds, plant oils, etc. They differ from saturated fatty acids in their chemical structure, as they contain one or more double bonds, and have beneficial effects on brain function and heart health by reducing low-density lipoprotein (LDL) and increasing high-density lipoproteins (HDL).

Q *How does diet influence sleep patterns and daily activity in a way that a general reader can easily understand?*

A Diet plays a role beyond being a calorie provider. Food influences how our body functions throughout the day, cumulatively affecting our health as we age. Dietary nutrients affect the cellular level by balancing hormones, energy maintenance, metabolism, brain activity, and muscle function, together influenced by the internal clock that regulates sleep-wake cycles. Our study suggests that dietary fatty acids influence sleep behavior and activity patterns, reinforcing the idea that "what we eat influences how well we act and rest to maintain daily rhythms."

Q *Your study highlights links between diet, lifespan, and gut health. Could you explain these connections in an intuitive way?*

A This fascinates me to explain, as gut health in relation to diet has been ignored for a long period. The gut is not just a digestive organ, but also a communication center in our body. It interacts with multiple systems in the body. Microbes living in our gut are known as gut microbiota, which communicate and maintain balance between different systems such as the immune, nervous, and metabolic systems.
Our study suggests that the gut acts as a major cost-bearing and regulatory organ that closely responds to dietary changes. The composition and microbial load of the gut microbiota are strongly influenced by diet, which in turn affects nutrient processing, inflammation, and overall physiological health. Certain dietary fats can alter the gut environment, and our dietary intervention studies indicate that diet, gut health, and lifespan are interconnected through strong biological cross-talk that helps maintain overall body function and homeostasis.

Q *During your research, what was the most surprising or unexpected finding that stood out to you?*

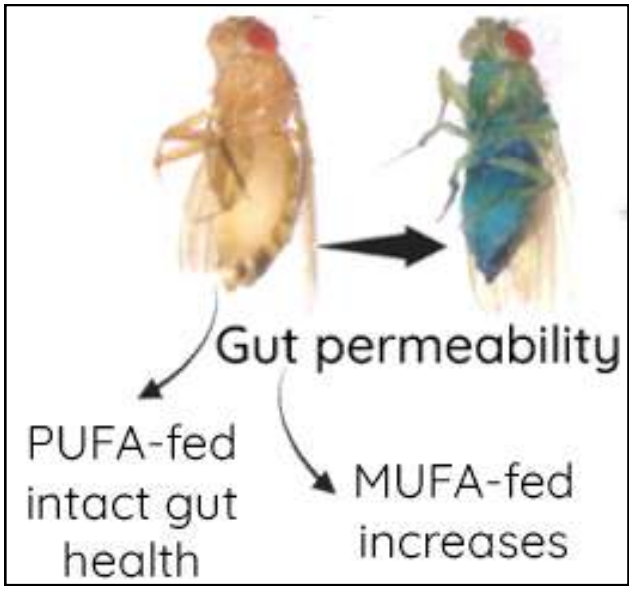
A One of the most surprising findings was how strongly dietary interventions impact multiple biological systems simultaneously. We expected dietary fats to affect metabolism, but it was particularly interesting to see effects on sleep patterns, activity, fitness traits, and aging-related characteristics as well. An experimentally striking observation was how distinct dietary fatty acids and gut-associated phenotypical

responses were depending on the quality of fatty acids.

Q *How can your findings help people make better dietary choices in their daily lives, and what are the next important questions in this field?*

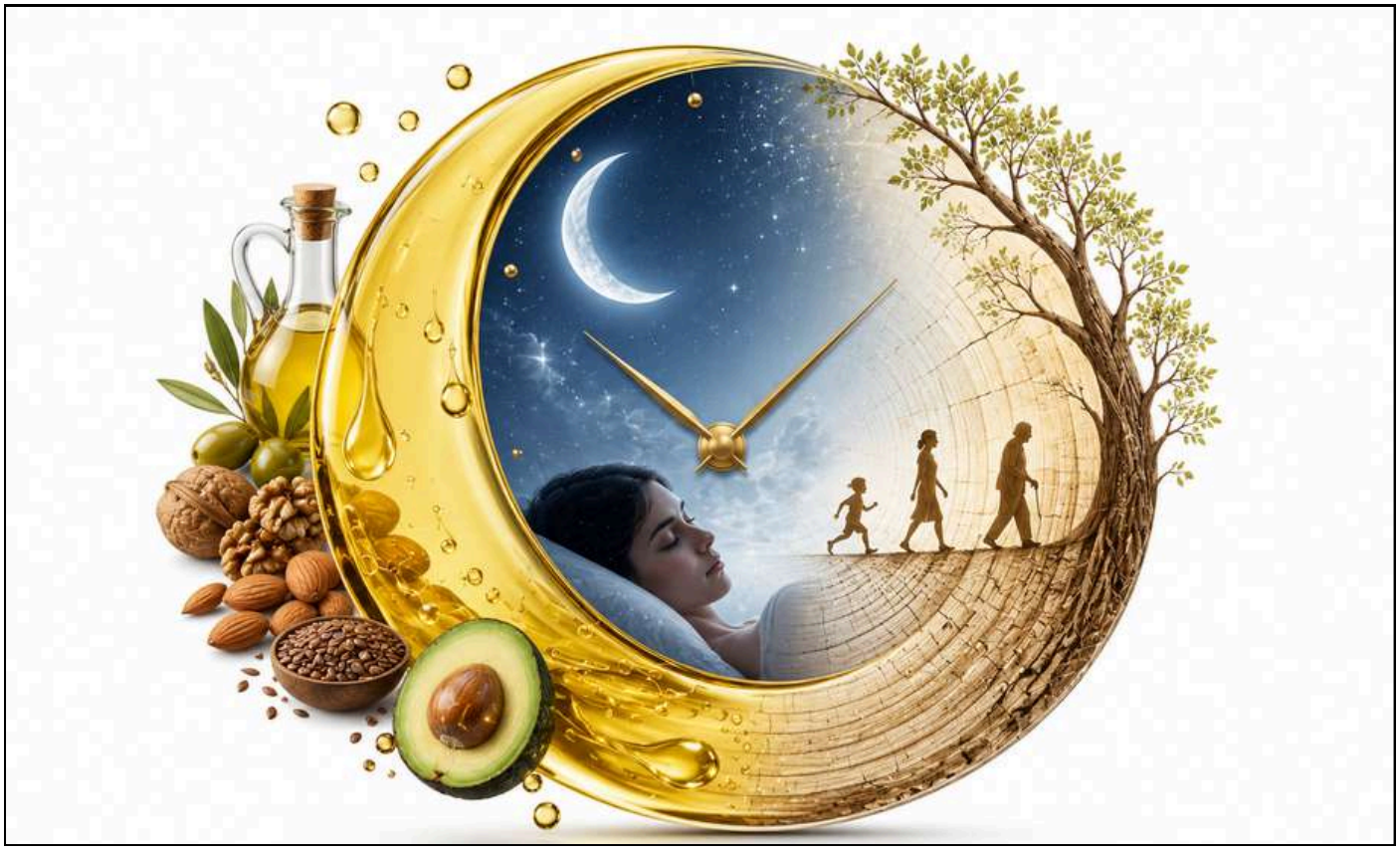
A Our findings highlight that dietary fatty acids from plant sources can influence many aspects of health beyond simple nutrition. While studies in model organisms cannot be directly applied to humans without further research, they provide valuable insight into the biological effects of diet and its impact on metabolism. The study suggests that the quality and quantity of dietary fats play important roles in sleep fragmentation (disturbance), gut health, and lifespan in a sex-dependent manner, revealing that one should consume nutritional fatty acids in the context of an individual's metabolism, lifestyle, and biological sex.

Further research needs to focus on understanding the precise avenue of the gut-brain axis and the molecular mechanisms behind these observed interactions, and on exploring how diet can support long-term health and healthspan in both biological sexes.



Reference

Dr. Yadav's contributions to this field are reflected in his publication in Biogerontology (2026), titled "Dietary Unsaturated Fatty Acids Distinctly Associate with the Early Age Sleep-Wake Cycle and Gut Integrity in Aged Fruit Flies, Drosophila melanogaster" DOI: 10.1007/s10522-026-10434-z, which provides important insights into the relationship between dietary lipids, aging, gut health, and sleep regulation.



SCIENCE DESK

Innovative Biomaterials for Combating Chronic Wounds and Antimicrobial Resistance

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Scientific Profile
Organization Link
Factors Press

AREAS OF EXPERTISE
Biomaterials • Tissue Engineering • Medical Device Development • Bone and Skin Regeneration

Q *What inspired you to explore new biomaterial-based approaches for chronic wound healing, especially combining bacteriophages and plant-derived extracts?*

A Chronic wounds can arise due to multiple conditions such as diabetic foot ulcers, bed sores, and burn wounds. Many times, such wounds are accompanied by microbial infections, causing further delays in the wound healing process. Such infections become more dangerous when the pathogenic microorganisms are multi-drug resistant (MDR) rendering conventional treatments ineffective. Therefore, it becomes highly imperative to not only address the complications arising due to such infections but also to accelerate the wound healing process. With this thought in mind, I wanted to look for a solution that can address both issues within a single platform. Hence, I came up with this idea of combining a biocompatible, highly porous and flexible biomaterial that can take the form of a wound dressing material, with bacteriophages that can act against the infections caused by drug-sensitive and multidrug-resistant pathogens as antimicrobial agents and plant-derived extracts (provided by ayurvedic doctors) aimed at enhancing the wound healing process. Herein, the biomaterial is expected to act as a substrate for the bacteriophages and plant-derived extracts while providing a moist wound environment through moisture retention at the wound site.

Q *In simple terms, could you explain why chronic wounds are so difficult to treat and how antimicrobial resistance makes this problem even more serious?*

A Chronic wounds are non-healing wounds that do not heal within the timeframe of an acute wound healing response, i.e., from a few days to few weeks, depending on the severity of the wound. They may take months or years to heal and sometimes may not heal at all if left untreated. Usually, the chronic wounds are associated with an underlying condition such as diabetes leading to diabetic foot ulcers, lack of mobility leading to pressure ulcers/bedsores, or surgical complications. Such conditions may worsen with the occurrence of infections in the chronic wounds leading to further complications of persistent inflammation and tissue damage. So far, the antibiotics were a promising solution for the treatment of infections in the chronic wounds. However, with the advent of antimicrobial resistance, the issue of chronic wounds has become even more serious because antibiotics are no longer effective against such infections leading to uncontrolled microbial growth at the wound site that may cause dire consequences such as amputations.

Q *How does your composite biomaterial work particularly the role of bacteriophages and phytoextracts in improving wound healing?*

A In our work, the porous and biocompatible composite biomaterial acts as the dressing material that forms the substrate for the incorporation of bacteriophages and phytoextracts. The bacteriophages are adsorbed onto the biomaterial surface and they are released from the biomaterial in a sustained manner so that the antimicrobial activity against the specific pathogen can be achieved for a longer duration. On

the other hand, phytoextracts are expected to contribute to the anti-inflammatory and wound regenerative properties within the biomaterial to provide a slow and sustained release for enhanced and efficient wound healing.

Q *During your research, what was the most surprising or important finding regarding healing efficiency or antimicrobial activity?*

A The research journey during this work was quite exciting where the most important finding was that the bacteriophages as antimicrobial components and phytoextracts as wound regenerative components retain their activity without interfering with one another and could function effectively together by providing a synergistic effect.

Q *How can your research impact real-world healthcare, especially in developing more effective and affordable treatments for patients?*

A Our research opens up a new avenue for using affordable ayurvedic/herbal formulations as phytoextracts for enhancing chronic wound healing, and host-specific bacteriophages as antimicrobial agents against MDR pathogens, within a biomaterial system in the form of a composite biomaterial-based wound dressing. Considering that both the phytoextracts and bacteriophages are nature-derived sources, they are expected to form an affordable, sustainable and environment-friendly alternative to the currently available components used as wound care solutions.

In future, such solutions can impact the real-world healthcare by providing personalized treatments through the flexibility to incorporate bacteriophages depending on whether or not the wound is infected. Also, the bacteriophages can be incorporated in the form of a cocktail that can be further personalized by selecting the wound-specific bacteriophages for efficient and targeted antimicrobial action. Similarly, the choice of phytoextracts can be varied depending on the etiology of the wound, leading to more effective wound healing.

Q *What are the next key challenges in this field, and what needs to be achieved before such biomaterials can be widely used in clinical practice?*

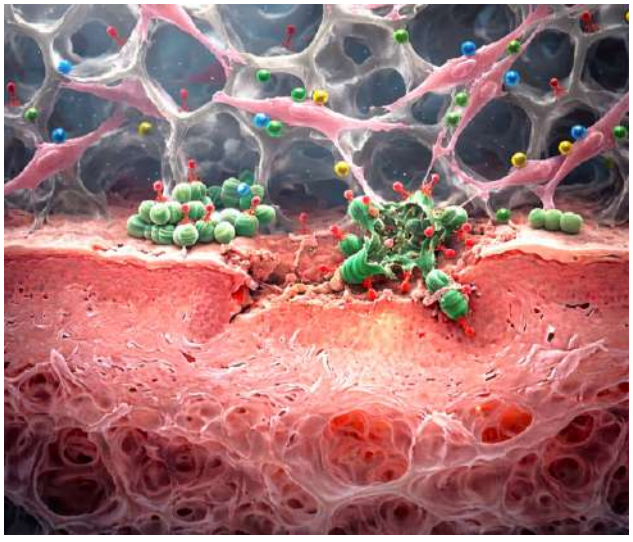
A Some of the challenges that still need to be addressed include efforts to enhance the duration of antimicrobial activity by finding ways to overcome the bacterial resistance through development of phage cocktails comprising multiple phage strains. Such cocktails can further be optimized based on the predominant pathogens of the chronic wound.

In case of phytoextracts, further research on optimizing the best formulation, i.e., in the form of powder or oil, and the dose composition for incorporation into the biomaterial, needs to be determined for anti-inflammatory activity that not only promotes wound healing but also supports the antimicrobial activity of bacteriophages.

With such advancements of our research, these composite biomaterials are expected to find broader applications in clinical practice, particularly in the form of advanced wound care products. However, the regulatory hurdles arising from the probable classification of the developed composite biomaterials as a new medical device are likely to pose challenges during clinical translation. Therefore, it is important to address the regulatory barriers through structured and robust regulatory reforms. The anticipated developments in the national regulatory guidelines may reduce the time lag between device development and commercialization.

Reference

Dr. Tiwari's contributions to this field are reflected in his recent publication in ACS Applied Bio Materials (2026), titled "Bifunctional Composite Biomaterials Integrating Bacteriophages and Phytoextracts for Chronic Wound Healing" https://doi.org/10.1021/acsabm.5c02578, which highlights innovative biomaterial-based strategies for advanced wound healing and antimicrobial therapy.



SCIENCE DESK

Understanding Cancer Resistance: How Cells Rewire Their Metabolism to Survive Treatment

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Scientific Profile
Organization Link
Factors Press

AREAS OF EXPERTISE
Cancer Epigenetics • Biomarker Discovery • Mitochondrial Metabolism • Exposomics

Q *What motivated you to explore how cancer cells develop resistance to treatments like cisplatin, and how did this research direction evolve?*

A Cisplatin is a DNA-damaging agent that is commonly used as the standard of care for treating locally advanced and metastatic cervical cancer. It is usually combined with radiation to improve treatment effectiveness. Although effective, a substantial proportion of patients develop resistance to cisplatin, showing resistance and recurrence. Treatment of recurrent cases is costly and is associated with poor clinical outcomes. Our research on cervical cancer and cisplatin revealed that the structural, functional and biochemical changes in mitochondria occurred in resistant cells. More specifically, the glucose uptake, lactate production and reactive oxygen species (ROS) levels significantly differed between the resistant and sensitive populations. In addition, we also observed that the activation of the chromosome 14 miRNA cluster sensitized cervical cancer cells to cisplatin, with simultaneous changes in cellular properties, notably metabolic changes. Our experiments suggested that changes in the genome and epigenome and associated metabolomic reprogramming may play critical roles in cisplatin resistance and that targeting these changes may be used to reverse cisplatin resistance. Using microRNA sequencing, we revealed that a cluster of miRNAs on chromosome 14 was consistently downregulated in resistant cells. One of their key targets was PDK3. This discovery connected two previously separate fields: noncoding RNA biology and metabolic reprogramming. Research has evolved from epigenetics to metabolism to regulatory RNA networks, and this integrated view has opened an entirely new therapeutic window.

Q *In simple terms, what does "metabolic reprogramming" mean, and why is it important in helping cancer cells survive therapy?*

A Metabolic reprogramming is a process in which cancer cells change/alter how they produce and utilize energy and build cellular materials that shift from normal metabolism to fuel rapid growth. To induce metabolic reprogramming, cancer cells exhibit changes in the genome, epigenome, proteome and metabolome. These cells use alternative fuels such as fatty acids and glutamine to maintain energy levels even under stress. Metabolic reprogramming helps cancer cells resist cisplatin. It does this by adjusting the antioxidant defense system of cells to overcome and neutralize drug-induced damage to cells, increasing the DNA repair capacity of cells, decreasing cisplatin import and increasing drug efflux. Thus, metabolic reprogramming helps cancer cells survive and continue growing. Thus, targeting metabolic reprogramming may be used as an approach against cancer cells to improve therapeutic outcomes.

Q *Your study highlights the role of PDKs. Can you explain what these molecules do and why they are so important in cancer resistance?*

A Pyruvate dehydrogenase kinase (PDK) comprises four members (PDK1–4). They function as metabolic regulators by controlling the function and activity of the pyruvate dehydrogenase complex (PDC). These kinases phosphorylate PDC to inhibit processes that convert pyruvate into acetyl-CoA, preventing its entry into the TCA cycle and mitochondrial respiration. As a result, cells undergo lactic acid fermentation even in the presence of oxygen, a phenomenon known as the

Warburg effect. In cancer, the overexpression of different members of PDK has been shown to activate oncogenic signaling, notably cell survival pathways and mitochondrial targeting. Accordingly, the PDK family has become an important treatment target. Blocking these kinases can restore mitochondrial oxidative function and improve the pro-apoptotic effects of chemotherapy drugs. In cervical cancer, we noted that the chromosome 14 miRNA cluster targeted PDK3. We detected reduced expression of the chromosome 14 miRNA cluster and increased expression of PDK3, which correlated with the reduced ability of cisplatin to kill cervical cancer cells. Restoration of the chromosome 14 miRNA cluster reduced PDK3 expression and, in turn, sensitized the cervical cancer cells to cisplatin by enhancing their cell-killing ability.

Q *One key idea is that cancer cells shift how they produce energy. How does this shift help them escape the effects of chemotherapy?*

A Metabolic reprogramming allows cancer cells to escape cisplatin-induced cell death. Cisplatin kills cells by inducing extensive DNA damage. Cisplatin-resistant cells modify metabolism to generate a surplus of NADPH and glutathione. By binding to cisplatin, glutathione deactivates it to reduce its cytotoxic effect. Scavenging of ROS generated by cisplatin by NADPH is another route to escape from cytotoxicity. A shift toward increased glycolysis and fatty acid oxidation provides a high-energy reservoir of ATP and nucleotide precursors and promotes enhanced DNA repair. By modifying the way they produce energy, cancer cells ensure that they have enough biosynthetic resources to survive. They proliferate and grow even in the presence of toxins such as cisplatin.

Q *How can targeting these metabolic pathways improve cancer treatment outcomes in the future?*

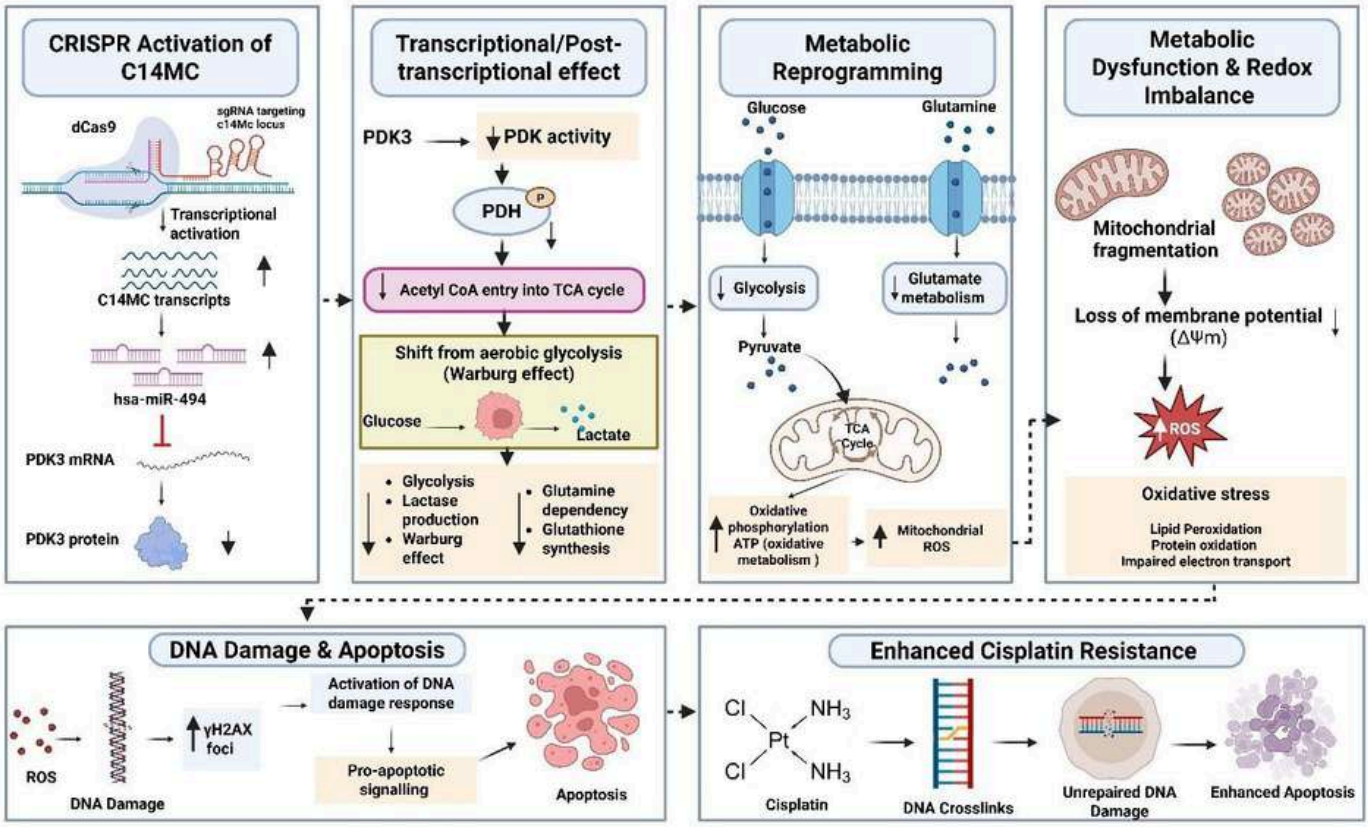
A This is the most exciting implication. If loss of the chromosome 14 miRNA cluster and subsequent PDK3 upregulation drive cisplatin resistance, then we have two complementary therapeutic strategies. We could administer artificial mimics of the deleted chromosome 14 miRNAs to reduce the expression of PDK3. Another possibility would be to target the kinase directly through inhibition by small molecules to reduce its activity. With a combination approach, we could first pretreat resistant tumors with mimics of chromosome 14 miRNAs or PDK3 inhibitors, effectively inducing mitochondrial metabolism and ROS generation and allowing apoptosis again. The sensitized cells can ultimately be treated with cisplatin for better outcomes. In our preclinical study, restoring the chromosome 14 miRNA cluster or inhibiting PDK3 pharmacologically sensitized resistant tumor cells to cisplatin. Overall, targeting this axis is a promising avenue for reversing resistance irrespective of the genetic profile of the tumor and may improve survival.

Q *What are the greatest challenges researchers still face in translating this knowledge into real therapies for patients?*

A There are still several obstacles to overcome. First, there is the issue of delivery. The miRNA mimics are highly unstable and must be transported to target cells without being degraded. This can be overcome by using liposomes or viral vectors that have shown promise but have not been utilized consistently. Second, the existing PDK inhibitors are nonselective and inhibit all the isoforms. The development of isoform-specific inhibitors is thus highly desired. Third, metabolic redundancy is present. Cancer cells are adaptive, and if we target one metabolic pathway, such as the PDK3 axis, then they may adapt and find other ways to sustain themselves. Hence, an approach should be devised to kill these cells before they adapt to another pathway for survival. Fourth, identifying people who will benefit from targeting the chromosome 14 miRNA cluster-PDK3 axis is important.

Q *What is the biggest message or conclusion from your research on cancer resistance?*

A Perhaps the most important conceptual shift from our work is that cancer resistance is not fixed. It is a dynamic state shaped by noncoding RNA regulation and metabolic adaptation. Rather than asking, “Which mutation causes resistance?”, we should ask, “Which regulatory and metabolic pathways stabilize resistance, and how can we destabilize them?” This perspective connects molecular events (loss of the chromosome 14 miRNA cluster → PDK3 upregulation → metabolic reprogramming) with clinical outcomes (chemotherapy failure). It also opens new avenues not only for cisplatin but also for other DNA-damaging



drugs, such as carboplatin and oxaliplatin.

We are in the process of understanding the noncoding RNA-metabolic architecture of chemoresistance. Future advances may allow us to map miRNA and PDK3 expression profiles from patient biopsies, design tumor-specific miRNA mimics, or even predict resistance before treatment begins. In my view, the next frontier in oncology lies not only in sequencing cancer genomes but also in decoding the regulatory logic that allows some cells to survive while others die. In the end, cancer is not governed by mutations alone. It is governed by RNA networks, metabolism, adaptation, and the quiet resilience of a cell that has learned to rewire its own engine.

Reference

Dr. Dr. Shama's contributions to this field are reflected in his publications in Cell Communication and Signaling (2026), https://doi.org/10.1186/s12964-026-02845-9 and Molecular Oncology (2024), DOI: 10.1002/1878-0261.13611. These works collectively highlight the critical role of RNA networks and metabolic reprogramming in driving cancer progression and chemotherapy resistance, offering new avenues for targeted cancer therapy.

SCIENCE DESK

Who Shapes New Science, Industry or Curiosity?”

Dr. Anubha Shokhand
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Scientific Profile
Organization Link
Factors Press

AREAS OF EXPERTISE
University-Industry Engagement • Science of Innovation • Science of Science • Technology Evolution • Science • Technology and Innovation (STI) policy

Q *What inspired you to explore the relationship between industry publishing and scientific novelty?*

A We often think of scientific research as something that happens primarily within universities and public research institutions. However, industry has a long history of contributing to science. Companies such as IBM and Bell Labs have produced influential scientific publications for decades, and more recently, firms like Google, Amazon, and OpenAI regularly publish in leading academic journals and conferences.

At the same time, firms do not participate in scientific publishing for the same reasons as universities. Their research agendas are often shaped by commercial objectives. Firms may even influence the direction of academic research. For example, studies have shown that industries such as alcohol or tobacco have funded research in ways that shift attention toward certain explanations or interventions while downplaying others.

This made me interested in a broader question: when firms become more active participants in scientific publishing, does this change the kind of knowledge that gets produced? Since novelty is central to scientific progress, I wanted to examine whether stronger industry presence in a scientific field is associated with different patterns of novelty.

Q *In simple terms, how would you explain “novelty in science” to a general audience?*

A Novelty in science is difficult to capture completely. No single conceptualization or operationalization can fully account for all forms of novelty, because newness can emerge in many different ways. However, one useful way to understand novelty is through the metaphor of LEGO bricks. Think of scientific knowledge as a giant set of LEGO bricks. Each brick represents an existing idea, concept, method, or finding. Novelty happens when a scientist takes bricks that have not usually been connected before and snaps them together to build something new.

For example, multiplication can be understood as building on the idea of repeated addition. In a more advanced sense, many scientific breakthroughs happen when disparate ideas are brought together. Similarly, Prospect Theory emerged by combining insights from psychology and economics to challenge traditional assumptions about how people make decisions.

So, novelty is not always about inventing something entirely from nothing. More often, it is about making a cognitive leap: seeing a connection that others have not seen before and using old ideas in a new combination.

Q *How does industry involvement influence the way new scientific ideas are generated and combined?*

A So, the core argument is that greater industry publishing does not simply increase or decrease novelty in a uniform way. Rather, it may relate to different kinds of novelty differently because of different underlying mechanisms. First, industry participation can increase the idea pool within a scientific field. Because industry research is often shaped by practical, commercial, and technical problems, it can introduce new kinds of questions, constraints, data, methods, and application-oriented insights into scientific conversations. These become additional “LEGO bricks” that researchers can combine with existing academic knowledge.

Second, the problems introduced by industry often require interdisciplinary research. Many industry-relevant problems are complex and cannot be solved from within a single knowledge domain. This can encourage researchers to draw on a wider range of th-

eories, methods, and fields, thereby increasing the scope of novel recombinations, or what I call novelty breadth. In this sense, industry involvement may push scientists to combine more diverse knowledge elements than they otherwise would.

However, industry involvement can also constrain novelty. Greater industry publishing may be associated with stronger commercial influence within a field, which can encourage secrecy, delays in publication, or the movement of important knowledge disclosure from publications to patents. These dynamics may limit the free flow of knowledge and reduce the diversity of ideas available for recombination.

At the same time, a stronger focus on industry-relevant problems may steer academic research away from more exploratory, curiosity-driven, blue-sky research toward safer, more immediately useful directions rather than risky, curiosity-driven combinations of intellectually distant ideas. Industry influence can also narrow research agendas, encourage secrecy, delay publication, or shift disclosure from publications to patents. Together, these mechanisms may reduce the novelty distance of scientific publications within a field.

Q *Your study highlights concepts like novelty breadth and novelty distance. Could you explain these?*

A I use three related but distinct measures of novelty in my study: novelty occurrence, novelty breadth, and novelty distance. Novelty occurrence captures whether a publication contains any novel combination of prior knowledge at all. In simple terms, it asks: does this paper connect ideas that are not usually connected? It is like asking whether someone at a dinner party introduced a new conversation by bringing together people or topics that normally do not interact.

Novelty Breadth captures the overall scope of novel recombination in a paper. A paper has greater novelty breadth when it introduces multiple new combinations, particularly when those combinations connect ideas that are relatively far apart. Using the dinner party metaphor, novelty breadth is like how many unusual conversations are happening across the room, while also considering how different the people in those conversations are. A party where a chef talks to a musician and an economist talks to a climate scientist has greater breadth than one with only a single unexpected interaction. And the breadth becomes even greater when the conversations connect people from very distant worlds — like a medieval historian and a rocket scientist.

Novelty distance captures how far apart the combined ideas are intellectually. Talking to a chef about food and nutrition may involve related ideas, so the distance is relatively small. But connecting ideas from medieval history and rocket science would involve a much larger intellectual jump. So, novelty distance is about how unfamiliar or distant the ideas were before they were brought together.

In short, novelty occurrence asks whether a novel combination happened, novelty breadth asks how wide the combination is, and novelty distance asks how far apart the combined ideas are. Together, these measures allow us to capture not just whether novelty occurs, but also what kind of novelty is being produced.

Q *What was the most surprising or impactful finding from your large-scale analysis of scientific publications?*

A One of the most surprising findings from the large-scale analysis was that greater industry publishing does not simply increase or decrease scientific novelty overall. Instead, it appears to shape different kinds of novelty differently.

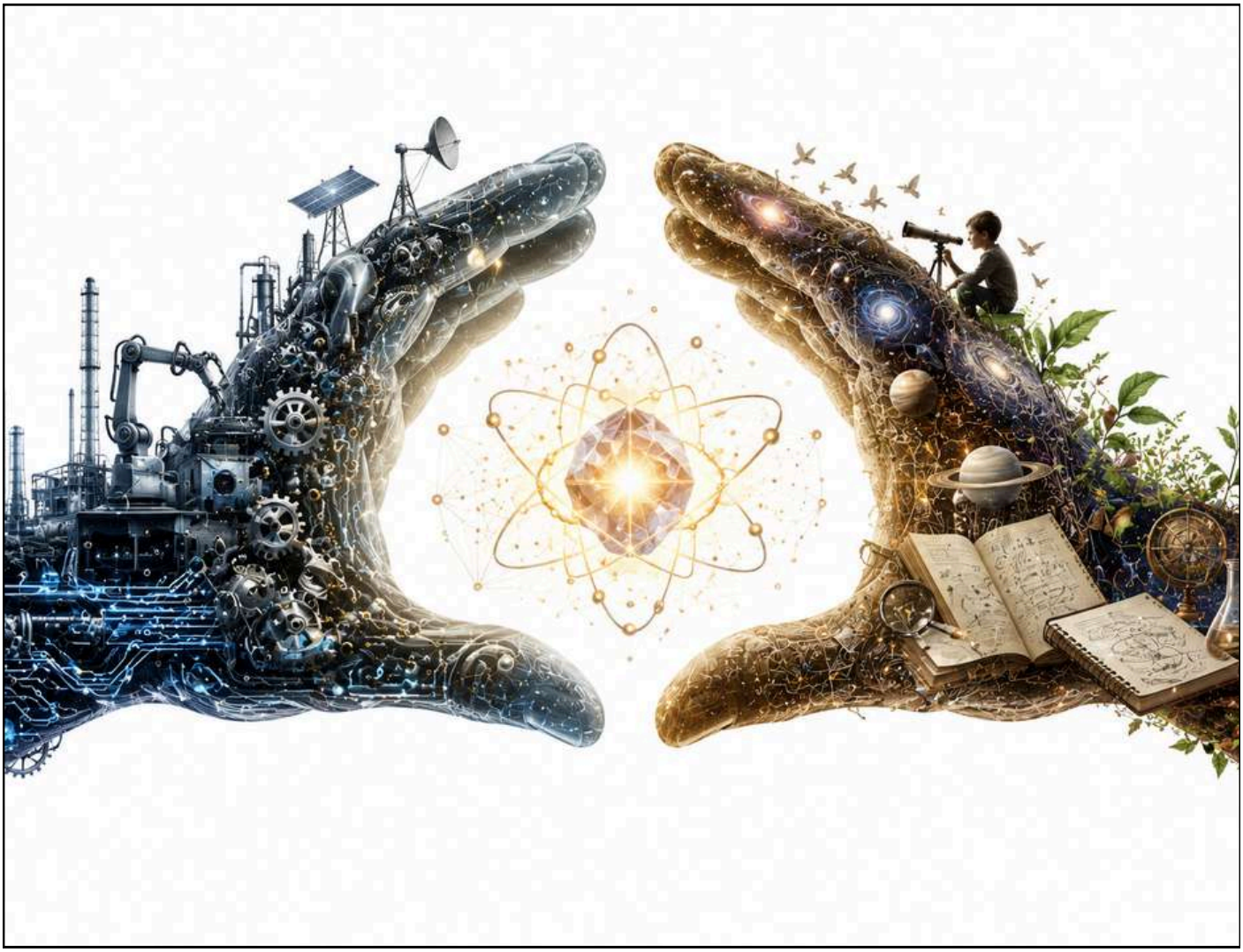
Specifically, fields with greater industry publishing activity, on average, showed higher levels of novelty occurrence and novelty breadth, but lower levels of novelty distance. In other words, greater industry involvement in scientific publishing may encourage more novel recombinations, particularly those involving a broader scope of ideas and interdisciplinary connections, while simultaneously discouraging riskier, blue-sky combinations across intellectually distant ideas.

This is particularly impactful because it adds on to the conversation that novelty is not captured through a single concept or measure. The broader implication is that understanding scientific creativity requires going beyond simply asking whether research is “novel.” We also need to ask what kind of novelty is being produced.

Q *How can your findings help researchers, institutions, or policymakers make better decisions about research collaboration and funding?*

The findings have important implications for researchers, institutions, and policymakers designing research collaboration and funding strategies. The key takeaway is that greater industry publishing does not influence all forms of novelty in the same way. While greater industry publishing may encourage more novel recombinations and broader knowledge integration useful for complex problem-solving, it may also reduce more distant, exploratory, blue-sky recombinations. So, policymakers need to think beyond a single measure of novelty and pay attention to different dimensions of novelty. This means research funding systems may need to balance two goals simultaneously: encouraging industry engagement and preserving curiosity-driven science. If policymakers want fields with strong industry presence to also produce more exploratory breakthroughs, complementary mechanisms may be needed, such as long-term funding for basic research, institutional support for high-risk projects, or protections from short-term commercial pressures.

Another important finding is that top–ranked research institutions are relatively better positioned to retain the benefits of industry publishing while still supporting more exploratory forms of novelty. This suggests that policymakers may consider institutional research ranking when promoting university–industry engagement, while also strengthening the broader research capacity of other institutions to support long-horizon, curiosity-driven research.



Reference

Dr. Shokhand's contribution to this field is reflected in her recent publication in PLOS One (2026), titled "The Field Factor: Industry Publishing Contribution and Novelty in Science" https://doi.org/10.1371/journal.pone.0346227. This work provides valuable insights into the relationship between industry involvement, scientific publishing trends, and innovation across research fields.

SCIENCE DESK

THE EMERGING ROLE OF EPIPLASTIC MICROALGAE IN COMBATING FRESHWATER PLASTIC POLLUTION

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Scientific Profile
Organization Link
Factors Press

AREAS OF EXPERTISE
Microalgal taxonomy & diversity•
Algal biotechnology • Bioactive compounds•
Bioremediation & Biodegradation

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Scientific Profile
Organization Link
Factors Press

AREAS OF EXPERTISE
Epiplastic microalgal diversity • Plastic
Biodegradation

Q *What inspired you to investigate microalgae as potential degraders of plastic waste in freshwater ecosystems?*

A Our inspiration emerged from observing the increasing accumulation of plastic waste in freshwater environments. An increase in anthropogenic activities results in the discharge of plastic waste into lakes and reservoirs, which results in plastic pollution. People use HDPE, LDPE, PET, PP, and PVC plastics for their daily activities, but these materials create environmental problems because they do not decompose naturally in aquatic ecosystems. Prior and ongoing research has examined how bacteria and fungi break down plastic materials, yet there has been insufficient investigation of how epiplastic microalgae degrade plastic through biochemical and extracellular mechanisms. Our research team investigated how microalgae, which grow naturally in freshwater environments, adapt their behaviour to plastic materials. We also wanted to study microalgae to determine whether they use plastics as their growth substrate or use biological processes to break down the materials. The basis of our research originated from our desire to investigate this topic.

Q *How did your study begin, and what was the main objective of the research?*

A The preliminary observations were carried out, and field studies were conducted in lentic freshwater bodies in Chennai, Tamil Nadu, India, which were severely polluted with domestic plastic waste. We found that microalgae established dense growth on plastic materials, which led us to investigate how they adapted to synthetic polymer surfaces. Our research objective involved identifying indigenous epiplastic microalgae that possess the ability to break down various types of domestic plastics while we studied the biochemical processes and extracellular mechanisms that drive this process. We sought to investigate how different factors, including cellular metabolism, oxidative stress, extracellular polymeric substances and enzyme-like activities, interact to cause polymer degradation instead of simply measuring degradation percentages.

Q *What were the most important findings from your study?*

A One of the most significant findings was the identification of Uronema trentonense as a highly efficient plastic-degrading microalga. Interestingly, this study represents the first report of Uronema trentonense (PX724094) from India through molecular characterisation using 18S rRNA–ITS

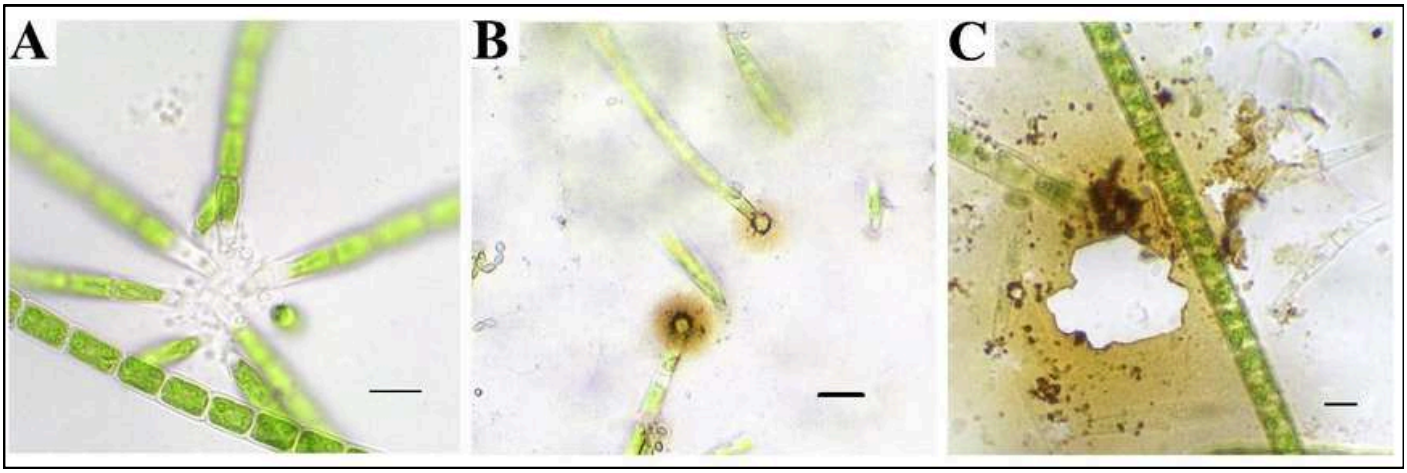


Fig. 1, A - Attachment of Uronema trentonense on plastics with the help of the holdfast cell, B – Change in colour of the plastic at the holdfast region after 30 days of inoculation, C – Prolonged incubation results in significant levels of biodegradation caused by Uronema trentonense.

sequencing. Among all the isolates screened, Uronema trentonense exhibited the highest degradation efficiency against HDPE and LDPE plastics, achieving up to 27 ± 2% and 21 ± 2% degradation, respectively. The cells underwent significant biochemical transformations that we detected during their exposure to plastic materials. The microalgae showed increased lipid, pigment and extracellular polysaccharide, protein production, which demonstrated their ability to adapt to metabolic stress. The cyanobacterial isolates Nostoc sp. and Oscillatoria sp. produced large amounts of EPS, which helped them create stable biofilms on hydrophobic plastic surfaces. The research results show that microalgae actively participate in the degradation process instead of just passively colonising their environment.

Q *Can you explain how microalgae actually contribute to plastic degradation?*

A The degradation mechanism shows evidence that it operates through three interconnected mechanisms, which include biochemical, oxidative and extracellular methods of degradation. Microalgae that grow on plastic surfaces encounter environmental stress because their cells must cope with synthetic polymers. The cells respond through increased production of pigments and lipids, together with extracellular metabolites. The metabolic changes lead to the production of reactive oxygen species (ROS), which cause oxidative damage to the plastic surface. The extracellular polymeric substances work together to create stronger attachments, which result in biofilm development that enables cells to maintain contact with plastic materials for extended periods. Our analyses determined that lipase-like enzymatic activity was present in the study. The combination of oxidative stress and the extracellular environment triggers polymer chain cleavage, which results in the conversion of long-chain plastics into smaller intermediate substances. The FT-IR and GC–MS analyses showed that oxidised functional groups and fatty acid methyl esters had formed, which served as evidence for both polymer degradation and metabolic transformation.

Q *What analytical techniques helped confirm the degradation process?*

A We conducted a full validation of the degradation process through their use of biochemical, molecular, spectroscopic and microscopic methods. We used Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM) to demonstrate structural degradation, which showed cracks, pits and erosion, which increased surface roughness in treated plastics. AFM analysis showed that the surface roughness increased from 31.9 nm in untreated plastics to 207 nm after treatment, indicating substantial nanoscale deterioration. The FT-IR spectroscopy results showed that oxidative degradation produced hydroxyl and unsaturated carbon groups, while GC–MS analysis identified multiple degradation intermediates, which included hexadecanoic acid methyl esters and oxygen-

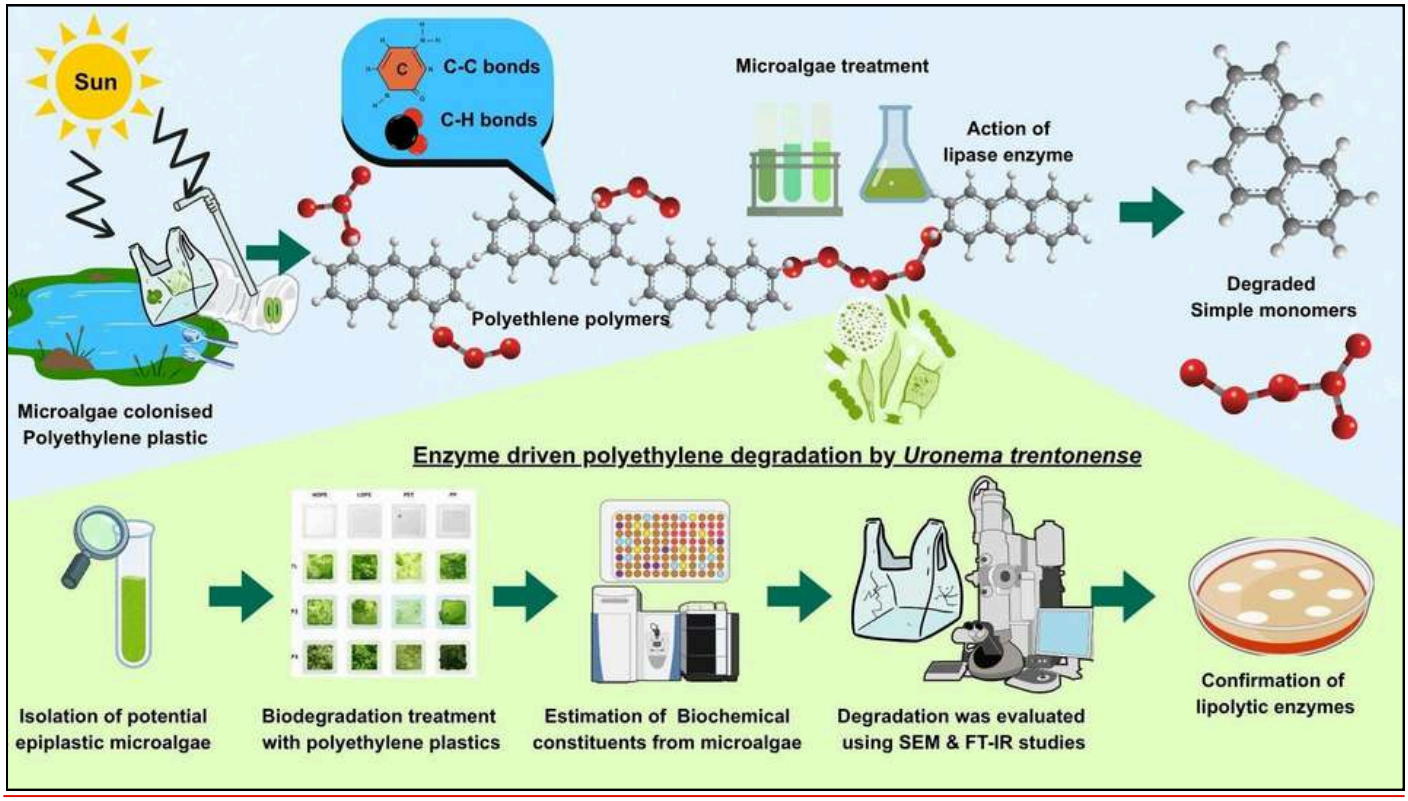
ated hydrocarbons. To understand the cellular metabolism, confocal microscopy and image flow cytometry to observe intracellular lipid accumulation and extracellular polysaccharide production during plastic exposure. The two analyses produced strong evidence that demonstrated that microalgae actively degraded the material through their metabolic processes.

Q *Why is this research important for environmental sustainability?*

A The research demonstrates that microalgae possess ecological value as they function as sustainable biodegradable agents that do not harm the environment. Microalgae establish themselves as a unique category of degraders because they use photosynthesis to produce energy while avoiding the toxic endotoxin emissions found in most bacterial and fungal degraders. The organisms possess the ability to use sunlight and carbon dioxide for survival, while they also interact with plastic waste materials. The research reveals new information about the "plastisphere" by showing that freshwater microalgae use their metabolic systems to break down polymers. The mechanisms found in nature will eventually lead to the development of sustainable bioremediation methods to treat plastic waste in water bodies. The study shows that plastic degradation depends on both enzymatic actions and a biological process, which includes metabolic changes and the release of substances from cells to their environment and how they interact with surfaces.

Q *What are the future directions of this work?*

A The present study demonstrates the significant potential of epiplastic microalgae in the biodegradation of plastic waste; Future research will primarily focus on elucidating the enzymatic and metabolic mechanisms involved in algal-mediated plastic degradation. We planned to determine how enzymes operate through their catalytic efficiency, substrate specificity and degradation pathways, which lead to plastic breakdown. The upcoming research work will use cutting-edge transcriptomic methods and molecular techniques to study stress-response pathways that become active when organisms come into contact with plastic materials. The optimisation studies will enable us to create biodegradation systems which can be used in both environmental and controlled conditions. The research will extend its scope to evaluate how epiplastic microalgae can restore freshwater ecosystems that have been polluted by both macroplastics and microplastics. The research team



will conduct long-term ecological studies to determine how plastic pollutants affect microbial community structure and biodiversity and ecosystem functioning during various exposure times. The ecological effects of plastic waste accumulation will be better understood through studying these interactions, which also show how algal communities help restore ecological balance. The research aims to create environmentally safe methods for managing plastic waste through its future research efforts. The research will establish biologically based methods to reduce plastic pollution and enhance aquatic ecosystem health by combining enzymatic studies, molecular analyses, ecological assessments, and environmental optimisation techniques.

Reference

Dr. Nagaraj's and Mr. Patrick's contributions to this field are reflected in their recent publication in Bioresource Technology (2026), titled "Biochemical and Extracellular Mechanisms of Plastic Degradation by Epiplastic Microalgae: A Novel Approach on Cellular Responses and Multi-Scale Material Interfaces" 10.1016/j.biortech.2026.134691. This work provides important insights into microalgae-mediated plastic degradation and highlights innovative mechanisms underlying sustainable bioremediation approaches.

SCIENCE DESK

Smart Gel Systems for Targeted Periodontal Treatment

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Scientific Profile
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The increasing interest in advanced drug delivery systems for the management of periodontitis stems from the complex, chronic, and site-specific nature of the disease, which continues to pose significant challenges to conventional treatment strategies. Periodontitis is a biofilm-driven, host-mediated inflammatory disorder in which a dysbiotic microbial community initiates and sustains immune responses that progressively destroy tooth-supporting tissues. This destruction is not uniform but instead occurs within the periodontal pocket, a confined, irregular, and structurally complex niche that both limits drug access and protects pathogenic biofilms. Within this microenvironment, keystone pathogens such as Porphyromonas gingivalis and Streptococcus mutans contribute to the formation of a resilient biofilm matrix that restricts drug penetration and enhances antibiotic tolerance.

Simultaneously, the host immune response promotes connective tissue destruction and alveolar bone loss through cytokine release, matrix metalloproteinase (MMP) activation, oxidative stress, and receptor activator of nuclear factor κB /osteoprotegerin imbalance. As these microbial and host factors continuously interact, they create a dynamic yet localized disease environment, thereby establishing a clear rationale for exploring more precise and responsive drug delivery systems.

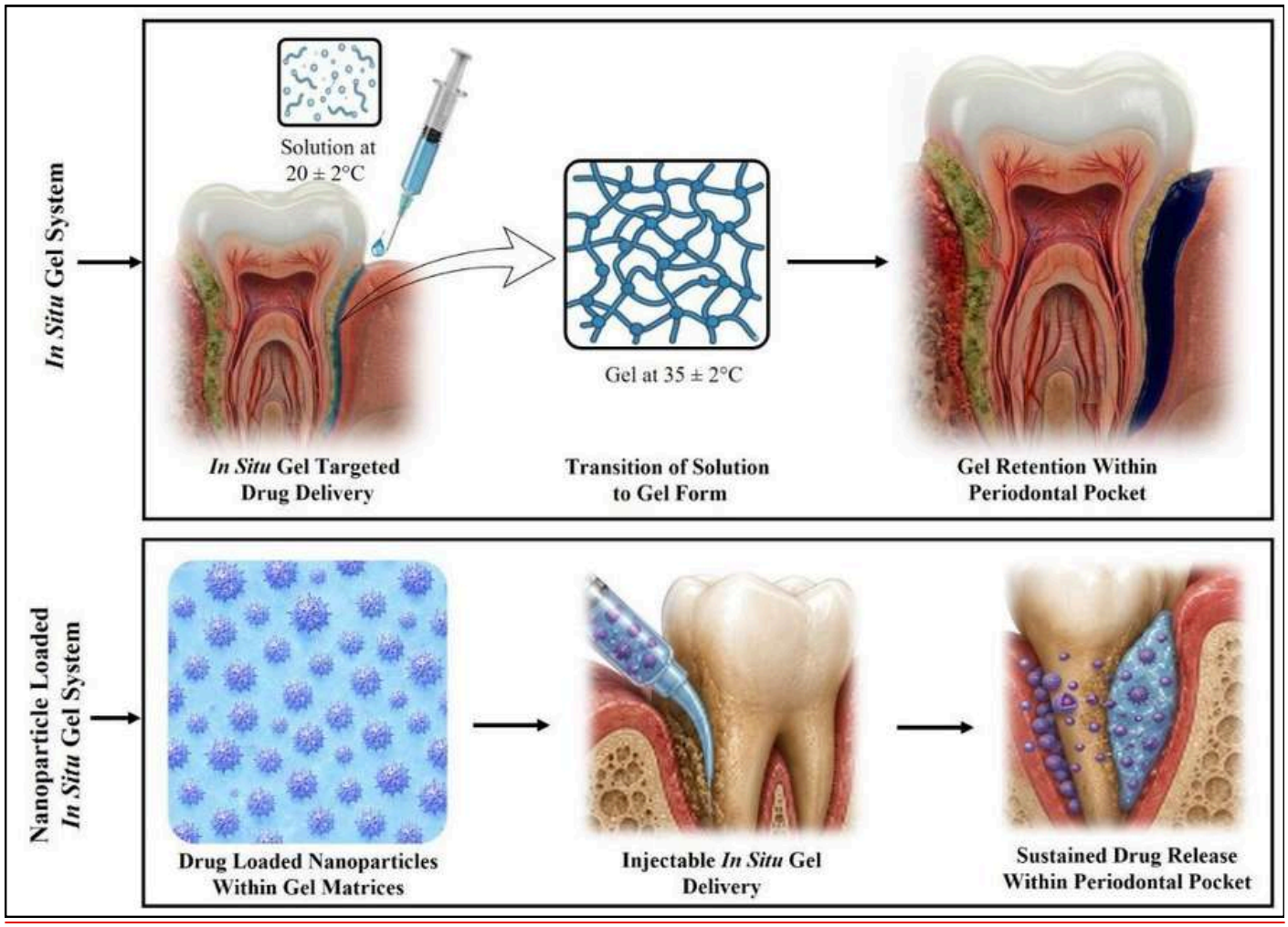
This understanding of disease complexity naturally explains why conventional treatment strategies often fail to produce long-term clinical success. Systemic drug administration, although widely used, is inherently limited by insufficient drug retention at the periodontal site, leading to subtherapeutic concentrations. Conventional topical formulations have been developed to overcome these limitations; however, their effectiveness is often restricted by rapid diffusion and inadequate retention within the periodontal pocket. Continuous salivary washout and gingival crevicular fluid turnover contribute to rapid drug elimination and poor penetration into the biofilm structure. As a result, these systems are unable to maintain sustained therapeutic drug levels or effectively eradicate the organized biofilm, leading to incomplete disease management and recurrent infections. Therefore, the disparity between the localized, protected nature of periodontal disease and the short-lived action of conventional delivery systems has driven the need for more advanced, adaptive, and site-specific therapeutic approaches.

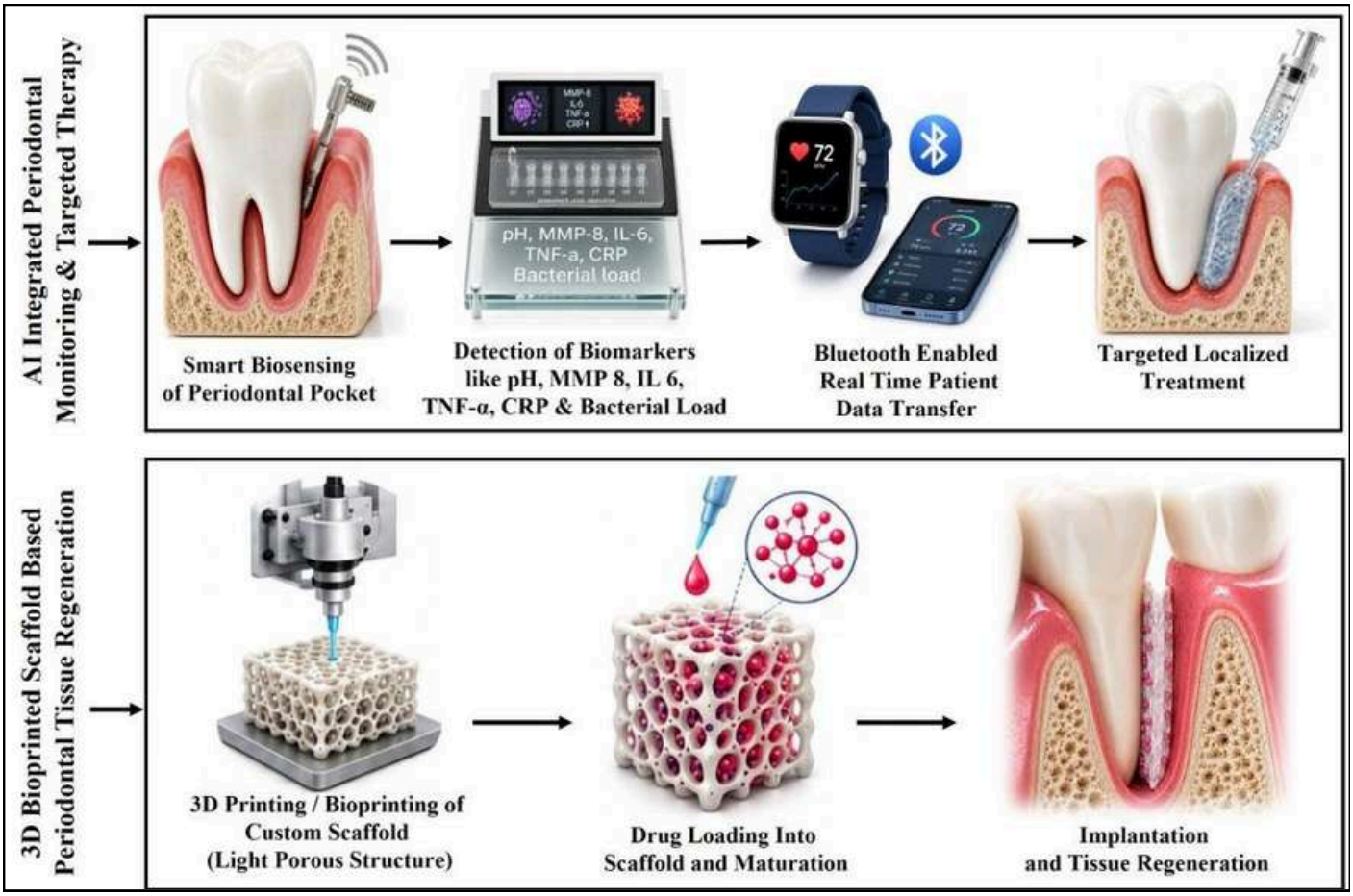
Addressing this gap has led to the emergence of smart in situ gel systems, which fundamentally redefine how drugs are delivered within the periodontal environment. In contrast to conventional formulations, these systems exist as low-viscosity liquids that can be conveniently administered into the periodontal pocket with minimal invasiveness. Following administration, they undergo a stimuli responsive sol-to-gel transition induced by physiol-

ogical conditions within the periodontal microenvironment, such as pH, temperature, ionic concentration, and enzymatic activity. This transformation produces a semi-solid matrix that closely adapts to the irregular architecture of the periodontal pocket, thereby ensuring localized and site-specific drug delivery. In addition, the gel matrix establishes intimate contact with the diseased tissues and acts as a localized drug reservoir, resulting in improved residence time and sustained retention. Consequently, these systems offer a considerable advantage over conventional formulations that lack such adaptive and prolonged delivery characteristics.

During active periodontitis, the periodontal microenvironment undergoes a shift toward a slightly alkaline pH, a condition that can be effectively utilized by pH-responsive polymers such as Carbopol. Under these conditions, ionization of polymeric carboxyl groups of the Carbopol induces swelling and network formation, leading to enhanced viscosity, mucoadhesion, and targeted drug retention. Simultaneously, the presence of divalent cations such as calcium and magnesium ions in gingival crevicular fluid enables ion-sensitive polymers like alginate and gellan gum to undergo rapid crosslinking through ionic bridging mechanisms, resulting in mechanically stable gels that resist washout. Building upon these mechanisms, thermosensitive polymers such as Poloxamer 407 introduce temperature-triggered gelation, allowing formulations to remain fluid during administration (20-25°C) while rapidly solidifying at physiological temperatures (37°C). Further enhancing this responsiveness, enzyme-sensitive systems, including peptide-crosslinked hydrogels, can utilize the elevated matrix metalloproteinase levels present within the periodontal pocket to dynamically modulate gel behavior and control drug release. Integration of these physiological triggers into multi-responsive systems enhances stability, prolongs retention, and enables precise site-specific drug delivery, thereby addressing the complex challenges of periodontal therapy.

As these smart systems continue to evolve, recent advances





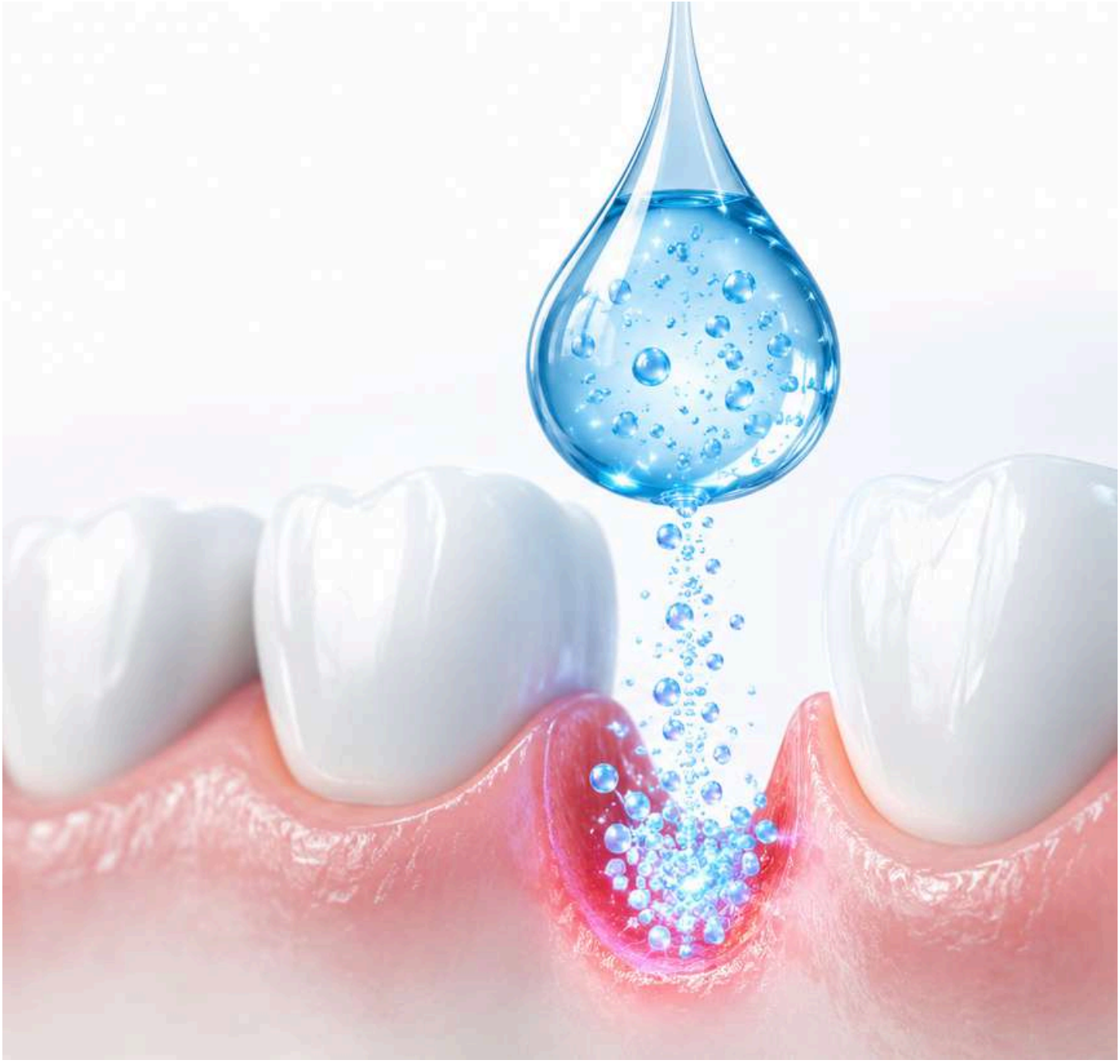
in nanotechnology, artificial intelligence, and 3D printing are further expanding their capabilities and redefining their clinical potential. The incorporation of drug-loaded nanoparticles into gel matrices enhances drug stability and promotes deeper penetration into dense biofilms, thereby improving antimicrobial efficacy while enabling controlled, multi-phase drug release. Simultaneously, artificial intelligence and computational modelling are increasingly being utilized to predict polymer behaviour and optimize formulation parameters. These approaches also facilitate the customization of drug release kinetics according to patient-specific disease characteristics, introducing a new level of personalization into periodontal therapy. This integration is further strengthened by digital diagnostic tools, including intraoral sensors and wearable monitoring devices, which enable real-time monitoring of critical disease markers such as inflammatory cytokines, and periodontal pocket depth. The resulting data-driven insights support the development of adaptive, feedback-controlled drug delivery systems capable of dynamically responding to disease progression. Complementing these advancements, 3D printing and bioprinting technologies are enabling the fabrication of customized scaffolds with tunable porosity and controlled drug distribution. In addition to localized drug delivery, these systems possess regenerative capabilities, thereby extending their application toward periodontal tissue regeneration. Furthermore, hybrid strategies combining injectable gels with 3D-printed constructs provide an effective balance between minimally invasive administration and structural support, ultimately enhancing therapeutic outcomes.

These technological advancements collectively translate into meaningful improvements in real-world dental care, where precision, efficacy, and patient comfort are critical considerations. Smart in situ gel systems are minimally invasive and easy to administer, reducing procedural complexity while enhancing patient acceptance. Their ability to maintain therapeutic drug concentrations at the site of infection over extended periods reduces dosing frequency and improves compliance, which is particularly important in managing chronic conditions such as periodontitis. At the same time, sustained and localized drug release enhances biofilm disruption, minimizes systemic exposure, and reduces the risk of adverse effects

and antimicrobial resistance. By adapting to the periodontal microenvironment and integrating emerging technologies, these systems enable precise and personalized treatment strategies. Smart in situ gel systems represent a progressive shift from conventional, passive drug delivery approaches toward intelligent, adaptive therapeutic platforms. By integrating site-specific targeting, sustained retention, and responsiveness to physiological stimuli with advancements in nanomedicine and artificial intelligence, these systems are well suited to address the complex nature of periodontitis. As a result, they offer a cohesive and forward-looking strategy for improving treatment outcomes, advancing personalized care, and ultimately transforming the management of periodontal disease.

Reference

Dr. Boregowda and Dr. Rajamma's contributions to this field are reflected in their research on Journal of Drug Targeting (2026) doi:10.1080/1061186X.2026.2653982 and Gels (2023) https://doi.org/10.3390/gels9070577. Their work focuses on developing smart in-situ gel systems and innovative biomaterial-based strategies for targeted treatment of gum disease, improved tissue regeneration, and enhanced patient-friendly dental care.



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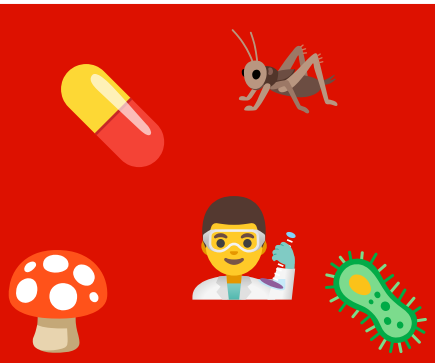


Q1

What is the major advantage of engineered antibodies?

A. They target specific molecules precisely
B. They replace all medicines
C. They are made from plants
D. They cure all diseases

Q2

Why are metal complexes useful in making advanced materials?

A. They increase pollution
B. They allow better control of material properties
C. They prevent crystal formation
D. They reduce conductivity

Q3

What type of materials are produced from metal complexes in the sulfide nanostructure study?

A. Nanomaterials and thin films
B. Plastics only
C. Glass fibers only
D. Wood composites

Q4

Single-atom catalysts are being developed mainly for use in:

A. Food processing
B. Fuel cells and energy technologies
C. Paper production
D. Textile manufacturing

Q5

Why is catalyst stability important?

A. It helps catalysts work longer and more efficiently
B. It increases their weight
C. It changes their color
D. It reduces electricity production

Q6

Why do scientists study how molecules move inside cells?

A. To understand cell color
B. To design better medicines
C. To increase cell size
D. To stop cell division

Q7

What technology helps scientists observe molecular movement inside living cells?

A. Optical microscopy
B. Telescope imaging
C. Radar systems
D. X-ray diffraction only

Q8

Why is early diagnosis of mercury poisoning important?

A. It improves the chance of recovery
B. It changes eye color
C. It increases appetite
D. It prevents aging

DISCOVERY HIGHLIGHTS

PUBLIC HEALTH AND AGEING

HIDDEN STILLBIRTH BURDEN IN INDIA REVEALED BY NATIONAL SURVEY DATA

Stillbirth remains a major but under-recognized public health challenge in India. Most official estimates count fetal deaths only after 28 weeks of pregnancy, overlooking a substantial number of losses that occur earlier. Using data from over 540,000 women across three National Family Health Surveys (2005–2021), researchers generated national, state, and district-level estimates of stillbirths occurring from 20 weeks onward. The study found that India's stillbirth rate increased from 12.8 per 1,000 births at 28 weeks or more to 22.0 per 1,000 births when losses from 20 weeks were included. This indicates that nearly 42% of stillbirths occur between 20 and 28 weeks and are missed in conventional reporting. Higher risk was associated with maternal anemia, illiteracy, short stature, rural residence, and use of unclean cooking fuels. The findings underscore the need for better surveillance and earlier tracking of pregnancy losses to guide targeted interventions across India.

Pandey A.K. et al., 2026.

INFLUENZA REMAINS A SERIOUS THREAT TO OLDER ADULTS IN INDIA

Influenza is often dismissed as a seasonal illness, but for older adults it can lead to severe respiratory infections and hospitalization. In a large community-based study conducted across four regions of India between 2018 and 2023, researchers tracked nearly 20,000 person-years of follow-up among adults aged 60 years and above to measure the true burden of influenza. The study identified more than 25,000 respiratory illness episodes and found that influenza caused 39 cases of upper respiratory infection and 8.5 cases of lower respiratory infection per 1,000 older adults each year. Influenza A(H3N2) was the dominant strain. Disease rates were higher before the COVID-19 pandemic and rebounded again in 2022–2023. The risk of severe influenza was greatest among adults over 65, women, individuals with chronic respiratory disease, and those living with disabilities. These findings provide strong evidence that older adults in India should be prioritized for seasonal influenza vaccination and other preventive measures.

Rajkumar P. et al., The Lancet Regional Health – Southeast Asia, 2026.

INFECTIOUS DISEASES AND IMMUNITY

DEVELOPMENT OF BENZIMIDAZOLE-BASED BZ-30 AS AN ORALLY BIOAVAILABLE BROAD-SPECTRUM INHIBITOR OF SARS-CoV-2

As SARS-CoV-2 continues to evolve, scientists are racing to develop antiviral drugs that remain effective against emerging variants. In a study, researchers reported a new class of benzimidazole-based compounds that potently inhibit the virus. Among the molecules tested, BZ-30 emerged as the most promising candidate. It showed strong antiviral activity against multiple variants of concern and demonstrated excellent oral bioavailability. Mechanistic studies revealed that BZ-30 partially blocks the virus from entering host cells through endocytosis pathways. When tested in SARS-CoV-2-infected hamsters, BZ-30 significantly reduced viral load and improved lung pathology, providing compelling evidence of its in vivo efficacy. This first-in-class compound represents a promising orally available antiviral that could help combat current and future coronavirus outbreaks.

Kaur S. et al., Journal of Medicinal Chemistry (2026).

HOW PROBIOTICS HELP PROTECT THE GUT FROM SALMONELLA INFECTION

Can beneficial bacteria help defend the gut against dangerous pathogens? A study published in the suggests they can. Researchers isolated four strains of *Lactiplantibacillus plantarum* from traditional fermented foods of Northeast India and tested their ability to protect cells from Salmonella-induced damage. All four strains survived harsh gastrointestin-

DISCOVERY HIGHLIGHTS

al conditions and adhered effectively to intestinal cells. When used to pretreat cultured cells, they significantly reduced cell death, restored antioxidant defenses, and preserved the integrity of the intestinal barrier. The probiotics lowered harmful nitric oxide levels, increased glutathione and superoxide dismutase activity, and helped maintain cellular energy production. Genome sequencing revealed genes associated with stress tolerance and metabolic adaptability, supporting their strong protective performance. These findings identify these indigenous probiotic strains as promising "immunobiotics" that could help prevent intestinal inflammation and strengthen host defenses against foodborne infections.

Hazarika P. et al., World Journal of Microbiology and Biotechnology (2026).

ARTIFICIAL INTELLIGENCE IN MEDICINE

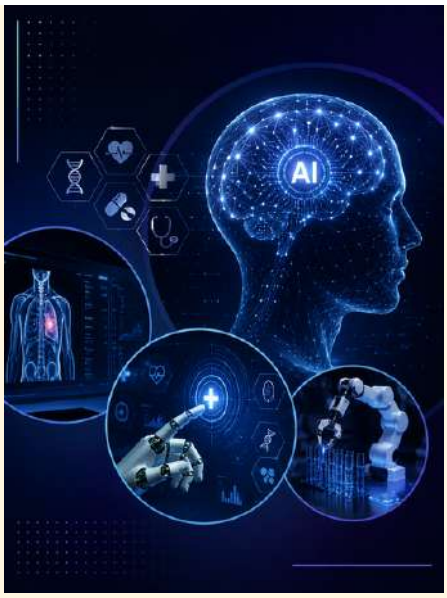
NEW CT-BASED TOOL HELPS SURGEONS PLAN OVARIAN CANCER TREATMENT

For women with advanced ovarian cancer, the success of surgery often depends on whether doctors can remove all visible tumors. Determining this before entering the operating room is challenging. In a prospective study from India, researchers developed and tested a structured imaging tool called the CT PAUSE score to help clinicians decide which patients are most likely to benefit from surgery. The PAUSE system evaluates five critical features seen on CT scans: the extent of peritoneal disease, ascites, involvement of unfavorable anatomical sites, small bowel disease, and spread beyond the abdomen. In 124 women with stage III or IV epithelial ovarian cancer, use of this tool in multidisciplinary decision-making led to an impressive complete cytoreduction rate of 89.3%. Researchers also created a simplified nomogram based on upper abdominal disease burden, which performed as well as more complex scoring systems while being easier to use in busy hospitals. This study shows that standardized CT reporting can improve surgical planning and help deliver more personalized care for women with advanced ovarian cancer.

Jeslin A.G. et al., The Lancet Regional Health – Southeast Asia, 2026.

AI FORECASTS THE FUTURE OF ANTIBIOTIC RESISTANCE

Antimicrobial resistance (AMR) is one of the world's most urgent health threats, turning common bacterial infections into diseases that are incr-



easingly difficult to treat. A new perspective highlights how machine learning, deep learning, and generative artificial intelligence (GenAI) are transforming our ability to predict where and when resistance will emerge. These technologies can analyze vast datasets, including bacterial genomes, hospital records, prescription patterns, and environmental information.

GenAI can also generate realistic synthetic data to fill surveillance gaps, especially in countries with limited monitoring systems. Together, these tools can identify hidden patterns, forecast future resistance trends, and provide early warnings before outbreaks escalate. Beyond prediction, AI is accelerating antibiotic discovery and helping clinicians select the most effective treatments.

However, their success depends on high-quality data, transparent algorithms, and global collaboration. By shifting from reactive monitoring to proactive forecasting, artificial intelligence offers a powerful new strategy to stay ahead of the growing antimicrobial resistance crisis.

Chakraborty C. et al., Annals of Medicine & Surgery, 2026.

DISCOVERY HIGHLIGHTS

CROP GENOMICS AND FOOD SECURITY

RICE ROOTS USE A NATURAL FILTER TO BLOCK ARSENIC FROM GRAINS

Arsenic contamination in rice is a serious food safety concern, affecting millions of people who rely on rice as a staple food. In a breakthrough study, researchers discovered that a rice protein called OsELP acts like a natural filter in the roots, trapping arsenic before it can reach the grain. Using genetically engineered rice and Arabidopsis plants, the team showed that plants overexpressing OsELP were far more tolerant to arsenic stress. Advanced imaging revealed that OsELP helps immobilize arsenic in the cell walls of root tissues, a process known as apoplastic sequestration. By locking arsenic in the roots, the protein greatly reduced its movement to shoots and grains. As a result, OsELP-overexpressing plants accumulated significantly less arsenic in edible grains while maintaining better growth, photosynthesis, and antioxidant defense. In contrast, plants lacking OsELP were more sensitive and accumulated higher arsenic levels. This discovery identifies OsELP as a promising genetic target for developing safer rice varieties with reduced arsenic content.

Chawda K. et al., Plant, Cell & Environment, 2026.

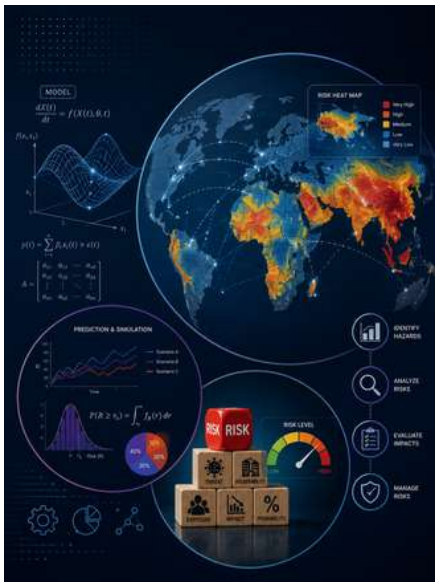
A RICE GENE THAT HELPS FUNGI ATTACK

Rice sheath blight, caused by the fungus Rhizoctonia solani, is one of the most destructive diseases affecting rice production worldwide. In a striking discovery, researchers found that a rice gene called OsNUOR actually helps the pathogen infect the plant by triggering a self-destructive process in host cells. Plants overexpressing OsNUOR became highly susceptible to disease, while genome-edited knockout plants showed significantly greater resistance. The gene promotes the buildup of reactive oxygen species (ROS), iron, and lipid peroxides, creating conditions that trigger ferroptosis-like cell death an iron-dependent form of cellular damage.

This process causes tissue necrosis, which benefits necrotrophic fungi that feed on dead cells. In contrast, plants lacking OsNUOR maintained stronger antioxidant defenses and avoided excessive oxidative damage. Chemical inhibitors of ferroptosis reduced disease symptoms, further confirming the mechanism.This study identifies OsNUOR as a susceptibility gene and highlights genome editing of this target as a promising strategy for developing rice varieties resistant to sheath blight.

Sahoo D. et al., The Plant Cell, 2026.

MATHEMATICAL MODELLING AND RISK ASSESSMENT



WHICH INDIAN CITIES FACE THE HIGHEST ROAD ACCIDENT RISK?

Road accidents claim thousands of lives in India each year, but not all cities face the same level of danger. In a new study, researchers used advanced mathematical modeling to assess road accident risk across 53 major Indian cities using official government data and 35 key safety indicators. The team applied a sophisticated Type-2 picture fuzzy framework, a decision-making approach designed to handle uncertainty and complex datasets. By integrating several ranking methods including TOPSIS, VIKOR, WASPAS, CODAS, and COPRAS, they created a robust and reliable index to compare accident risk across cities. Chennai consistently ranked as one of the safest cities, while Amritsar also performed exceptionally well. In contrast, Kanpur, Lucknow, and Ahmedabad were identified as high-risk cities, with Kanpur receiving the lowest overall ranking. Cities such as

DISCOVERY HIGHLIGHTS

Hyderabad and Pune occupied intermediate positions, showing moderate but stable risk profiles. The study provides policymakers with a rigorous tool to identify urban hotspots and prioritize interventions that can improve traffic safety and save lives across India.
Prabakaran R. et al., Scientific Reports (2026).

HOW FAR IS BLOOD FROM THOSE WHO NEED IT MOST IN INDIA?

When a patient needs an urgent blood transfusion, every minute matters. But how quickly can people across India reach a blood bank? In a nationwide geospatial study, researchers mapped access to blood banking facilities across all 735 districts of India. Using 2024 data from the national e-RaktKosh system, the team identified 5,679 blood banking facilities, an average of 4.13 facilities per million people. They estimated that nearly 94% of India's population can reach the nearest blood bank within 60 minutes by motorized transport. However, only 16.2% can reach one within 30 minutes on foot, highlighting major barriers for people without reliable transportation. The study also revealed stark regional inequalities. Northeastern states, island territories, and many rural districts had much longer travel times and poorer access than urban areas.

These findings provide a powerful evidence base for improving blood infrastructure and ensuring that life-saving transfusions are available to all, regardless of geography.
Urs G. et al., Transfusion Medicine (2026).

CHEMISTRY, MATERIALS AND CLEAN ENERGY

SCIENTISTS CREATE A CARBON-FREE COUSIN OF FERROCENE

In 1951, the discovery of ferrocene, an iron atom sandwiched between two carbon rings, revolutionized chemistry and opened the door to modern organometallic science. More than seven decades later, researchers have achieved a long-sought milestone: the creation of a carbon-free analog of this iconic molecule. In a study published in Science (2026), scientists synthesized $[Os(\eta^5\text{-}B_5H_{10})_2]$, a remarkable compound in which an osmium atom is sandwiched between two boron-hydrogen rings instead of carbon-based cyclopentadienyl rings. The structure closely resembles ferrocene but features even stronger metal–ring bonding and an unusually short distance between the two rings. The breakthrough demonstrates that boron clusters can mimic the elegant sandwich architecture that made ferrocene famous. Researchers also isolated an unusual isomer with a previously unseen coordination mode, revealing new possibilities in molecular design. This discovery expands the boundaries of organometallic chemistry and may lead to novel catalysts, electronic materials, and energy-related applications built from entirely new classes of molecules.
Mohapatra S. et al., Science (2026).

TURNING POLYCARBONATE PLASTIC INTO JET FUEL USING SUNLIGHT

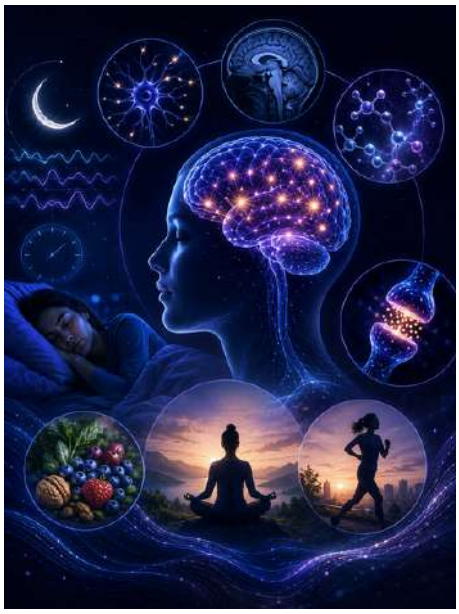
Polycarbonate is one of the toughest plastics to recycle. Found in products such as safety goggles, electronic components, and compact discs, this durable material contains strong chemical bonds that resist most conventional recycling methods. Now, researchers have developed a light-powered strategy to transform polycarbonate waste into valuable fuel-range hydrocarbons. In a study, scientists designed a multifunctional catalyst called Ru@P-CHS(g-C_3N_4) that uses visible light and hydrogen gas to break down polycarbonate under ambient conditions. The process converts the plastic into propane-2,2-diyldicyclohexane (DCHP), a saturated hydrocarbon with properties relevant to jet fuel. The catalyst integrates light absorption, electron transfer, acidity, and hydrogen activation in a single material, achieving near-quantitative conversion and about 94% selectivity for the desired product.

Importantly, the method also worked efficiently on real-world polycarbonate waste.This breakthrough introduces reductive photocatalysis as a powerful new approach for plastic upcycling, offering a sustainable route to convert difficult-to-recycle plastics into high-value fuels.

Ghalta R. et al., Angewandte Chemie International Edition (2026).

NEUROSCIENCE, SLEEP AND BRAIN HEALTH

DISCOVERY HIGHLIGHTS



ZEBRAFISH EYE MOVEMENTS REVEAL A HIDDEN ARCHITECTURE OF SLEEP

Sleep is often thought of as a simple switch between being awake and being asleep. But just as human sleep includes stages such as REM and non-REM, researchers have now discovered that zebrafish also cycle through multiple, distinct sleep substates. In a study, scientists tracked tiny eye movements in sleeping larval zebrafish and identified four conserved sleep substates. Three states showed unique patterns of eye motion (QEM-1, QEM-2, and QEM-3), while a fourth state (QNEM) involved no eye movement. Surprisingly, one state, QEM-1, occurred almost exclusively during the daytime, while QNEM dominated at night. These substates were associated with changes in arousal threshold, posture, and brain-wide neural activity, demonstrating that they represent genuine forms of sleep rather than random inactivity. The findings reveal that even small fish possess a sophisticated sleep architecture regulated by the circadian clock, providing a powerful new model for understanding the biology and evolution of sleep.

Choudhary V. et al., Nature Communications (2026).

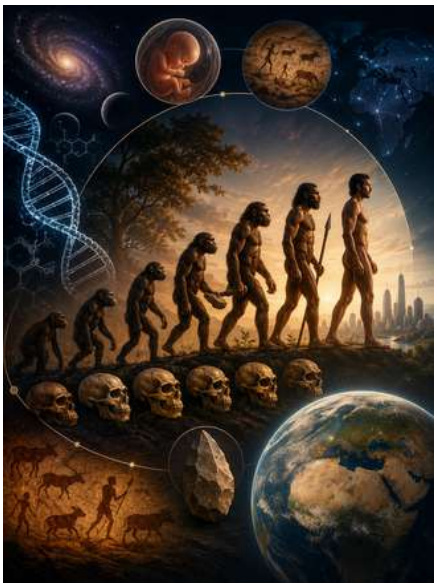
CAN BRAHMI PROTECT THE BRAIN AFTER A STROKE?

For centuries, Bacopa monnieri better known as Brahmi has been used in Ayurvedic medicine to improve memory and mental health. Now, modern research suggests that this traditional herb may also help protect the brain from stroke-induced damage. In a study, researchers tested Brahmi in rats subjected to middle cerebral artery occlusion (MCAO), a widely used model of ischemic stroke. Rats pretreated with Bacopa monnieri for 15 days showed improved motor coordination, stronger grip, and better performance in memory tests compared with untreated animals. The herb also reduced the size of brain infarcts and restored antioxidant defenses in the frontal cortex and hippocampus two brain regions critical for cognition and behavior. Levels of harmful oxidative stress markers declined significantly. These findings suggest that Brahmi protects the brain by strengthening natural antioxidant systems, offering scientific support for its traditional use and highlighting its potential as a complementary strategy for stroke recovery.

Khuwaja G. et al., Journal of Ethnopharmacology (2026).

HUMAN ORIGINS AND EVOLUTION

WHAT OUR TRIBAL GENOMES REVEAL ABOUT SOUTH ASIA'S DEEP PAST



Who were the earliest inhabitants of South Asia, and how are today's tribal communities connected to them? A new study reconstructs the genetic history of Austro-Asiatic- and Dravidian-speaking tribal populations, offering fresh insights into human migrations that shaped the region. Using whole-genome data from the GenomeAsia 100K Project, researchers found that the ancestral genetic components associated with Indian Austro-Asiatic speakers and Dravidian-speaking tribes diverged approximately 15,000–20,000 years ago, shortly after the Last Glacial Maximum. This suggests that these populations began separating long before the advent of agriculture. The study also showed that Austro-Asiatic ancestry in India and Southeast Asia split even earlier, indicating a widespread prehistoric population extending across both regions. Interestingly, some central Indian tribes displayed genetic profiles that did not match their present-day languages, reflecting recent gene flow over the last 750–1,500 years. These findings reveal a complex history of migration, isolation, and cultural exc-

DISCOVERY HIGHLIGHTS

hange that continues to shape South Asia's remarkable human diversity.
Dey A. et al., iScience (2026).

INDIA'S 54-MILLION-YEAR-OLD FOSSIL OFFERS A RARE GLIMPSE INTO EARLY PRIMATE EVOLUTION

A tiny fossil discovered in Gujarat is helping scientists understand what some of the earliest primates may have looked like. In a study , researchers describe an exceptionally well-preserved inner ear bone, or petrosal, recovered from the Vastan Lignite Mine in western India. Dating to about 54.5 million years ago, the fossil is likely the oldest and best-preserved petrosal known from a true primate, or euprimate. Its anatomical features suggest that it belonged to a small primate weighing less than 186 grams, probably Marcgodinotius indicus, an early adapoid primate. The structure of the inner ear provides clues about both evolutionary relationships and locomotion. Some features suggest cautious movement through trees, while others hint at more active behavior.

Importantly, the fossil preserves several primitive traits, supporting the idea that asiadapids represent one of the earliest branches of the primate family tree. This remarkable discovery highlights India's crucial role in uncovering the origins of primates, including the distant ancestors of lemurs, monkeys, apes, and humans.
Silcox M. T. et al., The Anatomical Record (2026).

SOCIAL BEHAVIOUR AND HEALTH

ASTHMA MAY AFFECT MORE THAN BREATHING IT CAN ALSO INCREASE SOCIAL ISOLATION

Asthma is widely recognized as a chronic respiratory disease, but its impact may extend far beyond the lungs. A new study suggests that middle-aged adults with asthma in India are more likely to experience social isolation. Using data from more than 48,000 participants in the Longitudinal Ageing Study in India (LASI), researchers found that people with asthma were less likely to engage in social activities such as visiting friends, attending cultural events, or participating in recreational outings. The association was particularly strong among men and urban residents. Depression also played an important role, influencing how asthma affected social connectedness. The findings highlight that managing asthma should involve not only symptom control but also attention to mental health and social well-being. Strengthening community support and psychosocial care could help improve quality of life for millions living with chronic respiratory diseases.
Garud A. et al., The Journal of Allergy and Clinical Immunology: In Practice (2026).

WHY STRONG SOCIAL CONNECTIONS HELP INDIA'S ELDERLY STAY HEALTHIER

As India's population ages, staying healthy depends not only on medicine but also on meaningful social connections. A new study shows that older adults with stronger social networks are far more likely to engage in preventive health behaviors. Analyzing data from more than 31,000 participants aged 60 and above from the Longitudinal Ageing Study in India (LASI), researchers examined how social participation, friendships, support for others, and neighborhood safety influence healthy habits. The results were striking: older adults who were socially active were three times more likely to receive adult vaccinations, nearly twice as likely to exercise regularly, and more than four times more likely to practice yoga. They were also more likely to undergo preventive health checkups and cancer screening. In contrast, social participation was uncommon, with only 4.2% of older adults reporting high levels of engagement. The study highlights social capital as a powerful and often overlooked determinant of healthy aging in India.
Tripathy J. P., International Journal of Behavioral Medicine (2026).

BIODIVERSITY AND CONSERVATION SCIENCE

TEA PLANTATIONS IN INDIA ARE HELPING ENDANGERED WILD DOGS SURVIVE

Tea estates are usually seen as agricultural landscapes, but in India's Western Ghats they are also providing a surprising refuge for one of Asia's most endangered predators

DISCOVERY HIGHLIGHTS

the dhole, or Asiatic wild dog (Cuon alpinus). In a study, researchers investigated how dholes coexist with people in tea-dominated agroforests. Using field surveys, habitat analyses, and dietary assessments, the team found that these landscapes support thriving dhole populations that feed primarily on wild prey rather than livestock. Despite living close to human settlements and areas with high densities of domestic animals, the researchers found no evidence of dhole attacks on people and very little dependence on domestic animals as food.

This suggests that tea agroforests can function as effective coexistence landscapes, where biodiversity conservation and agricultural production go hand in hand.

The findings challenge the idea that endangered carnivores can survive only within protected areas and highlight the potential of working landscapes to preserve ecological balance.

Pious A. et al., Ambio (2025/2026).

A NEW BENT-TOED GECKO DISCOVERED IN THE EASTERN HIMALAYAS

The forests of the eastern Himalayas continue to reveal hidden biodiversity. In a new study, researchers described a previously unknown species of bent-toed gecko (Cyrtodactylus) from the Darjeeling region of West Bengal, India. The new species was identified through a combination of detailed morphological analysis and DNA sequencing. It possesses a distinctive pattern of scales, pores, and toe lamellae that clearly separates it from related species. Genetic comparisons based on mitochondrial ND2 sequences showed substantial divergence from its closest relatives, confirming that it represents a unique evolutionary lineage. The study also included updated descriptions of two historically known Himalayan species, Cyrtodactylus gubernatoris and C. himalayicus, helping clarify their diagnostic features and taxonomic status.This discovery highlights the eastern Himalayas as an important hotspot of reptile diversity and underscores how many species remain undocumented in India's mountain ecosystems.

Ray S. et al., ZooKeys (2026).

WHEN OPPOSITE SPINS OUTPERFORM

In quantum physics, the way particles are paired can dramatically influence what scientists are able to measure. In a new study, researchers discovered that two particles with opposite (antiparallel) spins offer a remarkable advantage over particles with matching (parallel) spins. Using antiparallel spin pairs, the team showed that it becomes possible to simultaneously predict three mutually perpendicular spin properties with perfect accuracy, something that cannot be achieved using parallel spins. Extending their analysis to larger sets of measurements, the researchers uncovered a deep connection to classic quantum thought experiments, including the famous "Mean King" problem, and demonstrated how this approach could improve quantum cryptography and the calibration of unknown measurement devices. The findings reveal that simply flipping the orientation of one particle can unlock new possibilities for quantum information processing and precision measurement.

Patra, R. K. et al., Physical Review Letters (2026).

HOW MASSIVE STARS TRIGGER THE BIRTH OF NEW STARS

Massive stars do more than shine brightly, they can also trigger the formation of new stars. In a recent study, astronomers investigated Bright-Rimmed Cloud 44 (BRC 44), a dense gas cloud located at the edge of the H II region Sh2-145. Using optical, infrared, and radio observations, they identified numerous young stellar objects embedded within the cloud.

The researchers found that stars visible in optical wavelengths are older and more widely distributed, while deeply embedded stars are younger and still forming. Spectroscopic observations confirmed the youth of several stars, and molecular gas measurements showed that the cloud is being compressed by intense radiation fro-

DISCOVERY HIGHLIGHTS

m nearby massive stars. The motions of these stars also support the "rocket effect," where escaping ionized gas pushes the cloud inward.

Together, these results provide compelling evidence that radiation from massive stars is actively shaping BRC 44 and triggering a new generation of stars.

Rishi C. et al., The Astrophysical Journal (2025).

HOW THE COMPOSITION OF COSMIC JETS DETERMINES THEIR SHAPE

Supermassive black holes at the centers of galaxies can launch enormous jets of high-energy plasma that stretch for thousands of light-years. These jets are generally classified into two types: FR I, which are brightest near the galaxy's center, and FR II, which shine most intensely at their outer edges. In a new study, astronomers used three-dimensional magnetohydrodynamic simulations to investigate why these two strikingly different shapes emerge.

The researchers found that the answer may lie in the plasma composition of the jets themselves. Jets containing a mixture of electrons, positrons, and protons naturally evolved into FR I structures, while jets composed primarily of electrons and protons could transition between FR I and FR II forms during their evolution. These results suggest that the microscopic properties of jet material can strongly influence the large-scale appearance of some of the most powerful structures in the universe.

Tripathi, P. K. et al., The Astrophysical Journal (2026).

SCIENCE IN FOCUS

INDIA'S DEEP-TECH LEAP

Building AI and Quantum Sovereignty Through Indigenous Innovation

India has launched an ambitious Research, Development and Innovation (RDI) Fund to accelerate its emergence as a global leader in deep technology and frontier innovation. The initiative focuses on strengthening capabilities in artificial intelligence, quantum technologies, biotechnology, advanced manufacturing, healthcare innovation, and space systems. At the heart of the programme is the vision of achieving AI and quantum sovereignty through trusted indigenous ecosystems and reduced dependence on imported technologies. Implemented through the Technology Development Board (TDB), the fund aims to catalyse greater private-sector participation and long-term investment in research and development.

In its first phase, agreements were signed for five strategic projects, including advanced lithium-ion battery manufacturing, modular satellite platforms, regenerative cell therapies, AI-enabled portable ICU systems, and heavy-lift unmanned helicopters.

The programme also marked its first disbursement, awarding ₹50 crore to Eyestem Research for indigenous cell therapy development. With over 124 proposals worth more than ₹25,000 crore already submitted, the initiative reflects strong industry confidence and supports the broader vision of Atmanirbhar Bharat and Viksit Bharat by 2047.

BUILDING SAFER AND GREENER INDIA

CSIR Transfers 13 Indigenous Construction Technologies to Industry

On National Technology Day 2026, the Council of Scientific and Industrial Research (CSIR) achieved a major milestone by transferring 13 innovative technologies developed by the CSIR–Central Building Research Institute (CSIR-CBRI), Roorkee, to industries and start-ups.

These technologies address key challenges in fire safety, sustainable construction, infrastructure protection, and energy efficiency, reflecting India's growing focus on self-reliance and technology-led development. Significant innovations include a fire-resistant transparent coating for wood and wood substitutes, protective coatings for reinforced concrete structures, low-carbon brick manufacturing technology, a hybrid solar-assisted heat pump system, and prefabricated steel reinforcement solutions for wall protection.

Collectively, these technologies promote safer, stronger, and environmentally sustainable buildings. The event also featured the release of the CSIR Smart Village Initiative video and the CSIR-CBRI Annual Report 2025–26, highlighting efforts to improve rural infrastructure and quality of life.

By converting laboratory research into market-ready solutions, CSIR-CBRI is strengthening India's innovation ecosystem and advancing the vision of Aatmanirbhar Bharat and sustainable national development.

SCIENCE IN FOCUS

INDIA AND CANADA

India and Canada Strengthen Ties in Critical Minerals Research

As global demand for minerals essential to clean energy and advanced technologies rises, India and Canada are strengthening their strategic partnership to build sustainable and resilient critical mineral supply chains. A recent visit by Canada's High Commissioner to India, His Excellency Chris Cooter, to the CSIR–Institute of Minerals and Materials Technology (CSIR-IMMT) in Bhubaneswar highlighted expanding scientific collaboration between the two countries.

Critical minerals such as lithium, cobalt, nickel, and platinum group elements are vital for electric vehicles, batteries, renewable energy systems, and defense technologies. Canada brings abundant mineral reserves and advanced mining expertise, while India is rapidly advancing in mineral processing, extraction technologies, and downstream manufacturing. During the visit, discussions focused on joint research, technology transfer, and capacity-building initiatives.

A key outcome is the Joint Declaration of Intent between CSIR-IMMT and the University of Saskatchewan to promote collaborative research and academic exchange.

The delegation also toured advanced pilot facilities focused on recycling technologies, seabed minerals, platinum group elements, and molten salt electrolysis, demonstrating India's commitment to sustainable mineral innovation.

INDIA AND VIETNAM

India and Vietnam Join Forces in AI, Deep Tech, and Innovation

India and Vietnam are strengthening their partnership in science and technology with a renewed focus on artificial intelligence, cybersecurity, semiconductors, robotics, biotechnology, and startup innovation. During high-level discussions in New Delhi, both countries agreed to expand collaboration in frontier technologies that are increasingly shaping economic growth and societal progress. The talks emphasized the importance of science and technology as a key pillar of the India–Vietnam Comprehensive Strategic Partnership. Recognizing the transformative potential of AI and deep-tech innovation, the two nations highlighted opportunities for joint research, entrepreneurship, and technology-driven solutions to global challenges. India proposed deeper engagement between startups, research institutions, and innovators through startup exchange programmes, co-innovation centres, and industry-linked research partnerships.

Vietnam also expressed interest in developing a structured action plan with dedicated nodal officers to ensure effective implementation of collaborative initiatives. The discussions further covered academic cooperation, cybersecurity frameworks, technology transfer, and AI missions.

By combining scientific expertise and entrepreneurial strengths, India and Vietnam aim to build resilient innovation ecosystems and promote indigenous technological advancement across the region.

SCIENCE IN FOCUS

TURNING PLASTIC WASTE INTO ROADS

An Indian Innovation Sets a Record

Scientists at the CSIR–Central Road Research Institute (CSIR-CRRI), in collaboration with Bharat Petroleum Corporation Limited (BPCL), have demonstrated how discarded plastic can be transformed into sustainable infrastructure materials.

Their pioneering work earned recognition from both the India Book of Records and the Asia Book of Records for constructing the first roadblock section using technical textile geocells made entirely from end-of-life plastic waste. Geocells are honeycomb-shaped structures that stabilize soil and strengthen road foundations. In this innovation, difficult-to-recycle plastic waste was converted into durable geocells capable of meeting strict engineering standards. These recycled structures improve load distribution, increase road durability, and reduce environmental pollution by giving plastic waste a productive use.

The project addresses two major challenges simultaneously: plastic waste management and resilient infrastructure development. Extensive testing and field validation confirmed the structural strength and long-term performance of the recycled geocells.

The initiative also highlights successful collaboration between scientific research institutions and industry in advancing circular economy solutions that are environmentally sustainable, economically practical, and nationally significant.

NUCLEAR ENERGY COLLABORATION

India and U.S. Explore New Frontiers in Nuclear Energy Collaboration

India and the United States are strengthening their partnership in nuclear energy, opening new avenues for private investment, advanced reactor technologies, and clean energy innovation. During high-level discussions in New Delhi, representatives from major U.S. nuclear industry organizations engaged with Indian officials to explore collaborations supporting India's ambitious goal of expanding nuclear power capacity from 8.8 GW to 100 GW by 2047.

Recent policy reforms, including the SHANTI Act 2025, are expected to encourage greater private and foreign participation in India's nuclear sector. India's increasing focus on Small Modular Reactors (SMRs), micro-reactors, and AI-enabled nuclear safety systems has also attracted strong interest from global industry leaders. The discussions reviewed several ongoing bilateral initiatives, including the proposed Westinghouse AP1000 nuclear project, hydrogen production technologies, rare-earth cooperation, and the landmark LIGO-India scientific collaboration.

These initiatives highlight a shared commitment to advancing resilient clean-energy systems and strengthening technology-driven cooperation between two major scientific and industrial partners, while also supporting long-term energy security, sustainability, and innovation-led economic growth.

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

YOUR INTERVIEW COACH NEVER SLEEPS

Rohan was a talented graduate with strong academic achievements and a good resume. Yet every time he attended a job interview, he struggled. Nervousness affected his confidence, and he often found it difficult to answer unexpected follow-up questions. After several unsuccessful attempts, he realized that knowledge alone was not enough he needed better interview practice.

One day, Rohan discovered an AI-powered mock interview platform designed to help job seekers prepare for real interviews. After uploading his resume, the system analyzed his education, skills, projects, and work experience. Within seconds, a virtual interviewer began asking personalized questions tailored to his background.

Unlike traditional interview practice tools, the AI did not rely on a fixed set of questions. When Rohan mentioned a project he had completed, the system generated relevant follow-up questions, creating a realistic interview experience. It felt less like a software program and more like a professional recruiter.

As the interview progressed, the AI continuously analyzed his responses. Using advanced technologies, it evaluated his facial expressions, eye contact, voice tone, speaking pace, confidence level, and communication skills. The system could identify signs of hesitation, nervousness, and confidence while assessing both technical knowledge and soft skills.

At the end of the session, Rohan received a detailed performance report. The feedback highlighted his strengths, identified areas needing improvement, and suggested practical ways to improve communication, confidence, and answer structure. The system also compared his responses with the information provided in his resume, ensuring consistency between his claimed skills and actual performance.

Over time, Rohan completed multiple mock interviews and steadily improved. The AI tracked his progress, adapted questions to his skill level, and provided increasingly personalized guidance.

This innovation demonstrates how artificial intelligence can transform interview preparation. By combining adaptive questioning, speech analysis, facial recognition, and personalized feedback, it creates a realistic, accessible, and unbiased practice environment. For students and job seekers, it acts as a personal interview coach available anytime, helping them build confidence and prepare for career success.

INNOVATION

Radke, S. S., Patel, K. R., Gala, P. K., Doshi, R. R., Patel, Y. J., Devmane, V., Dhumal, A., Chotai, K., Hirlekar, V., & Narkhede, N. S. (2026). Artificial Intelligence Based System and Method for Conducting Mock Interviews to Candidates. Indian Patent No. :588420

📄 By Shah & Anchor Kutchhi Engineering College, Mumbai, Maharashtra - 400088, India

| By Dr. Priyanka

THE BOTTLE THAT KNOWS WHEN YOU NEED WATER

Like many professionals, Anita spent most of her day in front of a computer. Between meetings, deadlines, and endless emails, she often forgot a simple but essential habit drinking enough water. By the afternoon, she frequently felt tired, lost concentration, and sometimes developed headaches. Although she carried a water bottle everywhere, remembering to drink from it was another matter.

One day, Anita discovered a newly developed Smart Water Bottle with Hydration and Temperature Monitoring. Curious about its features, she decided to try it.

At first glance, the bottle looked ordinary, but it was packed with intelligent technology. Inside were smart sensors capable of monitoring hydration-related information and tracking her daily water consumption. A small display on the bottle showed useful information, including the temperature of the water, allowing her to know whether it was cold, warm, or just right for drinking.

The real magic happened when Anita connected the bottle to her smartphone. Through a dedicated mobile application, she could set personalized hydration goals based on her lifestyle and daily activities. Throughout the day, the bottle gently reminded her when it was time to drink water. If she became busy and forgot, notifications appeared on both the bottle and her phone.

As days passed, the app recorded her progress and provided real-time feedback.

Anita could easily see how much water she had consumed and how close she was to reaching her daily target. The bottle and phone communicated wirelessly using Bluetooth and other smart connectivity technologies, making the entire experience seamless.

After a few weeks, Anita noticed a difference. She felt more energetic, focused, and productive. What surprised her most was how such a simple device could help improve her daily health.

This innovation transforms an ordinary water bottle into a personal wellness assistant. By combining smart sensors, temperature monitoring, wireless connectivity, and personalized hydration reminders, it encourages healthier habits and helps users stay hydrated throughout the day.

In a world increasingly driven by smart technology, this intelligent bottle demonstrates how even everyday objects can contribute to better health and well-being.

INNOVATION

Prasad, K., Priyadarshani, P., Patel, A., Affaaque, M., Kumar, N., Singh, I. R., & Kumar, A. (2025). Smart Water Bottle with Hydration and Temperature Monitoring and Related Methods. Indian Patent No.589887

By National Institute of Technology Jamshedpur, Adityapur, Jamshedpur, Jharkhand

Turning Biodiesel Waste to Green Hydrogen: A New Way of Producing Hydrogen

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Scientific Profile | Organization Link | Research Lab Page | Factors Press
Areas of Expertise: Hydrogen Production | Biomass/Waste to High Value Products | CO2 Capture and Conversion | Catalysis

Rising global energy demand has made two problems impossible to ignore: the rapid decline of fossil fuel reserves and the environmental damage caused by burning them. This has intensified the search for cleaner, sustainable alternatives. Hydrogen is one of the most promising, producing only water in fuel cells. Yet its adoption is limited by challenges in safe storage and transport, and by the fact that most hydrogen is still produced from fossil fuels.

Meanwhile, the biodiesel industry generates large amounts of glycerol about 1 kg for every 10 kg of biodiesel. This crude glycerol is cheap, non-toxic, easy to store, and widely available, making it an attractive renewable feedstock. Hydrogen can be produced from glycerol, but current methods require very high temperatures and often generate carbon monoxide and carbon dioxide, gases that both harm fuel cells and reduce hydrogen's environmental benefits.

The invention described here offers a cleaner, safer, and far more efficient solution. It introduces a new catalytic process that converts glycerol into hydrogen and lactic acid at remarkably low temperatures between 90 °C and 120 °C. This is achieved using a specially designed ruthenium copper catalyst. Under basic conditions, glycerol undergoes a dehydrogenation reaction that releases hydrogen while simultaneously forming lactic acid, a valuable chemical widely used to produce biodegradable plastics such as polylactic acid (PLA). As a result, the process not only generates clean energy but also produces an eco-friendly industrial product.

What makes this invention particularly significant is its efficiency and practicality. While earlier catalytic systems required temperatures above 200 °C to produce hydrogen, the new catalyst operates effectively at around 110 °C and delivers a high hydrogen yield of 95–99%. This dramatic reduction in operating temperature lowers energy consumption, making the process more economical and environmentally friendly. Moreover, the catalyst can be easily recovered, and reused, and shows remarkable robustness and durability - an essential feature for industrial-scale applications.

The invention also addresses one of the biggest barriers to widespread hydrogen adoption: safe storage and transport.

Patent Reference:

Singh, S. K., Kumar, A., & Priya, B. (2026). A catalyst for one-pot synthesis of hydrogen and lactic acid from glycerol. Indian Patent No. 586698

Instead of relying on heavy, high-pressure hydrogen cylinders, industries can transport glycerol, a stable liquid. Hydrogen can then be generated on-site whenever needed. This approach is safer, more cost-effective, and far more convenient.

In alignment with the global clean-energy initiatives such as Mission Innovation and India's National Hydrogen Energy Mission, the team led by Prof. Sanjay K Singh has been working on the idea for producing CO2-free hydrogen from various carbon-based feedstocks recovered from biomass, biodiesel and even plastics. The key feature of the developed processes is the production of CO2-free hydrogen gas along with the high value products, such as formic acid, lactic acid, and transforming a low-value industrial byproduct into a clean, high-value energy source using a highly efficient catalyst. They have been granted several patents on hydrogen production. He is currently working on scaleup of the developed processes through his own startup Revive CleanTech Pvt. Ltd.

In summary, their processes offer a practical pathway toward greener hydrogen production, safer storage, and added economic value through lactic acid co-production, bringing us a step closer to a sustainable energy future.

Patent Reference:

Singh, S. K., Kumar, A., & Priya, B. (2026). A catalyst for one-pot synthesis of hydrogen and lactic acid from glycerol. Indian Patent No. 586698

A DUAL-ION ELECTROCHEMICAL DEVICE SAFE, SUSTAINABLE, AND HIGH-PERFORMING AQUEOUS ENERGY STORAGE

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

Areas of Expertise: Nanomaterials | Rechargeable Batteries | Supercapacitors | Water Splitting and Fuel Cell

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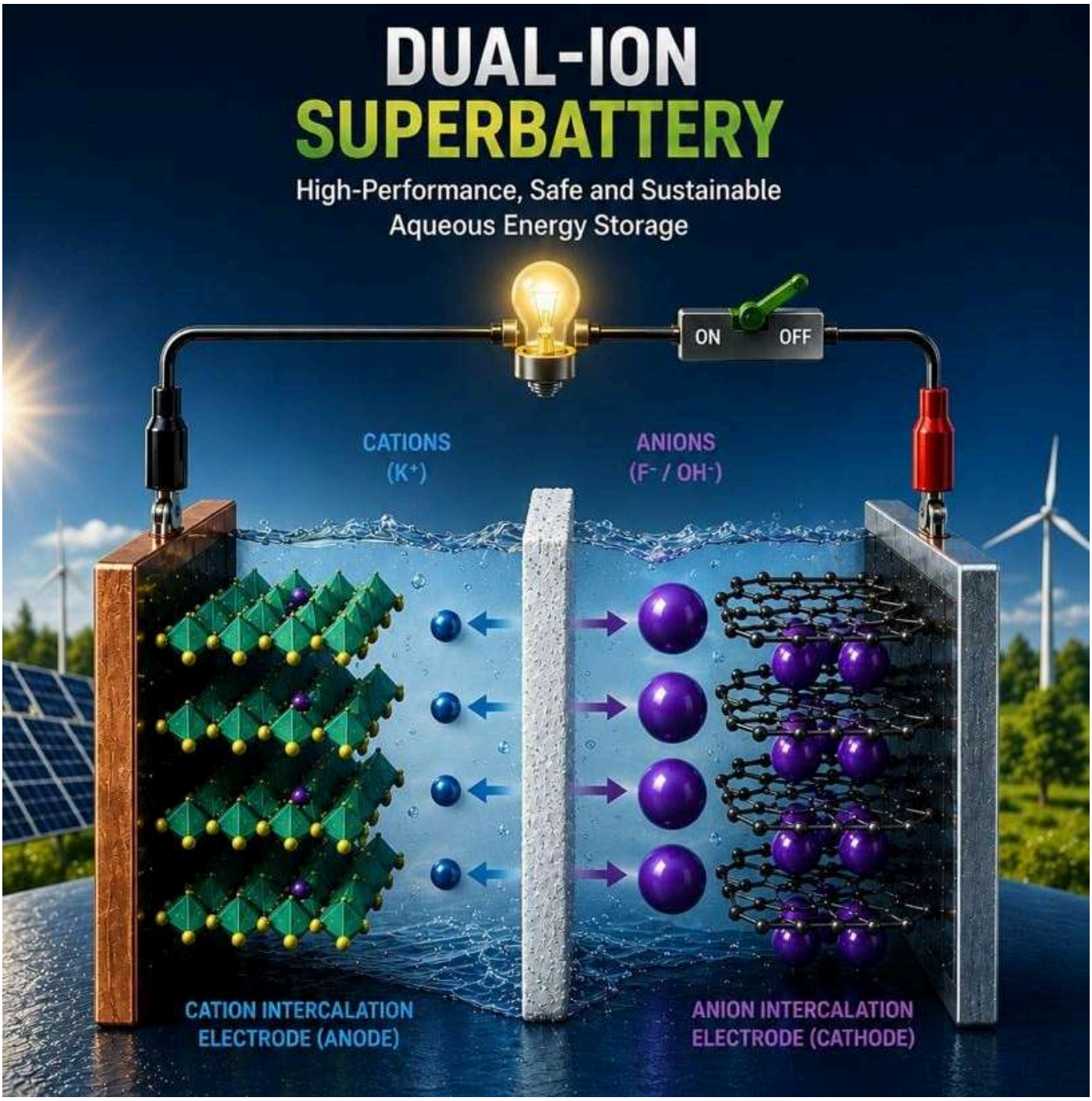
Areas of Expertise: Energy Materials | Rechargeable | Battery | Fuel Cells | Thermochemical water | splitting and thermoelectric

High-performance and low-cost rechargeable energy storage, particularly Electrochemical energy storage (EES), technologies are the key to achieving high levels of integration of renewables into different energy sectors, including electromobility, public transit, and stationary (grid) storage. This requirement is further accentuated by the fast growth of the battery market, where the Indian lithium-ion battery market is estimated to be worth nearly U$ 4,294.80 million in 2022 and expected to grow at a CAGR of 22.1% till 2031. Although Lithium-ion batteries (LIBs) have been successfully commercialized, the use of organic electrolytes and the high cost of lithium salts and transition metals make them uneconomical for grid-connected stationary energy storage systems. Compared with Lithium-ion batteries (LIBs), Lead Acid batteries (LABs) are less costly but have a hazardous impact on the environment and human health. Moreover, LIBs and LABs are preferably stored charged at a lower current rate. It is now widely recognized that creating a novel alternative to LIBs and LABs using stable electrode materials with faster charging-discharging rates, as well as large-scale energy storage facilities at an affordable cost, is a priority. This invention employs simultaneous charge storage through migration of dual ions, i.e., cation and anion, at the cathode and anode, respectively, in an aqueous medium. In contrast to traditional lithium-ion batteries, which rely on a single charge carrier for charging and discharging, aqueous dual-ion batteries use both cations and anions as charge carriers. A key feature of this invention is the use of a nonflammable aqueous electrolyte consisting of 4 M KOH/1 M KF, which provides exceptionally high ionic conductivity (~2 S cm-1) and highly mobile dual ions for rapid charge transfer. It consists of a transition-metal-based 3D framework material for the anode and cathode, which enables rapid and reversible ion intercalation/deintercalation during charge/discharge. The dual ion full cell arrangement, which contained aqueous electrolyte and PVA separator, was first attempted in this invention, which exhibits high specific capacity along with remarkable energy and power densities even at high current densities, thereby validating the superior high-rate capability and facilitating grid-scale energy storage at a reasonable cost. The invention further employs the polyanion (PO4) 3- and (C2 O4) 2 based electrode material, which provides an open pore structure that classifies them as an effective structure that facilitates rapid ion transport in the host lattice during charging and discharging, while also actively involving the M n/n+1 redox couple. Polyanion-based electrode materials are safer due to their porous framework design, which provides intrinsic structural stability from the presence of planar oxalate anions (C2 O4 2–) in the anode side, whereas the P-O bond inculcates the lattice's oxygen stability, which will ultimately help in high-rate charge storage and delivery, along with thermal stability and minimal volume change compared to other compounds. Furthermore, this research demonstrates that the doping of the first transition element at the M site can improve overall the electrochemical performance while helping to mitigate issues associated with the use of

Patent Reference:

Singh, P., Nigam, K. G., Tiwari, S. K., & Singh, A. K. (2026). A dual-ion electrochemical device and a method of fabrication thereof. Indian Patent No. 588585.



expensive and limited elemental resources. Overall, these dual-ion batteries have the unique benefit of using both cations and anions in the electrode anion are separately intercalated in the 3D framework host electrode lattice, which is economical, eco-friendly, and durable, which may be an alternative technology for currently commercialized hazardous lead-acid batteries or lithium-ion batteries.

Patent Reference:

Singh, P., Nigam, K. G., Tiwari, S. K., & Singh, A. K. (2026). A dual-ion electrochemical device and a method of fabrication thereof. Indian Patent No. 588585.

Sustainable Streets: Empowering Paver Blocks with a Quaternary Blend Engineered Geopolymer Composites (EGC)

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Areas of Expertise: Sustainable Construction Materials | Geopolymer Concrete and Composites | Engineered Cementitious/Geopolymer Composites

The construction industry is one of the largest contributors to global carbon emissions, mainly due to the extensive use of Ordinary Portland Cement (OPC). In response to the growing demand for environmentally responsible construction materials, researchers are actively developing sustainable alternatives that can reduce environmental impact without compromising structural performance. Addressing this challenge, Dr. Saravanan S and Dr. Robin Davis developed an innovative construction material titled “Quaternary Blended Engineered Geopolymer Composite (EGC) Paver Block with Hybrid Fibre Reinforcement”, which has recently been granted a patent.

The patented technology focuses on the development of high-performance geopolymer based paver blocks using industrial by-products and advanced fibre-reinforcement techniques. Unlike conventional cement-based paver blocks, this system minimizes or eliminates the use of OPC by utilizing sustainable precursor materials such as Fly Ash (FA), Oxygen Furnace (OF) slag, Ground Granulated Blast Furnace Slag (GGBFS) and Silica fume (SFU), iron ore tailings (IOT) etc., from various sources such as thermal, steel and iron mining industries. These materials, which are often treated as industrial waste, are effectively transformed into value-added construction products.

Engineered Geopolymer Composite (EGC) Paver Blocks

One of the key innovations of this patent lies in the use of a quaternary blended geopolymer matrix, combined with hybrid fibre reinforcement, to produce engineered geopolymer composites with improved mechanical and durability characteristics. The incorporation of hybrid fibres significantly enhances crack resistance, ductility, impact resistance, and load-bearing performance. As a result, the developed paver blocks exhibit superior strength and long-term durability compared to many conventional paving materials.

The technology also contributes to sustainability through waste utilization and reduction in carbon emissions associated with cement production. By converting industrial by-products into durable infrastructure materials, the patented system supports circular economy principles and promotes sustainable resource manageme-

Patent Reference:

Saravanan, S., Davis, R. P., Thomas, B. S., & Nagarajan, P. (2026). Quaternary Blended Engineered Geopolymer Composite (EGC) Paver Block with Hybrid Fibre Reinforcement. Indian Patent No. 586308

nt.

Furthermore, the improved durability and crack resistance of the developed paver blocks can reduce maintenance requirements and extend service life in practical applications such as pedestrian pathways, pavements, parking areas, and urban infrastructure systems.

Another important aspect of this innovation is its potential adaptability for large-scale manufacturing and infrastructure applications. The developed geopolymer composite system can be tailored for different engineering requirements while maintaining environmental benefits. The patent therefore represents a significant step toward greener and more resilient construction technologies.

This work reflects the growing global transition toward sustainable construction materials and low-carbon infrastructure solutions. The patented innovation demonstrates how scientific research can address both engineering performance requirements and environmental challenges simultaneously. Through this development, Dr. Saravanan S and Dr. Robin Davis aim to contribute to the advancement of next-generation sustainable construction materials for future infrastructure development.

Patent Reference:

Saravanan, S., Davis, R. P., Thomas, B. S., & Nagarajan, P. (2026). Quaternary Blended Engineered Geopolymer Composite (EGC) Paver Block with Hybrid Fibre Reinforcement. Indian Patent No. 586308

From Research to Real Impact

Dr. Aakash Agrawal
Learning Scientist, EkStep Foundation
Founder of AlphaKhoj, India

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

AREAS OF EXPERTISE
EkStep Foundation and AlphaKhoj | Computational Neuroscience | Reading | Computer Vision | Brain Imaging

Q *To begin, could you briefly describe your current roles at AlphaKhoj and EkStep, and the core problems you are working on today?*

A Most of us take reading for granted, so completely that we forget it was ever something we had to learn. But for millions of children across India, that skill never arrives. According to a national level survey by ASER, over 50% of Grade 5 children in India struggle to read text designed for Grade 2.

Imagine this situation, a 10 year old, in school every day, surrounded by words they cannot decode - unable to follow a lesson, unable to ask for help without exposing themselves. That child either starts acting out, or they go quiet. Either way, the system slowly loses them. This the core problem I solve at EkStep as a Learning Scientist - addressing foundational literacy crisis at scale, particularly within government school.

However, literacy isn't a one-size-fits-all journey. Approximately 10-15% of children face specific challenges due to neurodivergence, including dyslexia, autism, and ADHD. I founded AlphaKhoj to serve this specific community. While EkStep focuses on scale, AlphaKhoj focuses on specialized depth. Both organizations are unified by a single principle: our solutions are grounded in neuroscience to ensure that learning outcomes aren't just hoped for, but biologically supported.

Q *Your journey bridges research, startups, and education. What prompted this transition from academia to real-world impact?*

A My PhD focused on the "reading brain", specifically, how our neural circuitry rewires itself as we learn to process text. While phonics-based teaching is widely known, my research uncovered something less appreciated: the critical role of visual processing in reading fluency. We were able to identify new factors that explain why some children become fluent readers and others don't-factors that existing theories had not fully accounted for.

The work was going well. Papers were getting published. But I kept running into a familiar frustration: academic findings, however significant, typically take decades to influence what happens in a classroom. And I had something in my hands that felt immediately useful. These were not just theoretical insights, they pointed directly toward how a child could be taught differently, today.

I didn't want to spend the next decade waiting for academia to carry that forward. I wanted to build something with it.

Q *Was there a defining moment that shifted your focus toward building solutions rather than pursuing a traditional research path?*

A People often expect a pivot story-a clear before and after. There wasn't one. If anything, my entry into research was itself a happy accident: it was only after receiving the interview call that I realised I had applied for a PhD, not a Master's.

But perhaps that accidental beginning says something true about how I approach things. I was an engineer before I was a researcher, and engineers think in terms of problems. When my PhD supervisors, Prof. SP Arun and Prof. KVS Hari, proposed a project on reverse-engineering the reading brain, I was drawn to it not for the intellectual prestige but because it felt like the most interesting unsolved problem I had ever come across. What is actually happening inside the brain when a child learns to make sense of marks on a page? That question gripped me.

But throughout the research, I

kept pulling at a different thread: and so what? I was always more captivated by outcomes with real-world applications and I am grateful to my supervisors for giving me freedom to pursue my own research interests even if it was outside their own comfort zone.

Q *AlphaKhoj addresses real-world problems using data and AI. What gap did you identify, and why does it matter now?*

A Imagine you are a parent of a child who is struggling to read. You find a good special educator, the sessions are going well but they are expensive, and your child can only attend a few times a week. Progress is slow, measured in a handful of new words each month. Now imagine there was an app that continued that work between sessions using the same content, the same words, the same patterns the educator had just introduced. The child could practice dozens of times a day, in their own time, at no additional cost. The progress wouldn't just be faster , it could be transformational.

That is the gap AlphaKhoj is built to fill. Not just practice for its own sake, but practice that is aligned with what the educator is teaching and that feeds error patterns back to the educator so they can see exactly where a child is struggling and adapt accordingly. This loop between app and educator is what makes the difference between a tool that supplements learning and one that accelerates it.

The urgency is real. The number of trained special educators in India has not kept pace with the growing number of children being identified with dyslexia, autism, and ADHD, a rise driven partly by better awareness and improved diagnosis. Smartphones have reached communities that specialists have not. AI has matured to the point where genuine personalization is no longer theoretical. We are at a rare intersection, and I think it would be a mistake to wait.

Q *In your experience, what differentiates a successful research-driven startup from one that struggles to scale?*

A The startups I have watched struggle share a particular pattern: they are still, at heart, running a research project. They are optimizing for intellectual elegance rather than actual use. They are solving the problem they found interesting rather than the problem their users are living with.

The shift that changes everything and it is genuinely hard for researchers to make is accepting that your science is one ingredient, not the product. A startup has to sustain itself. That means doing work that feels far removed from discovery: chasing invoices, rewriting a feature for the fourth time because users keep ignoring it, making decisions with incomplete information on timelines that would make any careful researcher uncomfortable.

Q *For someone starting from scratch, what is the most practical way to translate a research idea into a viable startup?*

A The most underestimated early step is simply articulating why your idea is a business, not just a contribution. Researchers are trained to justify work on intellectual grounds. Investors, grant committees, and accelerators want to know: who will pay for this, and why will they choose it over what already exists? These are uncomfortable questions if you have not practiced them, but they are clarifying ones and the process of answering them will often change your idea for the better.

Funding is what buys you the time to find out if you are right. There are more routes to it now than most researchers realize: government grants, seed funds, incubation programs, startup competitions. Join an accelerator. The mentorship matters, but the connections matter more. And one last thing: start talking to users earlier than feels comfortable. Not to validate your assumptions- to challenge them.

Q *As a Learning Scientist at EkStep, how do you apply research insights to design impactful learning systems at scale?*

A Let me walk you through the way I think about this with a single concrete example.

Imagine a child learning to distinguish the letter B. I play an audio clip of the sound /b/ and ask them to pick the matching letter from four options on screen. If those options are W, X, Y, and B- the task is almost trivially easy. Any child will get it right. But if the options are B, D, P, and G- letters that look similar and sound similar-the task becomes genuinely demanding. And that difficulty is not a problem. That difficulty is the learning.
Getting this calibration right is at

the heart of what I do. Every learning system involves three components that have to work in concert. First, the tasks identifying precisely which cognitive skill a child is missing, whether that is phonological awareness, visual pattern recognition, attention, or working memory, and targeting that gap specifically. Second, the content setting exactly the right level of challenge, the sweet spot where a child is stretched without being overwhelmed. Third, the usage protocols ensuring that content is revisited at scientifically designed intervals, because repetition alone does not create retention. Spacing does.

When any one of these is off, the whole system underperforms. A perfectly designed task with poorly calibrated content produces boredom or frustration. Perfect content with no spaced repetition produces knowledge that evaporates. My job is to hold all three in balance and to make sure that every choice we make is backed by evidence, not intuition. Where the evidence is incomplete, we are actively collaborating with IISc to build it.

Q *AI is rapidly transforming education. What changes do you believe are truly meaningful, beyond the current hype?*

A Here is what AI can genuinely do, and it is not nothing: it can track where a child is struggling in real time, personalise the next task to exactly their current level, provide patient and infinitely repeatable practice, and give a child in a remote district access to something approximating the guidance of a trained educator. For families who cannot afford specialist support and live hours from the nearest qualified therapist, that is not hype. That is a real expansion of access.

But here is what AI cannot do: it cannot manufacture the willingness to struggle. Reading is hard. It is supposed to be hard. The cognitive effort required to decode, recognise, and eventually internalise written language is not a design flaw- it is the mechanism through which the brain builds working memory, fine perceptual discrimination, and general cognitive capacity. You cannot make that process feel effortless and still have it produce the same outcomes. AI can set the stage. It cannot do the work on behalf of the child.

Q *For students navigating uncertain career paths, how should they think about choosing between academia, industry, and entrepreneurship?*

A I would start by asking a different question entirely: not which path has the best outcomes but what kind of day do you want to live?

Academia offers depth, intellectual freedom, and the pleasure of a community organized around ideas alongside real uncertainty, long timelines to recognition, and the particular loneliness of original work. Industry offers structure, momentum, and the satisfaction of building things that reach people alongside the constraint of working within systems you did not design. Entrepreneurship offers the freedom to define the problem and chase it fully alongside financial uncertainty that can last for years and a solitude that is different in character from academia's, but equally real.

None of these is obviously better. What matters is which one you will still want to be doing on the hard days and every path has hard days.

There is one practical asymmetry worth naming: moving from academia into industry or entrepreneurship is relatively straightforward. The reverse returning to a faculty path after extended time away can be more constrained, particularly if you have not maintained an active research and publication record during that period. This is not a reason to stay in academia. It is a reason to be deliberate if you leave.

Q *Looking ahead, which skills or mindsets will define successful careers in AI, education, and innovation over the next decade?*

A A few years ago, at the height of the pandemic, coding was the most sought-after skill in every sector. Today, AI can produce functional code from a plain-language description. The half-life of specific technical skills is shrinking, and pretending otherwise is not useful advice for anyone trying to build a durable career.

What does not shrink is the value of asking the right questions. AI has made information more accessible than at any point in human history which means the scarcest resource is no longer information but the judgment to know what to do with it. The ability to identify what actually matters, to know what question to ask before reaching for an answer, is something no current AI reliably supplies.

Q *If you had to give one piece of advice to young people aiming to create meaningful, real-world impact, what would it be?*

A Real-world impact does not arrive quickly. The problems worth solving have resisted solutions for a reason- they sit at intersections that are genuinely difficult to navigate: between research and practice, between technology and human behaviour, between what is known and what can actually be done at scale. Progress in these spaces is slow, nonlinear, and often invisible for long stretches.

Most breakthroughs have happened at the intersection of people who would never otherwise have been in the same room. Someone had to put them there. Someone had to translate between the scientist and the teacher, the engineer and the community worker, the policymaker and the child sitting silently in the back of a Grade 4 classroom. Be willing to be that person.

Bitter Gourd Nursery

Tomato Nursery

FROM LAB TO FIELD

Breeding Disease-Resistant Vegetables for Real-World Agriculture

When most people think of plant breeding, they picture a scientist in a greenhouse, carefully cross-pollinating flowers by hand, waiting months or even years to see whether offspring carry a desired trait. That image is not entirely wrong but it tells only part of the story. Today, the journey from a breeding idea to a seed bag on a farmer's shelf is shaped as much by molecular biology, data science, and industry knowledge as it is by the traditional art of selection. We have working experience in both academic research and the commercial seed sector, and the experience has taught us that translating science into practical agricultural solutions is one of the most rewarding and humbling challenges in modern food production.

Vegetable crops feed billions of people every day, yet they remain among the most vulnerable to diseases. Pathogens do not distinguish between a small family farm and a large commercial operation; they spread wherever conditions allow, and they evolve. That is the central tension driving vegetable breeding programmes around the world: how do we stay ahead of a moving target, reliably, and at scale?

Pollination in Bitter Gourd

The real cost of plant disease

To understand why disease resistance occupies so much of a plant breeder's thinking, consider what disease actually costs. Anthracnose in chillies, early blight in tomatoes, and powdery mildew in peas, each of these can destroy a significant portion of a crop within days under the right weather conditions. Farmers have its own costs: financial, environmental, and increasingly regulatory, as governments tighten restrictions on chemical inputs.

MEET THE SCIENTISTS

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"EVERY SUCCESSFUL VARIETY BEGINS AS A SEEDLING, BUT ITS FUTURE DEPENDS ON SCIENCE, SELECTION, AND FIELD PERFORMANCE."

Molecular Laboratory - Detecting Resistance, Building Resilient Varieties

QTLs and gene discovery through biotechnology tools for stress tolerance

Over the past decade, rapid progress in genomics has revolutionized vegetable research, advancing from whole-genome sequencing to the development of innovative high-throughput genetic and molecular technologies. Numerous research initiatives employing genomic and molecular tools are currently underway, and several notable achievements have already been reported. Molecular markers have emerged as powerful tools in plant breeding, enabling more precise and efficient selection by minimizing environmental influences, facilitating early-stage selection, and reducing the size of breeding populations required for field evaluation. Furthermore, molecular markers support the efficient introgression of superior alleles from wild relatives into cultivated backgrounds and enable the pyramiding of genes controlling quantitative traits. Several quantitative trait loci (QTLs) associated with biotic stress tolerance have been identified in tomato. A comprehensive understanding of the genetic basis of stress tolerance facilitates the development of reliable molecular markers for marker-assisted breeding and supports the identification of candidate genes for genetic engineering aimed at enhancing crop resilience under adverse environmental conditions.

The SNP revolution: breeding at the molecular level

Perhaps the single most transformative development in modern plant breeding has been the widespread adoption of SNP (Single Nucleotide Polymorphism) markers. An SNP is a variation at a single position in the DNA sequence; think of it as a molecular signpost that can tell you, with high confidence, whether a particular gene or genomic region is present in a given plant. They are abundant throughout plant genomes, inexpensive to detect with modern sequencing technology, and powerful as breeding tools.

In practical terms, SNP markers allow breeders to screen seedlings in the laboratory, long before any symptoms of disease would appear, and identify which individuals carry the resistance genes we are looking for. The time savings alone are remarkable what might have taken two or three years of pheno-

Fruiting on Tomato Plants

Controlled Pollination

"LABORATORY SCREENING HELPS BREEDERS DETECT RESISTANCE BEFORE DISEASE BECOMES VISIBLE IN THE FIELD."

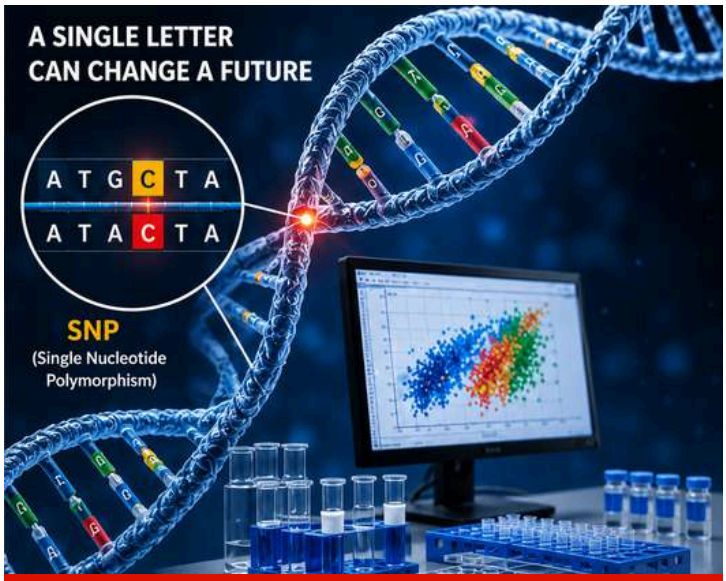
typic screening can be accomplished in a fraction of the time.

Achieving that stacking without molecular tools is extremely difficult. When you are trying to track four or five resistance loci simultaneously across a segregating population of hundreds of plants, phenotypic screening quickly becomes impractical — you simply cannot expose every plant to every pathogen simultaneously in a controlled way. SNP markers resolve this by allowing every individual to be genotyped for all target loci at once, from a single sample. Breeders can then identify the handful of plants that carry all desired resistance genes, in the correct configuration, and advance only those to the next stage.

But markers do more than accelerate selection. They enable a technique called Marker-Assisted Backcrossing (MABC), which allows breeders to transfer a resistance gene from a wild relative or donor line into an elite commercial variety while simultaneously recovering the entire genetic background of that elite parent. Before molecular markers, this process required six to eight generations of conventional backcrossing a decade of work. With SNP markers tracking both the target gene and the background recovery in parallel, the same outcome can be achieved in three to four generations. That is not a marginal improvement; it is a fundamental change in what is possible.

Genetic engineering for stress tolerance

Environmental stress tolerance is a highly complex trait regulated by the coordinated action of numerous genes and interconnected regulatory pathways, with several transcription factors playing central roles in stress-response mechanisms. A limited number of genes have successfully enhanced stress tolerance when over expressed in vegetable crops. Research on the physiological and molecular mechanisms underlying stress tolerance has demonstrated that tolerance to specific environmental stresses is controlled by multiple component traits and their associated genes. Therefore, the integration of genome-wide expression profiling using DNA microarrays with quantitative trait loci (QTL) mapping represents a powerful approach for identifying major genes associated with stress tolerance.



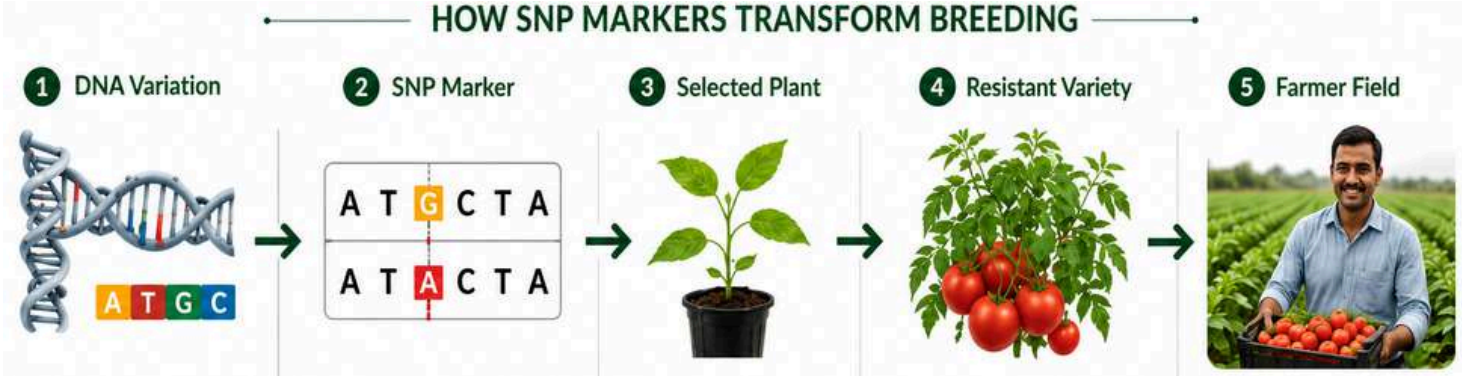
SNP genotyping in the laboratory reveals hidden genetic potential.

Combining resistances: the stacking challenge

One of the most important applications of molecular breeding in vegetable crops is the "stacking" of multiple resistance traits into a single variety. A tomato that resists early blight is useful; a tomato that resists early blight, late blight, fusarium wilt, and tomato yellow leaf curl virus is far more so. Seed companies can maintain smaller, more focused breeding populations, reducing the resources required per breeding cycle. For the farmer, this translates into varieties that are not just resistant to disease, but consistently productive, well-adapted, and of the quality that market channels demand.

Improved tolerance through grafting for enhanced vegetable production

Grafting is an important horticultural technique employed to enhance plant tolerance to various environmental stresses through the combination of elite commercial cultivars with vigorous and stress-tolerant rootstocks. In this process, two living plant components—the rootstock and the scion—are joined to develop into a single functional plant. In vegetable crops, grafting is primarily carried out by combining a desirable scion cultivar with a resistant or vigorous rootstock and improving vegetable production by enhancing resistance



"SNP MARKERS ALLOW BREEDERS TO READ THE PLANT'S GENETIC POTENTIAL BEFORE THE PLANT FACES DISEASE IN THE FIELD."

to soil-borne diseases, increasing tolerance to environmental stresses.

Recent advancements in grafting technology have also led to the development of innovative graft combinations such as "Brimato" and "Pomato," which have been successfully promoted by the Indian Council of Agricultural Research-Indian Institute of Vegetable Research, Varanasi, U.P., India. These technologies have demonstrated practical benefits for farmers by improving productivity, diversifying produce, and enhancing economic returns.

Integrated pest and disease management

Insect pests constitute one of the major biotic constraints affecting vegetable production in India. In addition to causing direct damage to crops, many insect pests also act as vectors of economically important viral diseases. Viral diseases particularly those caused by leaf curl viruses and spotted wilt viruses, represent major constraints to vegetable production because of their rapid spread and severe effects on crop growth and yield. Integrated pest and disease management strategies involving resistant varieties, cultural practices, biological control agents, need-based pesticide application, and regular field monitoring are therefore essential for sustainable vegetable production and for minimizing economic losses under changing climatic conditions.

Perspectives on the future: challenges ahead

It would be misleading to suggest that molecular breeding has solved vegetable disease management. It has transformed what is possible but the challenges ahead are real and significant. Climate change is altering the geographic distribution of pathogens and the frequency of disease-conducive weather events. New races of established pathogens or entirely new pathogens continue to emerge. The regulatory environment around plant genetic improvement is evolving rapidly and variably across different countries, creating uncertainty for breeding programmes with international scope.

The benefits of molecular breeding need to reach every part of global agriculture, not just the markets that can afford premium seed. Addressing that equity challenge requires sustained investment in public research, technology transfer, and collaborative models between industry, governments, and international agricultural organisations.

For young researchers considering a career in plant breeding or seed science, my most honest advice is this: cultivate breadth. The best breeders I have worked with understand genetics deeply, but they also understand plant pathology, agronomy, statistics, and the economics of farming. They are curious about the molecular mechanisms behind the traits they are selecting, but they are equally comfortable standing in a muddy field, talking with a farmer about what actually went wrong last season. That integration of the molecular and the practical of the lab and the field is what this work demands, and what makes it genuinely exciting.

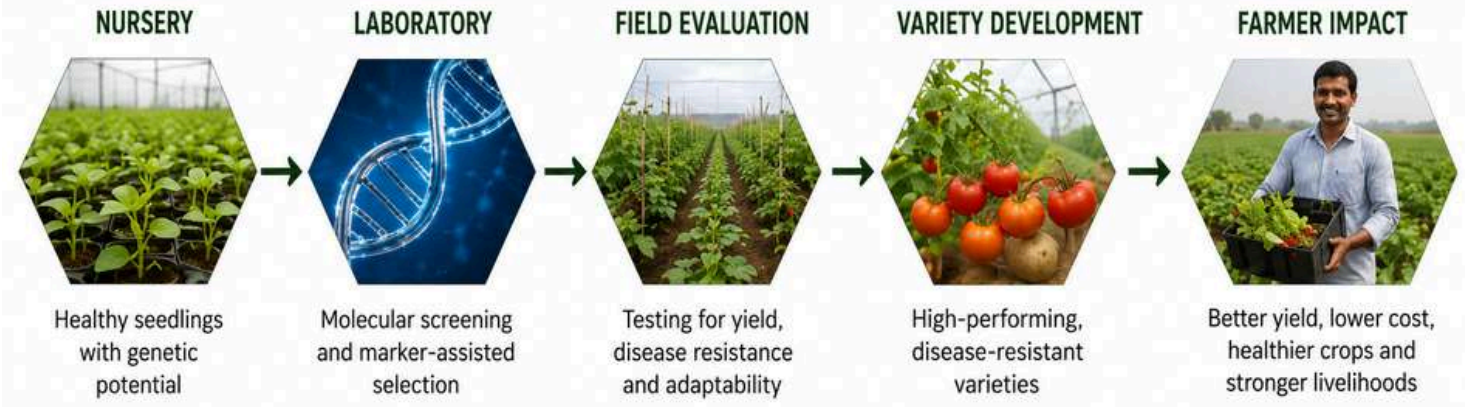
KEY TAKEAWAYS

- Faster development of disease-resistant varieties
- Early selection using molecular tools
- Reduced dependence on chemical inputs
- Better yield and fruit quality
- Stronger climate resilience
- Greater benefit for farmers and consumers


Pollinator Honey Bee


Transplants of Bitter Gourd


Harvested fruit of tomato



"PLANT BREEDING SUCCESS IS MEASURED IN PRODUCTIVE FIELDS, HEALTHY HARVESTS, AND FARMER CONFIDENCE."

| OBITUARY |

Madhav Gadgil

THE SCIENTIST WHO GAVE NATURE A VOICE

(1942–2026)

India lost one of its most respected environmental scientists on 7 January 2026, when Madhav Gadgil passed away in Pune at the age of 83. For more than five decades, he worked to understand India's forests, wildlife, and people and to protect them for future generations.

Born on 24 May 1942 in Pune, Gadgil grew up in a family that valued learning. He studied biology at Fergusson College in Pune, completed his master's degree in zoology from the University of Mumbai, and later went to Harvard University, where he earned his PhD in 1969. At Harvard, he was influenced by leading ecologists and developed a strong interest in mathematical ecology and animal behavior. After a short teaching period in the United States, Gadgil returned to India in 1971. He joined the Indian Institute of Science (IISc), Bengaluru, where he would spend more than thirty years building modern ecological research in the country. He founded the Centre for Ecological Sciences at IISc a pioneering institution that trained generations of Indian ecologists. He also helped establish the Centre for Theoretical Studies.

Gadgil believed that ecology was not just about forests and animals. It was also about people. He introduced scientific, quantitative methods to study ecosystems in India and emphasized that humans are an important part of nature, not separate from it. His work connected science with real-life issues such as forest management, biodiversity conservation, and sustainable development.

One of his most important achievements was helping India establish its first biosphere reserve the Nilgiri Biosphere Reserve in 1986. His research in the 1980s played a major role in identifying the ecological importance of the Nilgiri region. This was a turning point in India's conservation history. In 2010, the Government of India appointed him chairman of the Western Ghats Ecology Expert Panel (WGEEP), widely known as the Gadgil Commission. The panel studied the fragile Western Ghats mountain range and recommended that large parts of it be declared ecologically sensitive. His 2011 report sparked national debate. Environmentalists supported his strong conservation measures, while some state governments and groups opposed them. Even though not all recommendations were accepted, the report changed the way India discussed environmental protection.

Gadgil also played an important role in shaping the Biological Diversity Act of 2002 and promoted the idea of People's Biodiversity Registers, encouraging local communities to document and protect their natural resources. He believed that conservation should involve villagers, farmers, and indigenous communities.

Throughout his career, Gadgil published over 250 scientific papers and several influential books. His book This Fissured Land (co-authored with Ramachandra Guha) explored India's ecological history. He wrote in both English and Marathi, making science accessible to ordinary people. He also wrote columns for newspapers like The Hindu and Sakal, sharing stories about nature with the wider public.

His contributions were recognized globally. He received the Padma Shri in 1981 and the Padma Bhushan in 2006 from the Government of India. Internationally, he was honored with the Volvo Environment Prize, the Tyler Prize for Environmental Achievement, and in 2024, the prestigious Champions of the Earth Award from the United Nations.
Beyond science, Gadgil was known for his simplicity and integrity. As a young man, he was also an athlete, holding high jump records during his college days. He was married to noted meteorologist Sulochana Gadgil, who passed away in 2025. He is survived by his children.
Madhav Gadgil's legacy lives on in India's forests, in its environmental laws, and in the many students he mentored. He showed that science can guide society toward wiser decisions. More than a researcher, he was a bridge between knowledge and action a scientist who gave nature a strong and thoughtful voice.
India remembers him not only as an ecologist, but as a guardian of its natural heritage.

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.

World Environment Day (5 June)

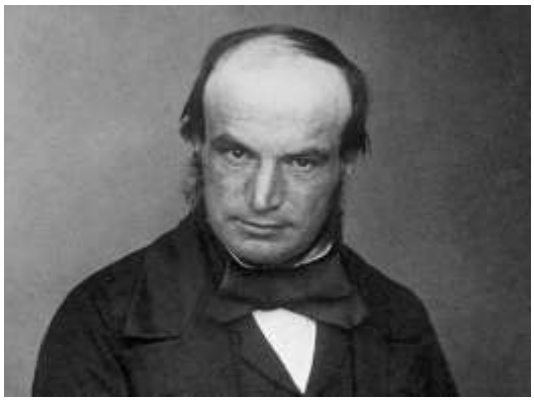
01

World Environment Day, observed every year on 5 June, was established by the United Nations in 1972 to promote environmental awareness and action. It is one of the world's largest environmental campaigns, bringing together people, communities, and governments to address challenges such as climate change, pollution, biodiversity loss, and deforestation. The day highlights that protecting the environment is a shared responsibility, and that simple actions like reducing waste, conserving resources, and planting trees can help create a more sustainable future.

John Couch Adams (5 June 1819 – 21 January 1892)

02

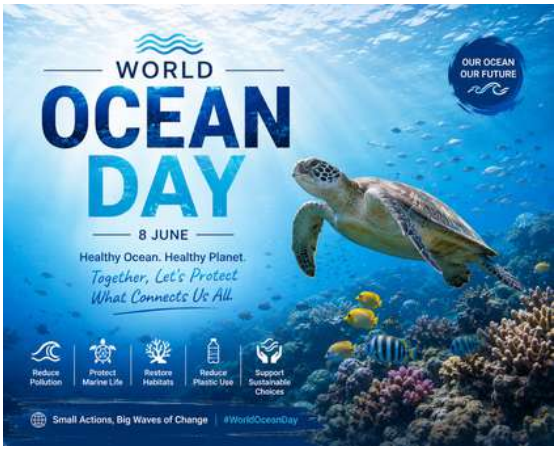
John Couch Adams was a mathematician and astronomer best known for predicting the existence of the planet Neptune using mathematics alone. While studying unusual movements in the orbit of Uranus, Adams realized that another, unseen planet might be affecting its path. Using his calculations, he predicted where this unknown planet should be located in the sky. In 1846, astronomers observed Neptune very close to the position Adams had predicted, making it one of the greatest achievements in the history of astronomy. His work demonstrated the power of mathematics to discover objects in space before they are directly seen. Beyond Neptune, Adams made important contributions to celestial mechanics, meteor astronomy, and the study of planetary motion.



World Oceans Day (8 June)

03

World Oceans Day is celebrated every year on 8 June to raise awareness about the importance of oceans and the need to protect them. The oceans cover more than 70% of Earth's surface, produce much of the oxygen we breathe, regulate the climate, and provide food and livelihoods for billions of people around the world. The day encourages governments, scientists, organizations, and individuals to work together to address challenges such as plastic pollution, overfishing, habitat destruction, and the impacts of climate change on marine ecosystems. It also highlights the importance of conserving marine biodiversity and using ocean resources sustainably. World Oceans Day serves as a reminder that healthy oceans are essential for a healthy planet. Simple actions such as reducing plastic use, supporting sustainable seafood, and participating in beach cleanups can help protect marine life and preserve ocean ecosystems for future generations.



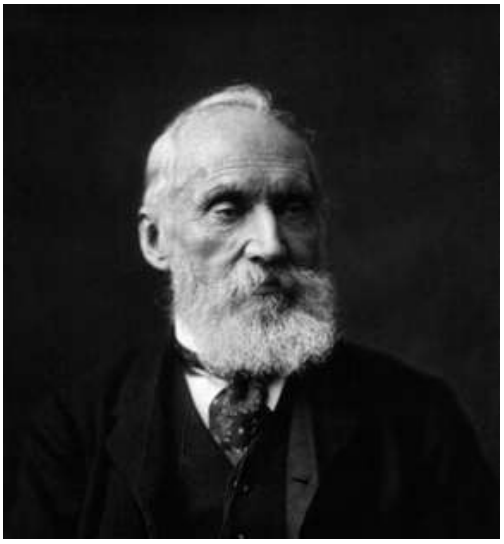
Thomas Young (13 June 1773 – 10 May 1829)

04

Thomas Young was a scientist, doctor, and linguist who made important discoveries in many different fields. He is best known for the double-slit experiment, which showed that light behaves like a wave. This discovery became one of the foundations of modern physics and helped scientists better understand the nature of light. Young also studied how the human eye sees colors and proposed ideas that later became the basis of the modern theory of color vision. In addition, he helped scientists understand the ancient Egyptian writing found on the Rosetta Stone, contributing to the decoding of hieroglyphics. Because of his work in physics, medicine, and languages, Thomas Young is remembered as one of the most talented and versatile scientists in history.

William Thomson (26 June 1824 – 17 December 1907)

05



William Thomson, better known as Lord Kelvin, was one of the most influential physicists and engineers of the 19th century. He is best known for developing the Kelvin temperature scale, an absolute temperature scale that begins at absolute zero, the lowest possible temperature in the universe. Today, the Kelvin scale is widely used in physics, astronomy, and engineering. Lord Kelvin made major contributions to the field of thermodynamics, helping scientists understand heat, energy, and the laws that govern their transfer. His work played a key role in the development of modern physics and engineering. In addition to his scientific achievements, Kelvin helped improve the technology used for the first successful transatlantic telegraph cable, which revolutionized long-distance communication between Europe and North America.

Prasanta Chandra Mahalanobis (29 June 1893 – 28 June 1972)

06

Prasanta Chandra Mahalanobis was one of India's most influential statisticians and the founder of the Indian Statistical Institute (ISI) in Kolkata. He is best known for developing the Mahalanobis Distance, a statistical method widely used in data science, artificial intelligence, genetics, economics, and agriculture. Mahalanobis also played a major role in India's economic planning after independence, helping establish the use of data and large-scale surveys in policymaking.To honor his contributions to science and nation-building, India celebrates National Statistics Day every year on 29 June, his birth anniversary.

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.

EMERGING INSIGHT

Materials Shaping a Sustainable Future

Dr. Subhadip Neogi
CSIR-Central Salt & Marine Chemicals Research Institute (CSIR-CSMCRI) Bhavnagar, Gujarat

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

AREAS OF EXPERTISE

Porous Materials • Pollutant Adsorption & Monitoring • Heterogeneous Catalysis • Renewable Energy Applications

Functionality Engineered Framework Materials for Clean Energy and Environmental Sustainability:

In today's world, where climate change, energy demand, and environmental pollution are becoming increasingly critical challenges, advanced materials offer practical scientific solutions for building a more sustainable future. Advanced materials are specially engineered substances whose structure and properties are carefully tailored at the molecular or atomic level to perform specific functions. These materials are central to the development of clean energy technologies because they directly influence how efficiently we can capture carbon dioxide, produce hydrogen fuel, store energy, or purify water. My research primarily focuses on two classes of porous crystalline materials, especially metal–organic frameworks (MOFs) and covalent organic frameworks (COFs). These porous framework materials are attractive because they possess exceptionally high surface areas, tunable pore environments, and chemically functional interiors. Such features allow them to selectively interact with gases, ions, or molecules, making them promising candidates for carbon capture, atmospheric water harvesting, water splitting, catalysis, hazardous chemical monitoring, and radioactive waste remediation.

A particularly exciting development for the field was the recognition of reticular and framework chemistry in the 2025 Nobel Prize in Chemistry, which highlighted the transformative impact of MOFs. The award reflected how precise molecular-level design can create materials with programmable porosity, selective adsorption properties, and tunable catalytic behaviour. This recognition strongly validates the growing importance of framework materials in addressing global challenges related to clean energy, carbon capture, hydrogen generation, and environmental sustainability. *For researchers engaged in MOFs and COFs, 2025 Nobel Prize represents not merely a scientific achievement but also a powerful reminder that such rational materials design can fundamentally transform future energy and environmental technologies.*

What inspired me to work in this area was the realization that many global challenges are fundamentally materials problems. Whether it is clean hydrogen generation, carbon neutrality, freshwater production, or detection of toxic pollutants in water and the environment, the efficiency of the process often depends on the material being used. I was particularly fascinated by how a small molecular-level modification in a material could dramatically alter its behavior and performance. *The interdisciplinary nature of framework chemistry, combining inorganic chemistry, organic synthesis, materials science, spectroscopy, and energy research, further motivated me to explore this field.*

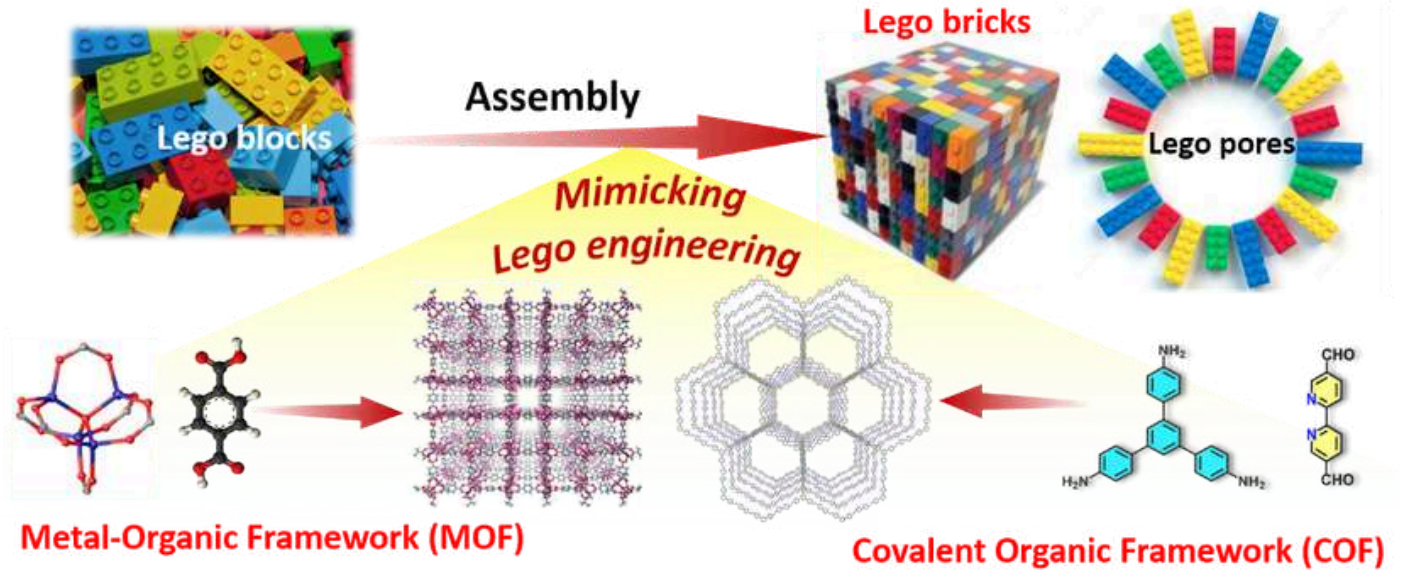
In simple terms, MOFs can be imagined as molecular sponges constructed from metal ions and organic linkers. These frameworks contain nano-sized pores that can trap, transport, or recognize specific molecules. For example, in gas capture applications, the pore walls can be decorated with functional groups that preferentially interact with carbon dioxide, enabling selective separation from industrial gas mixtures. Similarly, in water splitting, MOFs can act as electrocatalysts that accelerate the oxygen evolution reaction and hydrogen evolution reaction, thereby improving the efficiency of hydrogen fuel generation from water. In atmospheric water harvesting, poro-

us frameworks can adsorb water vapour from air even under low-humidity conditions and subsequently release it as usable water upon mild heating. We have also explored luminescent and electrochemical framework materials for monitoring environmentally hazardous chemicals such as antibiotics, pesticides, and explosive nitroaromatic compounds through selective sensing responses. *Because their structures can be precisely engineered, MOFs and COFs provide enormous flexibility in designing materials for targeted applications.*

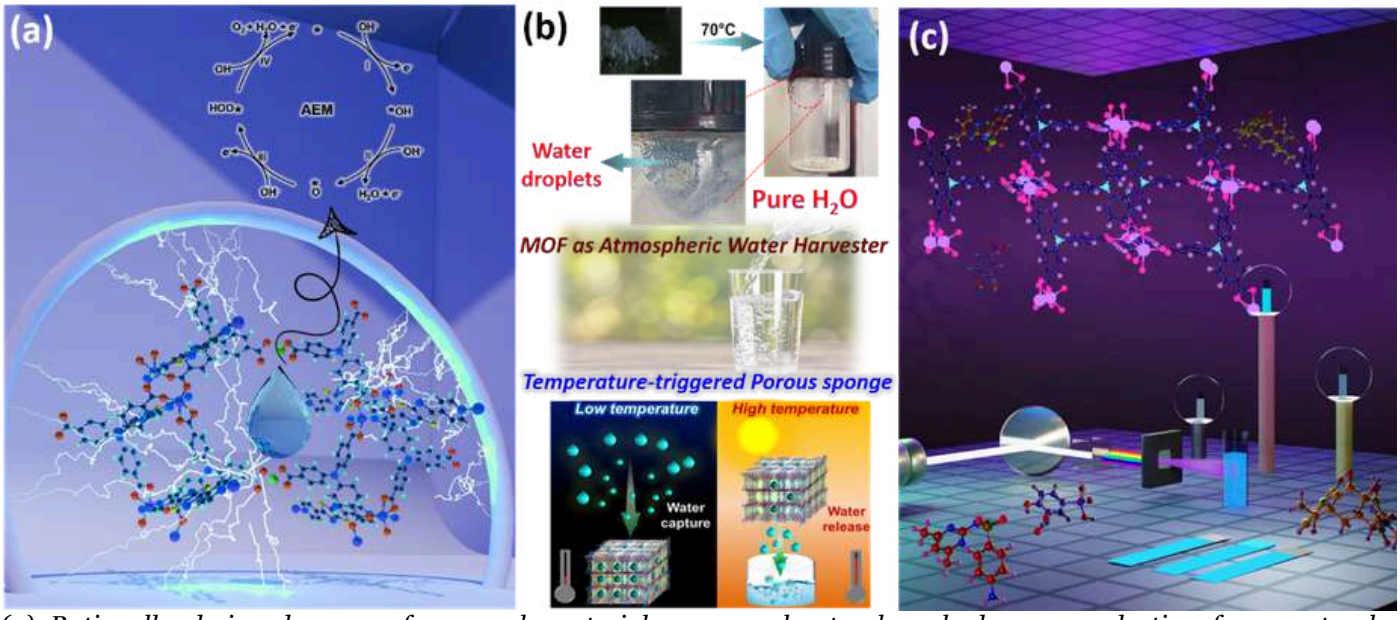
One of the most important lessons from my research is that very small structural modifications can create large functional differences. Introducing heteroatoms, tuning ligand electronics, creating open metal sites, or adjusting pore geometry can significantly influence adsorption strength, charge transport, catalytic activity, sensing selectivity, and stability. For instance, incorporating redox-active ligands into MOFs can facilitate electron transfer during electrocatalysis, while functional groups such as azo, carboxylate, nitrogen-rich moieties, or hydrogen-bonding sites can improve gas affinity, water uptake, or analyte recognition. Another exciting discoveries during my research journey has been observing how cooperative interactions between metal nodes and organic ligands can produce remarkable electrocatalytic activity for overall water splitting. Traditionally, metal centers were considered the primary active sites in many catalytic systems. However, our studies demonstrated that carefully designed ligands can actively participate in charge transfer and catalytic processes, creating synergistic effects that substantially improve performance. Another exciting aspect has been the ability of functionalized porous materials to selectively capture environmentally significant species such as carbon dioxide, iodine vapor, and uranium ions under challenging conditions.

I strongly believe that research on advanced framework materials can contribute significantly to real-world technologies. Efficient electrocatalysts can support green hydrogen production, porous adsorbents can help mitigate industrial carbon emissions, and selective extraction materials can assist in environmental remediation and resource recovery. In the future, these materials may also be integrated into membranes, sensors, and portable purification systems for field applications.

However, several challenges, including cost-effective synthesis, scalability, and device integration still remain before large-scale implementation becomes possible. Additionally, understanding structure–property relationships at a deeper mechanistic level remains essential for rational material design. Combining experimental research with computational modelling and engineering approaches will be crucial for translating laboratory discoveries in-



Just as Lego bricks create designed spaces and patterns, porous framework materials can be assembled from simple building blocks into highly ordered porous architectures with optimum-sized pores for a variety of clean energy and environmental applications.



(a) Rationally designed porous framework materials can accelerate clean hydrogen production from water by improving electrocatalytic water splitting reactions. (b) Advanced metal–organic frameworks can function as "molecular sponge" to capture water directly from air and release clean water upon mild heating. (c) Tailor-made porous crystalline materials act as sensor for detecting hazardous chemicals, pollutants, and toxic substances through selective optical responses.

to practical technologies. Looking ahead, *I believe the future of clean energy and sustainable environmental research will rely heavily on intelligent material design*. By engineering porous materials with precisely controlled functionality, stability, and electronic properties, we can develop next-generation systems capable of addressing some of the most pressing environmental and energy challenges facing humanity. Each novel material we develop imparts essential insights into the utilization of chemistry for fostering a cleaner and more sustainable environment.

Scientific contributions from Dr. S. Neogi's research group in MOFs and COFs include significant advances in sustainable energy applications
Sustainable energy application: J. Mater. Chem. A, 2026 (10.1039/D5TA10510B), ACS Appl. Mater. Interfaces, 2026 18, 16362-16374, Adv. Funct. Mater., 2026, 36, e08504.
Heterogeneous catalysis: Small, 2026, 22, e14442, J. Mater. Chem. A, 2025, 13, 40741-40756, Chemical Engineering Journal, 2025, 504, 158981
Pollutant monitoring: Small, 2025, 21, 2501941, Chem. Mater., 2024, 36, 10451−10473, ACS Appl. Eng. Mater., 2024, 2, 2177-2189

EMERGING INSIGHT

Mycotoxinsin Our Food: The Hidden Threat Requiring Regulatory Attention

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AREAS OF EXPERTISE
Bioprocess Engineering • Bioenergy and Biofuels • Mixed Culture Biotechnology • Functional Food Engineering

Food is not merely a basic need for physical development and functions but also a driver of the cognitive functions that altogether decides our state of well-being. Hence, ensuring safe and secure access of the society to nutritious and balanced platter of food is the utmost priority of every nation of world.

Unfortunately, the food which provides nourishment to our body and mind can sometime also become a carrier of toxic substances produced by nature itself. It is a common knowledge that being easily perishable, foods, either processed or unprocessed are prone to get contaminated by various spoilage causing microorganisms. At least majority of us have seen the greenish patches of that evil looking 'Bread mould' sitting over the surface of bread signaling possible harm from consumption. In the world of food spoilage causing microorganisms fungi and moulds are undoubtedly the dominants, overshadowing others. There is a remarkably vast number of varieties of them which can produce a specific type of toxin within the core of food materials once the fungi invade through infection. These toxins, produced by fungi ('Myco') are known as mycotoxins and are considered a serious 'biohazard' hreat to the safely of foodstuffs worldwide due to their short to long term adverse impacts on human health, agronomic practices and livestock raising. Mycotoxins are chemical compounds produced as the secondary metabolites by the mycotoxigenic fungi and excreted in the surrounding of the producer cells. They accumulate within the matrix of infected foods, staying hidden in plain sight and may reach the body of unsuspecting consumers undetected.

Mycotoxin induced 'food poisoning' may exhibit acute (nausea, fever, vomiting, abdominal pain, diarrhoea etc.) to chronic toxic impacts like hepatotoxicity (liver), nephrotoxicity (kidneys), neurotoxicity (nervous system), immunotoxicity (immune system) on humans or animals. Carcinogenicity is also associated with some mycotoxins, which makes them even more concerning for the safety of food and consumers' health. Upon consumption above critical levels, which could be ranging between 0.5 to 15 micrograms (µg)/kilogram (kg), death may also occur due to lethal mycotoxicosis.

Although, indications of mycotoxin contamination go back to a longtime in history, severe casualties caused by mycotoxin poisoning are reported in not-so-distant past. In 2004, mycotoxin poisoning caused by consumption of contaminated maize killed 125 people in rural Kenya. Alarmed by such instances of outbreak of mycotoxicosis the global health and food regulatory bodies like World Health Organization (WHO) and Food and Agriculture Organization (FAO) joined hands to form Joint FAO/WHO Expert Committee on Food Additives (JECFA). As the global representative of governments JECFA monitors the risk assessments of mycotoxins in foodstuffs in conjunction with Codex Alimentarius Commission (the intergovernmental standards-setting body for food) to facilitate mycotoxin control in food and management advices for prevention of mycotoxin poisoning. While these practices are implementable in developed countries where sorted, tested, packaged and properly labelled food materials are available in the supermarkets for the customers meeting the safety standards set by the international regulatory bodies, it is a cumbersome task for the deve-

loping countries.

In countries like Asia and Africa, a direct 'farm-to-market' practice is traditionally operated for majority of foodstuffs like the cereals, vegetables, fruits and oilseeds, which often skips the proper check points for possible fungal or mycotoxin contamination. The result can be disastrous as having a tropical/sub-tropical, warm and humid agro-climatic conditions, fungal infestations of crops and other raw foodstuffs is highly plausible in these countries during any stage of food supply chain. This calls for the development of 'quick-to-run-and-implement' protocols for accurately detecting, controlling and removing mycotoxins from foods to ensure safe consumption worldwide.

Modern research has identified over 400 structurally different mycotoxins produced by toxigenic fungus like Aspergillus, Penicillium, Alternaria, Fusarium, Claviceps etc. Among them a few stands out as potent contaminants of food and feed due to their frequent occurrence and high levels of toxicity. These include Aflatoxins (AFs), Ochratoxins (OTs), Nivalenol (NIV), Deoxynivalenol (DON), Patulin (PAT), Citrinin (CIT), Fumonisins (FBs) and Zearalenone (ZEN).

Mycotoxins can form throughout the cultivation, pre-harvest, harvest and post-harvest storage phases of crop/vegetable/fruit/spice production and during transportation and processing. Early detection of mycotoxins enables prompt action, such as separating contaminated fraction of foods or enhancing storage conditions.

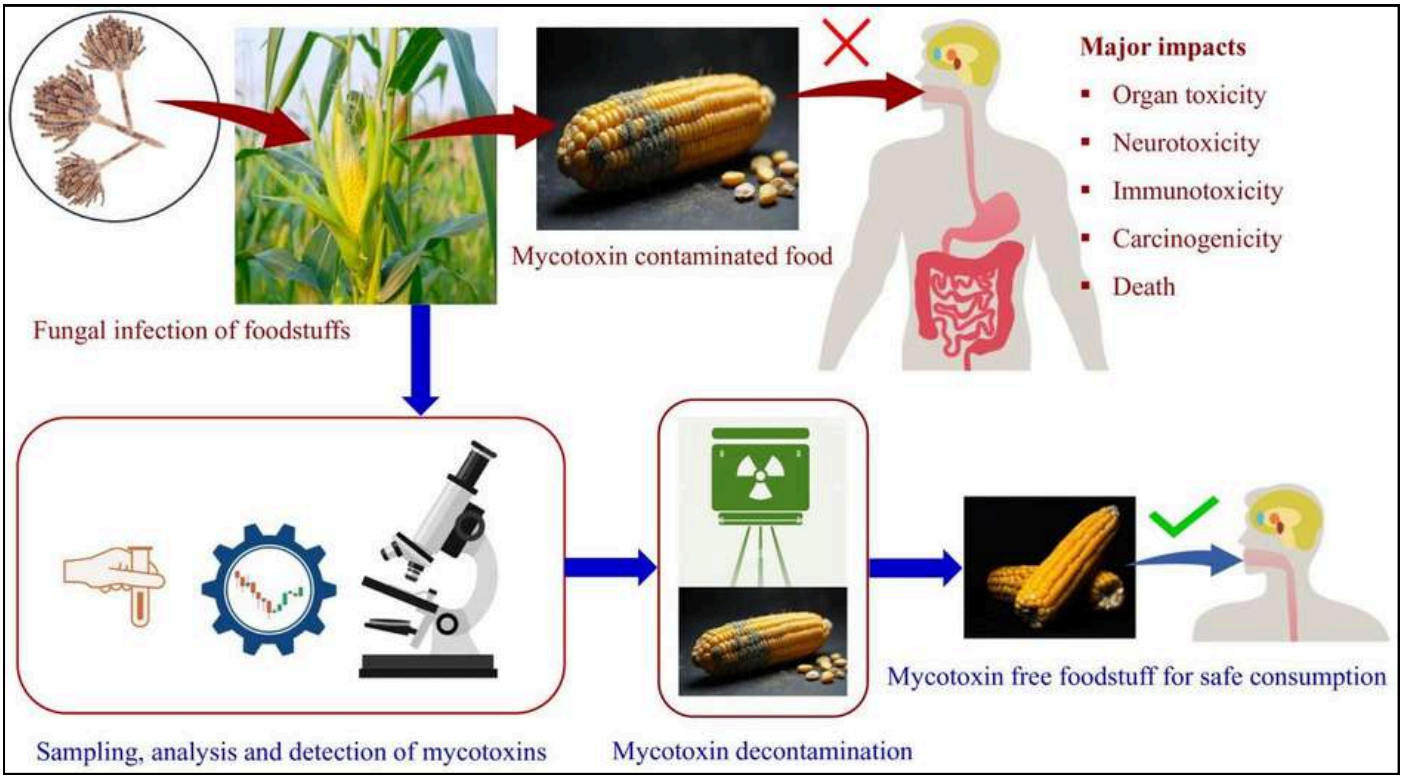
In the earlier times, for a visibly damaged or infected lot of foodstuffs simple physical (sorting, sieving, floating, washing, dehulling, steeping, milling, heat treatment etc.) or chemical (citric acid, hydrogen peroxide, propionic acid, sodium hypochlorite, ascorbic acid, aluminium hydroxide etc.) treatments were used to eliminate the toxigenic fungi or mycotoxins. Major limitations of these conventional methods are that they act in a non-specific manner targeting not only sources of mycotoxins but also damaging the nutritional quality and aesthetic attributes of the foodstuffs. More importantly these methods are more effective for removing the surface-residing fungi but less effective in penetrating and destroying deeply embedded chemically stable and robust structures of mycotoxins. In recent times various advanced techniques like chromatographic analysis, enzyme linked immunosorbent assay (ELISA), lateral flow assay (LFA) and recently biosensors have been applied due to their high specificity and sensitivity for detecting such well-hidden mycotoxins in foodstuffs.

Along with the accurate detection several advanced technologies have been employed for developing unconventional decontamination techniques for targeted destruction and elimination of mycotoxins without leaving behind toxic by-products or secondary residues. These include irradiation, ozonation, cold activated plasma, high hydrostatic pressure, pulsed electric fields, pulsed light, magnetic particles and nanoparticles, natural essential oils and phytochemicals. They are developed based upon different physical, chemical and biological principles and follow different mechanisms for target specific destruction of robust chemical structures of mycotoxins with high degradation efficiency reaching as high as >95% in some specific cases. Additionally, these techniques safeguard preservation of overall nutritional and aesthetic qualities of foods without much damage compared to the conventional mycotoxin decontamination methods.

Most recently, combined application of some of these unconventional methods showed the promise of higher mycotoxin degradation in foods. However, the requirements of advanced technical infrastructures equipped with high-end machineries for implementing some of these promising unconventional techniques i.e., cold activated plasma, high hydrostatic pressure, pulsed electric fields, pulsed light, magnetic particles and nanoparticles has restricted their progress within the laboratory-based studies.

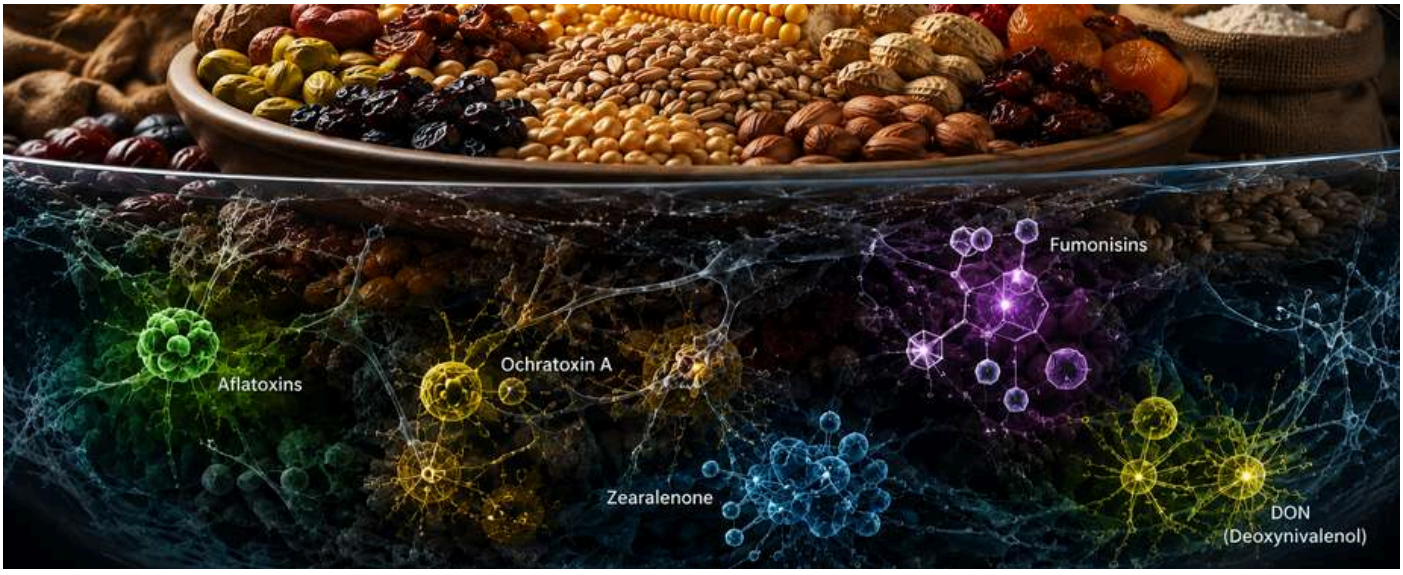
Complete elimination of fungal contamination of foods throughout all phases of their supply chains is practically impossible due to their almost omnipresent nature. Thus, standardization of the best practices for mycotoxin decontamination is one yet to achieve goal requiring further research attention. Being directly related to global food safety this is a very important and dynamic field of research. It is swiftly transcending from being a solitary research field towards a highly interdisciplinary domain combining multiple scientific and technical innovations.

To achieve high success rates in targeted mycotoxin degradation, principles of analytical chemistry,



nutrition and food biochemistry, agro-food processing, process engineering and optimization and computational modelling must be integrated into the focused research endeavours. Inclusion of sustainable development goals (SDGs) has necessitated the mycotoxin decontamination techniques to be completely green, economically feasible and serve societies of the global nations in a satisfactory manner. Beyond optimizing the applicability of the core research findings, successful implementation will require strategic planning by the governmental policymakers to make the mycotoxin decontamination affordable and fully compatible with the latest agro-food-processing operations in practice.

Dr. Ghosh's contributions to this field are reflected in his recent publication in Food Chemistry (2026), titled "A Comprehensive Review of Decontamination Techniques for Mycotoxin Control in Food: Advancement from Conventional to Unconventional Strategies and the Way Forward", 10.1016/j.foodchem.2026.148362, which provides valuable insights into emerging approaches for improving food safety and reducing mycotoxin contamination through advanced decontamination technologies.



EMERGING INSIGHT

Can Tiny Materials Help Produce Clean Hydrogen Energy?

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AREAS OF EXPERTISE

Nanomaterials • Superlattices • water splitting • Optoelectronics

The increasing global demand for energy continues to depend heavily on conventional resources such as coal, oil, natural gas, and nuclear power. Rapid industrialisation, electrification of transportation, rising cooling demands, and the expansion of data centres have further accelerated energy consumption. However, the excessive use of fossil fuels has significantly increased carbon dioxide emissions, leading to serious environmental and climate-related concerns. To reduce greenhouse gas emissions and achieve sustainable development, renewable energy technologies are being actively explored. Among them, hydrogen energy has emerged as one of the most promising clean energy solutions. Hydrogen is considered an environmentally friendly fuel because it possesses a very high gravimetric energy density of approximately 120 MJ kg^{-1} and produces only water vapour during combustion. Its energy density is nearly three times higher than gasoline, making it highly attractive for fuel-cell vehicles and future clean energy technologies. Hydrogen can be produced by water splitting reactions [Nature 238, 37–38 (1972)]. The water splitting process requires a minimum thermodynamic energy of 237 kJ mol^{-1} or 1.23 V. In 1972, Akira Fujishima and Kenichi Honda first demonstrated photoelectrochemical water splitting using an n-type titanium dioxide (TiO_2) semiconductor electrode under ultraviolet irradiation, commonly known as the Honda–Fujishima effect. This discovery established semiconductor materials as important candidates for solar-driven hydrogen production. However, TiO2 possesses a wide band gap of approximately 3.2 eV and absorbs only ultraviolet light, which represents nearly 5% of the solar spectrum. In addition, bulk semiconductor materials often suffer from rapid recombination of photogenerated electrons and holes, limiting their photocatalytic efficiency. Their relatively low surface-to-volume ratio also reduces the number of active catalytic sites available for water splitting reactions. Semiconductor nanomaterials overcome many of these limitations because of their nanoscale dimensions and large surface-to-volume ratio. The increased surface area enhances interaction between water molecules and catalytically active sites, thereby improving hydrogen generation efficiency. Moreover, reducing the size of semiconductor nanomaterials produces quantum confinement effects that modify their electronic structures and charge carrier dynamics. These effects help suppress electron–hole recombination and improve the reduction and oxidation potentials required for water splitting. Consequently, semiconductor nanostructures have become highly promising materials for clean and sustainable hydrogen production.

Band gap engineering through semiconductor heterostructure formation further improves light absorption and charge separation efficiency. Combining a wide band gap semiconductor with a narrow band gap material extends optical absorption from the ultraviolet region into the visible and near-infrared regions of the solar spectrum. More importantly, the heterostructure interface controls the movement and separation of photogenerated electrons and holes under light illumination. Cadmium sulfide (CdS) is one of the most widely investigated semiconductor materials for hydrogen evolution because of its suitable band gap of

approximately 2.42 eV, which allows strong visible-light absorption. Highly quantum-confined CdS quantum dots with particle sizes below 4 nm exhibit improved charge separation and reduced recombination compared with bulk semiconductor systems. As a result, CdS nanomaterials demonstrate higher photocatalytic hydrogen generation efficiency than TiO2. However, CdS-based photocatalytic systems often suffer from photocorrosion and photobleaching during long-term operation. To overcome these limitations, CdS has been combined with silver sulfide (Ag2S), a narrow band gap semiconductor with a band gap of approximately 0.9–1.0 eV. The incorporation of Ag2S broadens the optical absorption range from ultraviolet to infrared wavelengths and improves charge transport properties. In addition, the CdS–Ag_2S interface promotes efficient separation and transfer of photogenerated charge carriers, thereby enhancing photoelectrochemical hydrogen production. Conventional CdS–Ag_2S heterostructures prepared in patchy, core–shell, type-I, or type-II configurations often exhibit poor surface charge passivation and weak electronic coupling. In type-I heterostructures, the narrow- band gap semiconductor is generally located at the core while the wider-band gap material forms the shell, resulting in charge confinement within the nanostructure. In contrast, type-II heterostructures spatially separate electrons and holes between two semiconductor domains, improving charge separation and reducing recombination losses. A more advanced strategy involves the synthesis of semiconductor superlattice heterostructures. In these systems, periodically arranged heterostructures generate electronically coupled miniband states that facilitate rapid charge transport and enhanced light–matter interaction. Superlattice structures possess strongly quantum-confined electronic states and improved interparticle coupling, making them highly effective for photocatalytic and electrochemical applications. Such nanostructures can be fabricated using methods such as electron-beam epitaxy, vapour–liquid–solid growth,

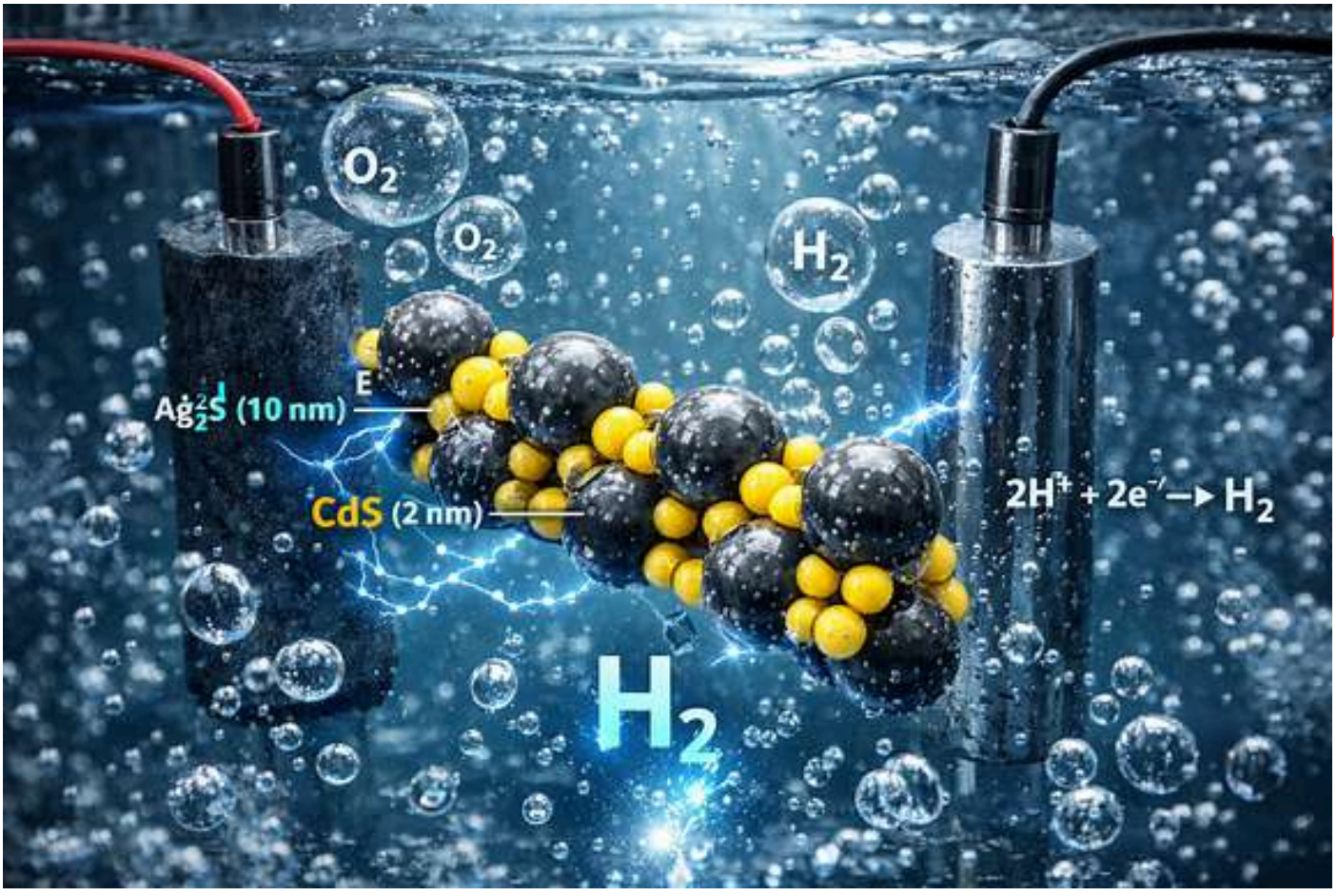

Figure: Electrochemical water splitting and hydrogen generation by CdS-Ag2S nanorod superlattice.

electron-beam lithography, and cation or anion exchange reactions. The first colloidal superlattice nanostructures were reported by C. B. Murray and co-workers in 1995, demonstrating their importance for optoelectronic applications [Science 270 (1995); 1335-1338]. Later, Alivisatos et. al. reported spontaneous CdS–Ag2S nanorod superlattice formation by cation exchange reactions in colloidal systems [Science 317 (2007), 355]. We successfully developed ordered CdS–Ag2S nanorod superlattices by a dual molecular source synthesis approach. The diffusion behaviour and miniband formation within the CdS–Ag2S heterostructures were controlled using thiocarboxylate molecular precursors, namely (PPh3)2Ag(SCOPh) and Cd(SCOPh)2, together with dodecane thiol (DDT) and octadecyl amine (ODA) surface ligands. The presence of triphenylphosphine and the associative interaction of DDT ligands promoted the formation of highly ordered one-dimensional superlattice architectures. X-ray photoelectron spectroscopy studies of the thiol-capped CdS–Ag2S nanorod superlattice revealed strong polarisation of the CdMMN valence band and electron transfer from Cd 3d and Ag 3d orbitals toward the S 2p states. These observations confirmed strong electronic coupling and efficient charge redistribution within the superlattice structure. In contrast, ODA-capped CdS–Ag2S quantum dot superlattices exhibited disordered atomic packing with weaker electronic interaction, leading to electron transfer mainly from Cd 3d and S 2p orbitals toward Ag 3d states. Furthermore, conventional CdS–Ag2S heterostructures showed negligible shifts in Cd 3d, Ag 3d, and S 2p spin-orbit energies, indicating poor surface charge passivation. Photophysical studies further demonstrated the advantages of the superlattice architecture. The DDT-capped one-dimensional CdS–Ag2S nanorod superlattice displayed a dominant fast charge-carrier recombination component with a lifetime of 0.95 ± 0.007 ns associated with band-edge emission and minimal non-radiative surface trap states. This behaviour indicates efficient charge transport and reduced trapping losses. In contrast, ODA-capped zero-dimensional CdS–Ag2S quantum dot superlattices exhibited dual-band emission caused by disordered atomic packing and increased surface trap formation. These structures showed short-lived band-edge recombination with a lifetime of 0.90 ± 0.008 ns together with long-lived surface-trap emissions centred at 670 nm, with an average carrier lifetime of 78.8 ± 1.00 µs. Overall, our findings demonstrate that ordered CdS–Ag2S superlattice nanostructures significantly improve light absorption, charge separation, and electronic transport compared with conventional heterostructures.

This study does not include photoelectrochemical water-splitting studies on indium tin oxide (ITO) or fluorine-doped tin oxide (FTO)-based superlattice devices.

In future, optimising the ultrafast charge-carrier dynamics and interfacial charge transfer of nanorod superlattices on n-type ITO/FTO electrodes remains a major challenge for next-generation clean hydrogen and renewable energy applications.

Dr. Chaturvedi's contributions to this field are reflected in her publication in Small, "Surface Modulation, Optics, and Electrochemical Hydrogen Evolution Studies on CdS-Ag2S Superlattice Heterostructures" (2026 that show highly ordered CdS-Ag2S nanorod superlattices improve charge transport and significantly enhance hydrogen production from water, highlighting their potential for clean energy applications. https://doi.org/10.1002/smll.73427

EMERGING INSIGHT

Rethinking PFAS Removal Toward Sustainable Water Systems: Persistence, Challenges, and Future Possibilities

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AREAS OF EXPERTISE
Bio-derived Carbon Adsorbents • Adsorption Mechanisms • PFAS & Emerging Contaminants • Sustainable Water Treatment • Adsorbent Regeneration

PFAS, known as "forever chemicals," persist due to strong carbon–fluorine bonds, creating significant water contamination challenges. Current treatment approaches include adsorption, membrane separation, and destruction, each with limitations. Key gaps involve selectivity, energy efficiency, and scalability. Integrated systems and advanced materials offer promising pathways toward sustainable, efficient, and scalable PFAS remediation solutions.

A Journey from Persistence to Possibility

Water has always symbolized purity, yet modern chemistry has introduced substances that challenge this idea. Among them, per- and polyfluoroalkyl substances, commonly referred to as PFAS, stand out because of their unusual persistence. These chemicals are called "forever chemicals" because they resist breaking down in natural conditions. The reason lies in the carbon–fluorine bond, one of the strongest in chemistry, which prevents degradation through heat, sunlight, or biological activity. As a result, PFAS remain in water, soil, and living organisms for decades. Their widespread use has made the problem even more complex. PFAS have been used in everyday products such as non-stick cookware, water-resistant fabrics, firefighting foams, and food packaging. Over time, these substances have entered groundwater, rivers, and even drinking water supplies. Once present, they travel easily and accumulate, creating long-term risks to ecosystems and human health. The challenge is not only their presence but also the difficulty in removing them effectively.

Scientific efforts have gradually transformed this challenge into an area of active innovation. Recent research has focused on understanding how PFAS interact with different materials and how these interactions can be used to remove them from water. Among various approaches, adsorption has emerged as a practical and widely used method. Traditional materials such as granular activated carbon have shown reliable performance, especially for long-chain PFAS. However, research has gone further to explore engineered adsorbents with improved surface properties. Modified carbons and functionalized materials have demonstrated better efficiency, particularly in complex water systems where multiple contaminants compete for removal.

Another important contribution has been the study of advanced porous materials such as metal-organic frameworks and covalent organic frameworks. These materials offer very high surface areas and tunable pore structures, enabling stronger interactions with PFAS molecules. Such developments highlight the potential for designing materials that are not only more effective but also more selective. At the same time, research has emphasized the importance of understanding real-

world conditions, ensuring that performance observed in laboratories can be translated into practical applications.

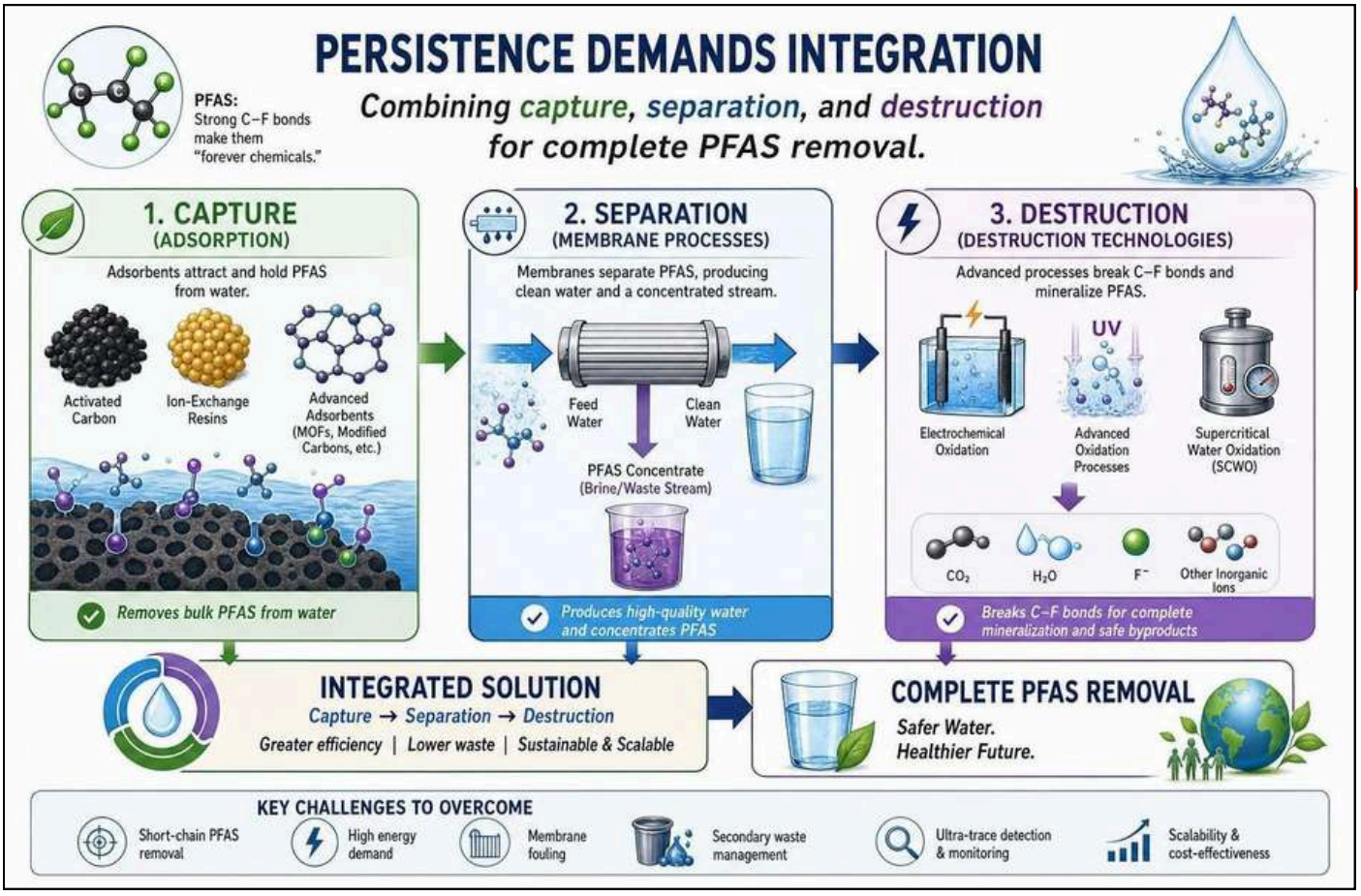
Membrane technologies have also played a significant role in advancing PFAS treatment. Processes such as reverse osmosis and nanofiltration can remove nearly all PFAS from water through physical separation. These systems provide high-quality treated water but create concentrated waste streams that still require further treatment. This limitation has led to growing interest in combining different technologies rather than relying on a single method.

Destructive technologies represent another important step forward. Techniques such as electrochemical oxidation are capable of breaking the strong carbon–fluorine bonds, leading to complete mineralization of PFAS. This approach addresses the root of the problem by eliminating the compounds rather than simply separating them. However, high energy requirements and operational complexity limit widespread application at present.

Despite these advances, several limitations continue to shape the field. Adsorption systems often struggle with short-chain PFAS, which are more mobile and less likely to bind strongly to materials. The presence of dissolved organic matter and other ions further reduces efficiency. Membrane systems face challenges related to fouling, energy consumption, and the management of concentrated waste. Advanced materials, while promising, remain expensive and difficult to scale. Destructive technologies, although effective, require significant energy input and further optimization.

These limitations point toward deeper scientific and technological gaps. One major gap lies in the development of materials that can selectively remove a wide range of PFAS compounds under realistic conditions. Another challenge involves improving energy efficiency, ensuring that treatment systems remain sustainable as they scale up. In addition, the behavior of PFAS in complex water systems is not yet fully understood. Variations in water chemistry can significantly influence treatment performance, making it difficult to predict outcomes.

Several unanswered questions continue to guide future research. A



key question involves whether a single treatment system can effectively address both long-chain and short-chain PFAS. Understanding the pathways of PFAS degradation during destructive processes is also essential to ensure that no harmful byproducts are formed. Scaling laboratory innovations into full-scale systems presents another challenge, requiring solutions that are not only effective but also economically viable and easy to operate. At the same time, safe management of secondary waste and accurate detection at very low concentrations remain critical concerns.

Looking ahead, the future of PFAS treatment lies in integration and innovation. Hybrid systems that combine adsorption, membrane separation, and destruction offer a balanced approach. Adsorption can capture bulk contaminants, membranes can concentrate them, and destructive technologies can eliminate them completely. Such systems reduce overall energy use and improve efficiency while addressing multiple challenges simultaneously.

Emerging materials will play a central role in this transition. Research is moving toward designing adsorbents that are not only highly efficient but also durable, regenerable, and cost-effective. Advances in membrane design aim to reduce fouling and improve selectivity, while new approaches in destructive treatment focus on reducing energy demand. Digital monitoring tools and data-driven methods are expected to enhance system performance through real-time control and optimization.
For young researchers, this field offers both challenge and opportunity. Addressing PFAS contamination requires knowledge across chemistry, materials science, and environmental engineering, along with creativity and problem-solving skills. The journey ahead calls for innovative thinking that connects fundamental science with practical solutions. Contributions from the next generation will be essential in developing technologies that are scalable, sustainable, and accessible.

The story of PFAS is still unfolding. What began as a problem of persistence is gradually becoming a pathway toward innovation. With continued effort, collaboration, and forward-looking research, the goal of safe and sustainable water systems can move closer to reality.

Dr. Sivakumar's contributions to this field are reflected in his article, "Advanced Adsorbent Materials for the Removal of PFAS from Water: Challenges, Progress, and Future Directions," https://doi.org/10.1007/s11356-026-37723-x, published in Environmental Science and Pollution Research, which highlights emerging material-based strategies for addressing persistent PFAS contamination in water systems.

EMERGING INSIGHT

The Story Behind Rethinking Obesity Through the Gut Microbiome

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AREAS OF EXPERTISE

Gut microbiome and metabolic health • Nutrition science in South Asian populations • Synbiotics and prebiotic-botanical interventions • Translational clinical research

For years, I have been struck by a paradox that walks into Indian clinics every day: people of normal or only mildly elevated body weight by the numbers we have inherited from Western medicine, who nonetheless live with type 2 diabetes, fatty liver, dyslipidemia, and the cardiovascular risk profile of someone visibly obese. As a nutrition scientist working at the interface of clinical research and microbiome science, I kept arriving at the same question: if the simple equation of calories in versus calories out cannot fully explain why Indians become metabolically ill at "healthy" weights, what is the missing layer? Increasingly, the evidence pointed toward the trillions of microbes living quietly in our intestines, shaping how our bodies handle food, fat, and inflammation.

The pattern itself, first articulated by Indian clinicians and now well-documented across South Asian cohorts, is called the thin–fat phenotype. At any given body mass index, an Indian adult tends to carry more visceral fat-the deep abdominal fat that wraps around organs and less skeletal muscle than a European counterpart. We are also more prone to ectopic fat in the liver and pancreas, and our insulin sensitivity falters earlier. Waist circumference and body-fat percentage often track metabolic risk far more accurately than BMI in our population. The roots of this phenotype run deep: low birth weight, postnatal catch-up growth, an evolutionary "thrifty" metabolism shaped by generations of scarcity, and a rapid nutritional transition toward refined carbohydrates and away from fermentable fibres. It is a phenotype that the standard global obesity yardstick was simply never designed to measure.

The gut microbiome turns out to be far more than a digestive aide. The bacteria in our colon ferment dietary fibres into short-chain fatty acids particularly butyrate and propionate. These small molecules are not just energy substrates; they bind to receptors on the cells lining our gut and trigger the release of GLP-1 and PYY, the same satiety-and-glucose-control hormones that the new generation of weight-loss drugs target. Butyrate also strengthens the gut barrier itself. When that barrier weakens, fragments of bacterial cell walls leak into circulation and activate a low-grade, body-wide inflammation in fat, liver, and muscle that quietly impairs insulin signalling and accelerates the deposition of visceral fat. Microbial products also reshape bile-acid chemistry and how our adipose tissue stores triglycerides. The gut, in short, is a metabolic organ and dysbiosis lands us squarely in the territory of insulin resistance and cardiovascular risk.

> *"The Western model of obesity, built around a number on a scale, fundamentally underestimates how Indian bodies become metabolically ill."*

> *"The gut microbiome is not a competing therapy to incretin drugs. It is the ecological substrate on which those drugs work."*

What makes this picture particularly relevant for India is a nutritional irony. Our traditional diets are cereal- and legume-based, with the structural conditions for excellent microbial fermentation. But high-quality fermentable fibres resistant starches, soluble fibres, whole-grain matrices have been steadily refined out of the modern Indian plate in favour of polished rice, white flour, and ultra-processed snacks. The microbes that produce butyrate need substrate, and we have largely stopped feeding them. Layered on top is an Indian-specific microbiome signature: lower alpha-diversity in cross-population comparisons, Prevotella-dominant configurations whose fermentative output depends heavily on dietary diversity, and reduced abundance of key butyrate producers such as Faecalibacterium in adults with obesity. The same gut environment that should be a metabolic asset has been weakened just as the metabolic stress of urban life has risen.

The finding that surprised me most as we synthesised this literature was the bidirectional relationship between GLP-1 receptor agonists and the gut microbiome. We tend to talk about these drugs—semaglutide, tirzepatide, and the newer dual agonists—as direct hormonal interventions. But emerging evidence shows that they also reshape the gut ecosystem through delayed gastric emptying, altered bile-acid flow, and changes in nutrient transit, while the microbiome in turn modulates how patients respond to the drugs and how well they tolerate them. It reframes synbiotics and fibre-rich nutrition not as alternatives to pharmacotherapy but as ecological partners. Durable metabolic health may emerge from the conversation between drug, microbe, and diet rather than from any one of them in isolation—a perspective that quietly upends the old framing of "diet versus drugs."

For the general reader, the practical implication is gentler than the headlines often suggest. There is no single magic strain or supplement that will undo metabolic disease. But the direction of the evidence converges on actions genuinely available to most Indian households: eat for the microbes by reintroducing fermentable fibres whole pulses, millets, vegetables, fruit, and traditionally fermented foods such as dahi, kanji, and idli batter alongside whatever else one eats. Where diet alone falls short, well-characterised synbiotics probiotic strains paired with matched prebiotic substrates are emerging as a scalable adjunct. In a recent ninety-day randomised, placebo-controlled trial in adults with overweight, a multi-strain synbiotic produced measurable reductions in body weight, waist circumference, and insulin-resistance markers. None of this replaces lifestyle, sleep, or movement; it complements them. And it shifts the cultural framing of obesity treatment in India from one of failure and willpower to one of biology, ecology, and feeding the right system.

Several questions remain genuinely open. We do not yet have phenotype-specific long-term trials in South Asians: most data come from short studies in mixed populations, and the durability of synbiotic effects on weight, glycaemic control, and cardiovascular outcomes is unproven over years. Strain specificity matters not all probiotics are equivalent, and matching strains to individuals based on baseline microbiome composition is still aspirational rather than clinical. The virome and mycobiome the viral and fungal members of the gut community are barely mapped in Indian populations. Larger questions sit on top: how do we standardise commercial formulations and verify viability? How do synbiotics interact with GLP-1 agonists in routine practice? Will we eventually see precision microbiome therapy guided by multi-omics rather than population averages? My own work in the years ahead will sit at this intersection, drawing on the insights of clinicians, microbiologists, and policy researchers including my co-authors Drs. Nirmal Kumar Ganguly, Sanjay Kalra, Nitin Kapoor, and Manorama Bakshi to translate this science into something that meaningfully serves Indian metabolic health.

Reframing obesity through a gut–metabolic lens does not solve India's metabolic crisis on its own. But it offers something the calorie-centric paradigm has not: a mechanism that fits the patient in front of us, a culturally compatible set of interventions, and a research direction in which India is uniquely positioned to lead. That, I think, is worth getting right.

Rao's and her team's contributions to this field are reflected in their article, "Reconsidering Obesity in India Through a Gut–Metabolic Lens: Mechanistic Insights and the Emerging Role of Synbiotics in Individuals with the Thin–Fat Phenotype," 10.1007/s12325-026-03577-5 published in Advances in Therapy (2026), which highlights the complex relationship between gut health, metabolism, and obesity in the Indian population.

EMERGING INSIGHT

Can Smart Molecules Think, Adapt, and Work Like Living Systems?

Dr. Rajorshi Das

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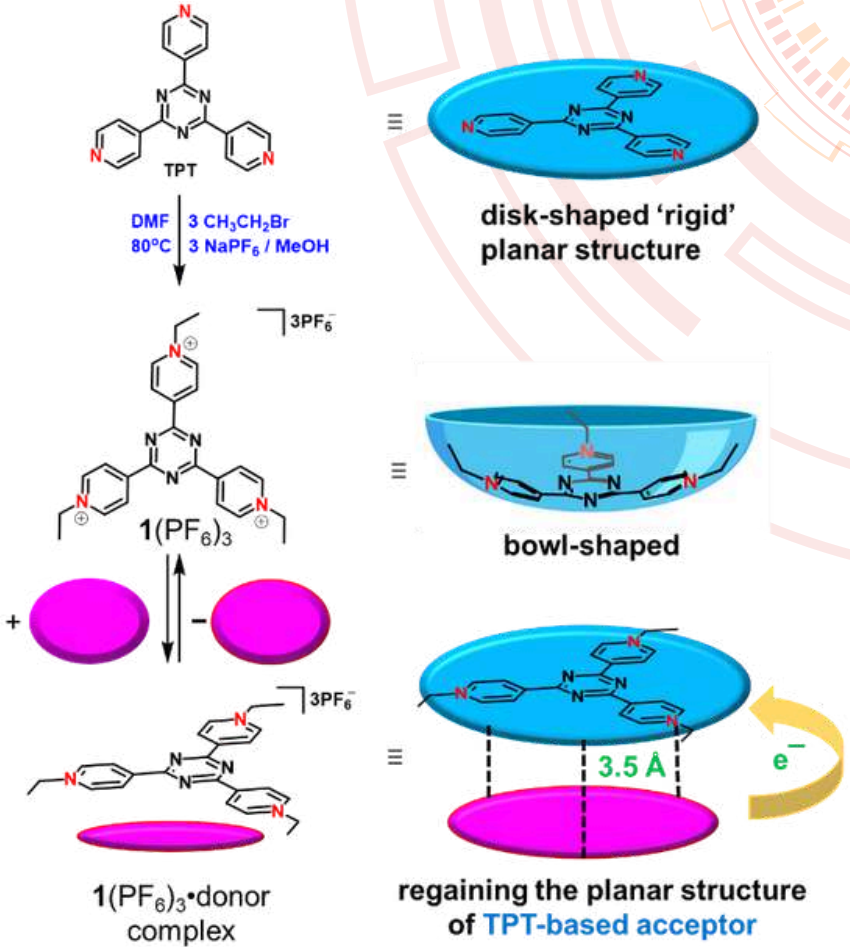
| Scientific Profile |
| Organization Link |
| Factors Press |

AREAS OF EXPERTISE

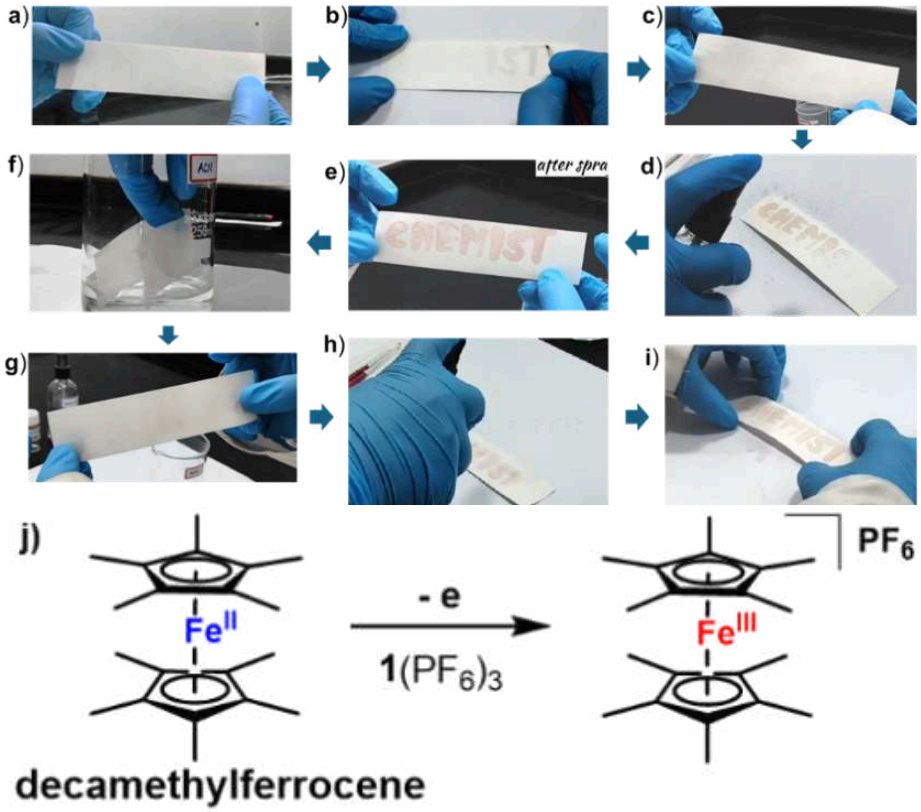
Smart materials • Organometallic chemistry • Molecular intelligence | Supramolecular chemistry • Bioinspired chemistry

Chemistry has traditionally been rooted in the design and understanding of static molecules, entities defined by fixed structures, predictable reactivity, and well-established mechanistic pathways. While this approach has enabled remarkable advances in synthesis, catalysis, and materials science, it falls short of capturing the dynamic complexity inherent in living systems. In contrast, biological matter operates through highly interconnected molecular networks that continuously sense, process, and respond to environmental cues. These systems exhibit properties such as adaptability, self-regulation, and functional autonomy, features that collectively define what could be described as 'molecular intelligence'. Bridging the conceptual gap between static chemical systems and dynamic living matter has thus become a central challenge and opportunity in modern chemistry.



Scheme 1. Inducing chemical flexibility in the rigid tripyridyl triazine scaffold by trialkylation.

The emergence of systems chemistry and supramolecular design has begun to reshape how chemists think about function at the molecular level. Seminal reports by Koshland, Lehn, Pederson and Cram have made a paradigm shift. Rather than focusing solely on individual molecules, attention is increasingly directed toward ensembles of interacting components capable of collective behaviour. In such systems, non-covalent interactions, reversible bonding, and energy flow enable continuous reorganization and responsiveness. This shift from isolated molecules to dynamic networks is critical for developing



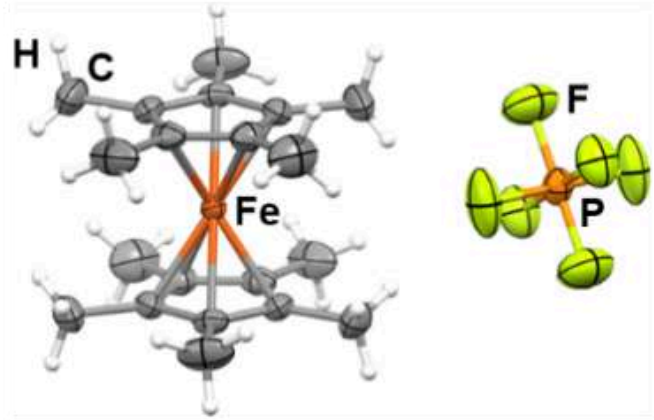


Figure 1. a-i) Schematic illustration of molecular information encoding through visible-range donor–acceptor complexation. The workflow demonstrates reversible encryption of information on a white paper substrate, where the hidden message can be selectively revealed upon exposure to an electron donor whenever needed. j) Metal-free oxidation of decamethylferrocene by 1(PF6)3.

chemical systems that can mimic life-like processes, including signal transduction, feedback regulation, and adaptive function.

In a recent study, we have demonstrated that chemical systems can also be intelligent and smart enough to understand the external stimuli to process themselves accordingly. Our exploration led to the development of electroactive, reconfigurable organic receptors capable of performing multiple functions simultaneously, marking a shift from single-purpose molecules to integrated chemical systems. One of the most notable breakthroughs lies in the demonstration of chemically induced flexibility in inherently rigid molecular scaffolds (Scheme 1). Traditionally, structural adaptability in supramolecular chemistry has relied on metal–ligand reassembly or dynamic covalent exchange. However, we have shown that even a rigid, planar ligand framework can undergo dramatic and reversible conformational transformations through simple chemical modification. Specifically, N-alkylation of a planar tripyridyltriazine (TPT) core induces an unprecedented transition to a bowl-shaped geometry, revealing that structural plasticity can be embedded directly into molecular design without altering the core connectivity.

Upon interaction with electron-rich guest molecules, the distorted “bowl” conformation reverts to its original planar structure. This dynamic switching not only enables adaptive host–guest recognition but also demonstrates how molecular systems can reorganize in response to environmental inputs to maximize functional output. Such behaviour closely parallels biological receptors, which alter their conformation to achieve selective binding and signal transduction.

Another major advancement is the integration of information encoding and processing at the molecular level. The tunable electronic structure of these adaptive systems, modulated through conformational and redox changes, enables donor–acceptor interactions that can be ha-

rnessed for molecular-level encryption and decryption (Figure 1). This represents a significant step toward chemical data processing and secure information technologies that operate beyond traditional electronic platforms.

In parallel, these systems demonstrate functional reactivity coupled to adaptive behaviour, particularly in the context of metal-free redox chemistry. The enhanced electron deficiency of the tricationic receptor enables it to act as an efficient organic oxidant, capable of transforming electron-rich substrates such as decamethylferrocene under mild conditions (Figure 1j). This dual role, combining adaptive recognition with catalytic or redox function, highlights the emergence of multifunctional molecular platforms that can sense, respond, and act within a single system. Adaptive molecular systems capable of sensing, processing, and responding to stimuli open new avenues for designing autonomous functional matter. Such systems could revolutionize catalysis by enabling self-regulating catalysts that adjust activity and selectivity in real time.

Despite these promising prospects, several fundamental challenges remain. One major limitation is the control of complexity, as systems become more multifunctional and interconnected, predicting and directing their behaviour becomes increasingly difficult. Achieving precise spatiotemporal control over molecular responses, especially under non-equilibrium conditions, is another critical hurdle. Additionally, energy management remains a key challenge, as sustaining adaptive and life-like behaviour requires continuous and efficient energy input. Furthermore, integrating multiple functions, such as sensing, processing, and actuation, within a single system without cross-interference demands careful molecular design. Finally, translating proof-of-concept systems into scalable, real-world applications requires improvements in stability, reproducibility, and synthetic accessibility. Addressing these challenges will be essential for advancing molecular intelligence from conceptual frameworks to practical technologies. Currently, we

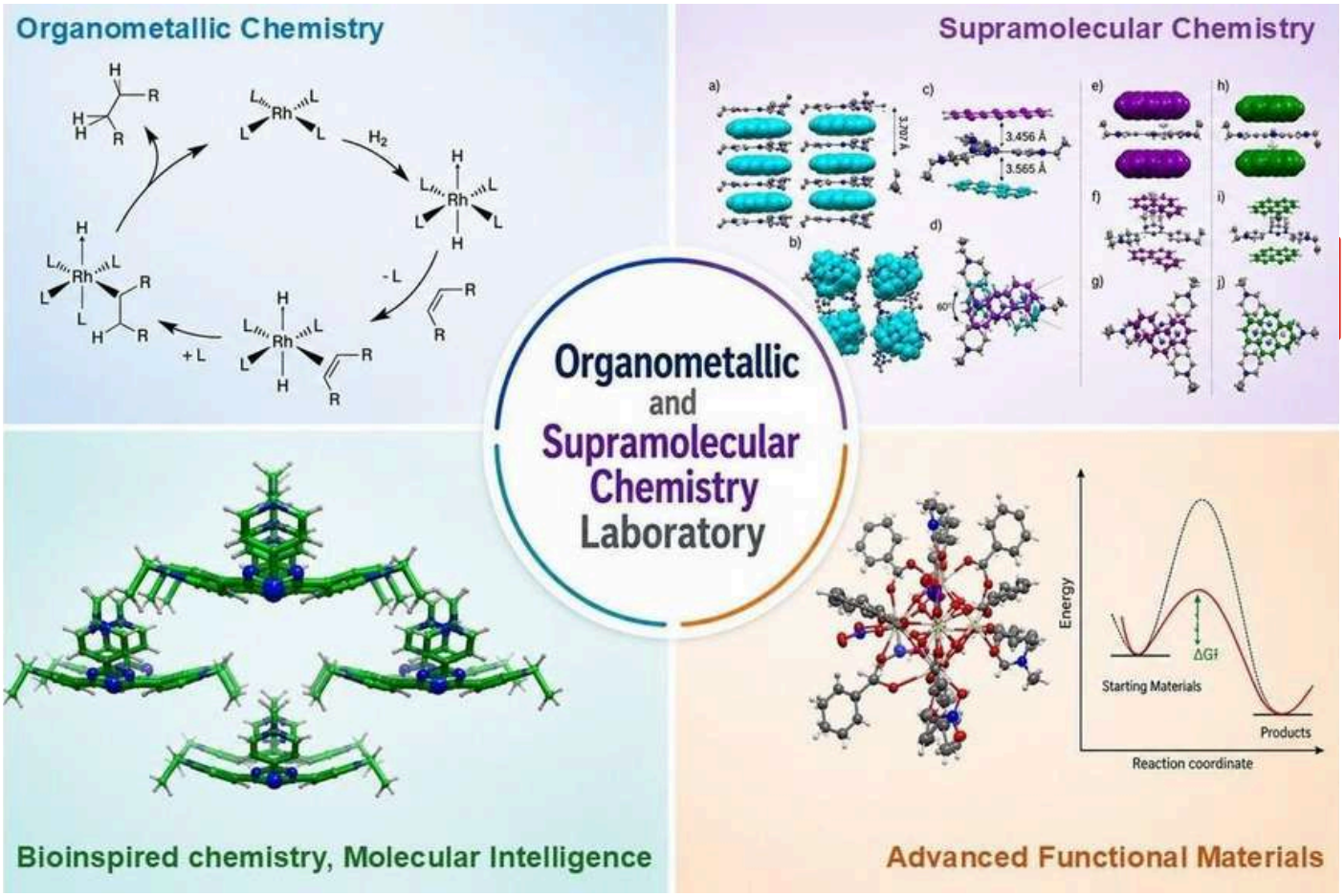
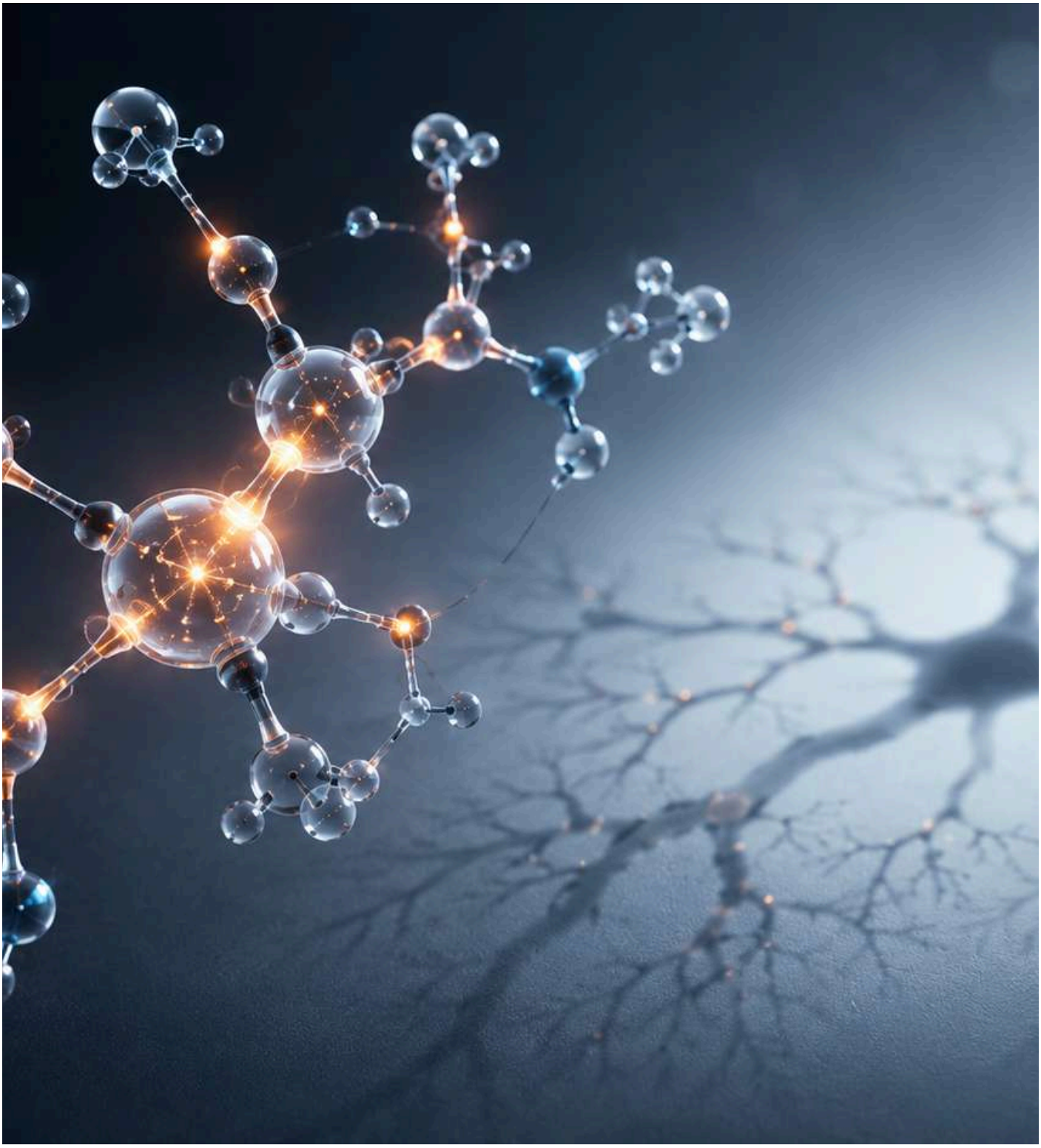


Figure 2. The ongoing projects in our laboratory.

are focusing to solve these problems.

Dr. Das's contribution to the field are reflected in his publication Materials Horizons "One system, three functions: an electroactive reconfigurable organic receptor for adaptive binding, information encoding, and metal-free oxidation."(2026). https://doi.org/10.1039/D5MH02406D where the authors developed a smart molecular systems that can change their structure, recognize different molecules, and perform useful chemical functions for future applications in advanced materials and molecular electronics.



EMERGING INSIGHT

How Malaria Parasites Take Control of Human Blood Cells

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AREAS OF EXPERTISE
Malaria parasitology • chaperones • host-parasite interaction • metabolomics

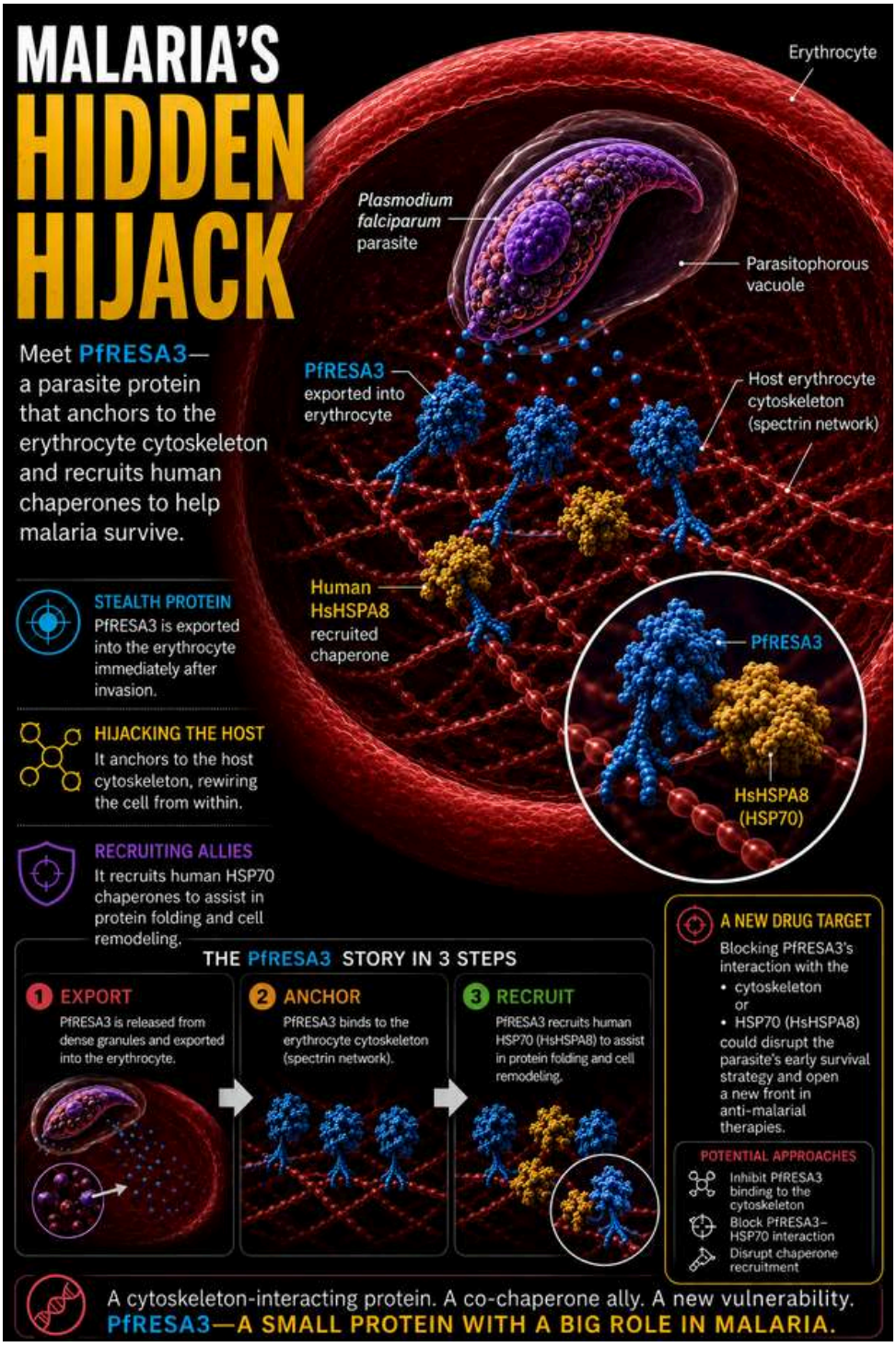
Malaria, an ancient disease caused by Plasmodium parasites, remains one of the most significant global public health challenges. Among the various Plasmodial species, Plasmodium falciparum is the major contributor to the lethal complications and mortality associated with malaria. As the existing repertoire of antimalarial drugs has been rendered increasingly obsolete by the relentless evolution of parasite resistance, the discovery of new antimalarials has become critical. A detailed understanding of the malaria parasite survival tactics inside the human host would significantly facilitate the identification of new drug targets thereby accelerating the drug discovery process.

P. falciparum being a digenetic parasite, needs human as a host for its asexual phase of its lifecycle. Infective sporozoite forms of the parasite transmitted from the bite of an infected Anopheles mosquito, initially develops inside the liver hepatic cells and later mature into merozoites to infect the human erythrocytes. This erythrocytic stage is the primary driver of both parasite proliferation and the clinical pathology of malaria. The erythrocytic cycle spans approximately 48 hours, during which the parasite progresses through distinct developmental stages, ultimately yielding multiple daughter merozoites. The subsequent egress and reinvasion of new erythrocytes drive the exponential increase in parasite biomass, directly correlating with malaria's clinical severity.

As with any intracellular parasites, P. falciparum needs to extensively remodel the host human erythrocyte in order to create a suitable niche for their survival. Following erythrocyte invasion, the parasite surrounds itself within a parasitophorous vacuolar membrane (PVM) and constructs a specialized tubulovesicular network. This parasite-derived membrane system serves as a vital conduit, trafficking parasite encoded proteins into the host cell to facilitate survival and pathogenesis. It is believed that around 20% of the P. falciparum erythrocytic proteome cross the PVM to remodel the human erythrocyte. The changes optimize nutrient exchange through increased permeability, modify erythrocyte rigidity through cytoskeletal remodelling, and establish surface knobs that facilitate cytoadherence to prevent splenic clearance of infected erythrocytes.

An important aspect of this protein trafficking is that in order to cross the parasite PVM, the proteins have to go through a protein translocon complex (PTEX) where they unfold and get released into the erythrocyte cytosol in unfolded state. For these exported proteins to function and reach their targets in the red blood cell, they must fold correctly; a process heavily dependent on chaperone assistance. Export motif analysis has identified a group of P. falciparum J domain proteins (JDPs) are trafficked into the host erythrocyte, where they likely facilitate protein refolding and trafficking. JDPs characterised by the presence of a conserved J domain with an HPD motif, are not chaperones themselves. Instead, they act as co-chaperones that deliver substrates to HSP70 proteins and activate their folding activity. Curiously, P. falciparum exports only one HSP70 protein (PfHSP70-x), which is dispensable for the parasite survival. In contrast, several of these exported JDPs have been reported to be indispensable for the parasite growth, and thus led to a speculation that human chaperones may be involved in the chaperoning process.

In this regard our lab has been working on characterising these JDPs. Our recent report talks about the P. falciparum Ring-infected Erythrocyte Surface Antigen 3 (PfRESA3), identifying it as a dense granule merozoite protein that is exported to the inner face of the host erythrocyte membrane immediately after erythrocyte invasion. Unlike many canonical JDPs, though PfRESA3 lacks the conserved HPD motif, it remains functionally active, acting as a potential co-chaperone. We demonstrated that PfRESA3 interacts with the host cytoskeleton and effectively stimulates the ATPase activity of human HSPA8 (Hsc70). PfRESA3 interaction with the erythrocyte cytoskeleton suggests it to play an important role in erythrocyte cytoskeleton remodelling. By recruiting host chaperones to assist in protein folding, PfRESA3 plays a vital role in the initial 'hijacking' of the erythrocyte, providing a molecular blueprint for how the parasite exploits host machinery to ensure its survival.



Our group previously established that P. falciparum JDPs, such as PfA8iJp and PfeCiJp, hijack host erythrocyte chaperones; however, these proteins are primarily trafficked during the later trophozoite and schizont stages (beyond 24 hours post-invasion). Since the extensive remodelling of the host cell begins immediately after invasion, a critical knowledge gap remained regarding how early exported proteins are folded and functionalized. Our recent characterization of PfRESA3 addresses this lacuna. As a dense granule protein exported immediately post-invasion, PfRESA3 hijacks the host chaperone HSPA8, providing the necessary folding machinery to facilitate the parasite's initial establishment and survival within the erythrocyte.

The identification of PfRESA3 as a functional co-chaperone offers a strategic advantage for antimalarial drug discovery by targeting the parasite's proteostasis network. Because PfRESA3 is exported immediately post invasion, inhibiting its function could stall the remodelling process. Since PfRESA3 stimulates human HSPA8 (Hsc70) without the classic HPD motif, the interaction interface is likely unique compared to human J-domain prot-

eins. Designing small molecules or peptide mimics to block this molecular interaction would prevent the parasite from hijacking host machinery, leaving its exported proteome unfolded and non-functional. Furthermore, molecules that will prevent PfRESA3 from anchoring to the host cytoskeleton may collapse or weaken the scaffold needed for establishing nutrient channels and cyto-adherent knobs. By preventing the formation of these knobs, the infected erythrocyte remains flexible, ensuring it is recognized and cleared by the spleen. This approach of targeting a parasite-specific recruiter of host chaperones would minimize the potential toxicity to human cells while effectively neutralizing the parasite's ability to survive and sequester within the microvasculature. Furthermore, if this hijacking mechanism is conserved across other human infecting species like P. vivax, targeting PfRESA3 like proteins could pave the way for broad spectrum antimalarial therapeutics.

Dr Reddy's contribution to this filed is reflected in his publication in FEBS Lett (2026), titled "Plasmodium falciparum ring-infected erythrocyte surface antigen 3 (PfRESA3) is a cytoskeleton-interacting protein and potential co-chaperone" https://doi.org/10.1002/1873-3468.70340Digital Object Identifier (DOI). This study provides important insights into malaria parasite biology and the molecular mechanisms underlying host–parasite interactions.

EMERGING INSIGHT

How Antennas Are Powering the Future of Connected Vehicles

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| Scientific Profile |
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AREAS OF EXPERTISE
5G • Biosensors • IoT • RF & Microwave • Wearable Electronics

The notion of vehicles talking to each other sounded futuristic a few years ago. Connected vehicles are already a part of everyday life today. Cars can communicate other nearby cars when they are braking hard, link to traffic lights to reduce congestion, connect to the cloud for navigation updates and even help autonomous driving systems. All of these capabilities depend on one invisible, but critical technology: the antenna.

Cars today are more than machines. They are becoming intelligent communication platforms. Every second, enormous amounts of data are moving between vehicles, road infrastructure, satellites, sensors and mobile networks. To keep this ecosystem running smoothly, wireless connectivity must stay stable even in difficult conditions such as crowded highways, urban traffic, tunnels, rain, or high-speed mobility. While losing a connection in a smartphone can be an inconvenience, a loss of communication in a smart vehicle could directly impact safety.

The growing need for dependable vehicular communication is accelerating the pace of innovation in the field of antenna technology. In recent years, research on vehicular antennas has made significant advances from the conventional single-band designs. Antennas today must work across multiple frequency bands, support high data rates, provide stable connectivity in all directions, and fit inside increasingly compact vehicle structures. One of the biggest engineering challenges in modern transportation systems is to achieve all of this simultaneously.

We have been working on solving some of these challenges through advanced multi-band and multiple-input-multiple-output (MIMO) antenna systems for connected vehicles. In our work, a cubic metasurface-based RFID reader antenna was developed for providing 360-degree coverage in internet of vehicles applications. The antenna provided a high gain and a wide directional coverage, which enabled vehicle detection and communication reliably, at road intersections and smart traffic junctions. This design illustrates how three-dimensional antenna arrays can dramatically enhance communication reliability in vehicle-to-infrastructure networks, unlike conventional systems that often face limitations in coverage areas.

A significant trend in our work has been the development of massive MIMO systems for intelligent vehicular communication. Today's connected vehicles need to be able to communicate with a variety of devices and networks simultaneously, including GPS, Wi-Fi vehicle-to-everything (V2X) and cloud infrastructure. To address this growing complexity, we designed a sixty-port MIMO antenna system that operates in multiple bands and maintains low correlation and high diversity performance. The basic concept of these systems is simple: rather than depending on a single communication path, multiple antenna elements work together to increase signal strength, reduce interference, and ensure reliable connectivity even in rapidly changing environments.

At the same time, the physical appearance and the integration of MIMO antennas in vehicles become more and more important. Transparent and embedded structures that are integrated into the vehicle surfaces such as windshields or panoramic glass roofs

are increasingly replacing the classic protruding antennas. We explored this concept in our work on optically transparent automotive antennas, where we designed transparent multi-service antennas with conductive oxide materials on glass substrates. These antennas accommodate a wide range of communication standards, while preserving vehicle aesthetics and minimizing aerodynamic impact. Such designs are an important step towards future smart vehicles where the communication hardware is nearly invisible.

One of the biggest unresolved challenges is balancing compact size with high performance. There are already many electronic systems built into vehicles include radar sensors, cameras, LiDAR units, GPS modules, infotainment systems and wireless communication devices. It is very difficult to place multiple antennas without creating any electromagnetic interference. With each additional communication band, antenna structures become more congested and intricate. A second critical problem lies with mutual coupling in massive MIMO systems. Mutual interference arises when multiple antenna elements are positioned in close proximity, resulting in reduced efficiency and weakened signal quality. Although techniques such as metasurfaces, defected ground structures, orthogonal placement, and polarization diversity can mitigate coupling, achieving robust isolation within compact vehicular platforms remains a significant challenge. Ensuring reliability in real-world environments is also a critical concern. While antennas may exhibit optimal performance in laboratory settings, actual vehicular conditions are considerably more variable. High-speed movement, reflections from surrounding structures, fluctuating weather, dense traffic, and changes in vehicle orientation all affect wireless performance. Overcoming the challenge of maintaining stable communication links under these dynamic conditions constitutes a key technol-

Figure: This illustration highlights the evolving role of advanced antenna technologies in enabling seamless V2X communication for future smart transportation systems. It showcases transparent antennas, MIMO architectures, and intelligent wireless connectivity that are shaping safer, faster, and more connected mobility networks.

ogical gap in connected transportation systems.

However, there are several important unanswered questions about future integration. How to satisfy the need for enormous bandwidths of autonomous vehicles without increasing the power consumption of antennas? How can vehicles seamlessly switch between 5G, Wi-Fi, satellite and roadside communication systems? Is the efficiency of transparent antennas comparable to conventional metallic structures? And perhaps most importantly, how can all these technologies be kept affordable enough for widespread deployment in everyday vehicles, and not just in premium models?

The emergence of 5G and the initial evolution of 6G technologies are predicted to make this field even more transformative. Future communication networks will demand ultra-low latency, massive device connectivity and real time data exchange between millions of moving systems. Antennas will no longer be simply communication devices, they will become intelligent sensing and networking platforms embedded in the whole transportation ecosystem. Massive MIMO systems have a great potential to enhance channel capacity, reliability and data throughput by exploiting multiple parallel communication paths. This translates into faster communications, quicker safety response times and more robust autonomous driving capabilities for connected vehicles. However, the scalability of MIMO systems with small, energy-efficient and low-cost antennas is still an open research problem.

Artificial intelligence could also transform antenna technology in the near future. In future smart antennas may be able to dynamically change their radiation patterns, frequencies and polarization states according to traffic density, environmental conditions or communication requirements. Antennas can evolve from static hardware systems into adaptive and self-optimizing components of intelligent transportation systems. Another exciting frontier is the convergence of communication and sensing technologies. In the future, vehicle antennas may incorporate a single integrated platform that simultaneously supports radar sensing, wireless communications, environmental monitoring and positioning systems. This can drastically cut down hardware complexity and enhance vehicle intelligence

The exciting part of this field is that the story is yet to be written. Every step forward in antenna design moves connected transportation closer to safer roads, smarter cities, less congestion and more efficient mobility systems. Passengers may not see the antennas tucked away in the cars of tomorrow, but they will silently power the intelligent transportation networks that will define the future of mobility.

Dr Kumar's contribution to this filed is reflected in his recent publication in Sci Rep (2026), titled "Sixty-port dual-band octa-pentacle MIMO antenna for vehicular communications" https://doi.org/10.1038/s41598-026-47590-8 . This work highlights advanced developments in high-capacity MIMO antenna systems designed for next-generation vehicular communication technologies.

Patent Reference: Bajaj, C., Upadhyay, D. K., Kumar, S., & Kanaujia, B. K. (2024). A 3-D RFID reader antenna system with cubic metasurface backing. Indian Patent No.: 557217.

EMERGING INSIGHT

The Quest for the Ultimate Green Photocatalyst through Nanomaterial Engineering

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AREAS OF EXPERTISE

Solar Photocatalysis • Photoelectrocatalysis • Green Hydrogen•Metal Oxides•2D Materials.

In the race to solve the crises of global energy demand and environmental pollution, the light from our own sun can be far more effective than we often realize. Imagine a material that we could put in a container of polluted water, catch a few rays of sunlight, and instantly begin breaking down toxic chemicals into harmless substances. Likewise, a material that uses sunlight to split water molecules into clean hydrogen fuel. This isn't science fiction, it's the power of photocatalysis. Photocatalysis is about using light to start a chemical reaction. Among the many materials studied for this task, Zinc Oxide (ZnO) stands out as a champion. It is abundant, cheap, and safe. However, in its natural state, ZnO has a bit of a native issues such as it only responds to high energy ultraviolet (UV) light, which makes up less than 5% of the sunlight reaching our planet (Earth). To make it a real world hero, we have to upgrade it further. To push ZnO to its full potential, our research focuses on two main modifications: doping and heterostructure design.

Think of doping like adding a pinch of seasoning to a dish to change its character. By introducing small amounts of copper atoms into the crystal lattice of ZnO, we fundamentally change how it interacts with light. Copper narrows the bandgap, the energy required for electrons to become active in the reaction. This also allows the material to and absorb visible light (45% of the solar spectrum), not just UV (5% of the solar spectrum). But absorbing light is only half the battle. For the chemistry to happen, these electrons and holes need to stay apart and move to the surface of the material. In pure ZnO, they tend to find each other and recombine almost instantly, wasting the energy as heat. To solve this, we design heterostructures. By pairing ZnO with another material (like another semiconductor). One material pulls the electrons, the other pulls the holes. This spatial separation ensures that the charges live long enough to reach the surface and perform the reaction of breaking down pollutants.

Our findings have been eye-opening. When we compare standard ZnO to our copper-doped heterostructures, the efficiency gains are impressive. By precisely controlling the amount of copper, we have observed a significant increase in the degradation rates of organic dyes in water. The results reveal a special role of charge separation induced by the copper doping in ZnO structure. On the other hand, it also turns out that more is not always better. Excess amount of copper can actually act as a trap that stops the electrons from moving. However, when balanced correctly within a heterostructure, the synergy is undeniable. We aren't just making the material more sensitive to light, we are making it more productive. We have seen charge carrier lifetimes extend significantly, which translates directly to a faster, more thorough catalytic process in water treatment tests.

Now the question arises: If the lab results are so promising, why don't we have these materials in every water treatment plant? But the transition from a small beaker in a lab to a real world application is troubled with challenges. Currently, the biggest limitation is stability and recovery. In a lab, we use pure, distilled water. In the real world dirty water contains salts, bacteria, and various minerals that can impact the catalyst surface, making it less effective over time. Furthermore, most high-performance photocataly-

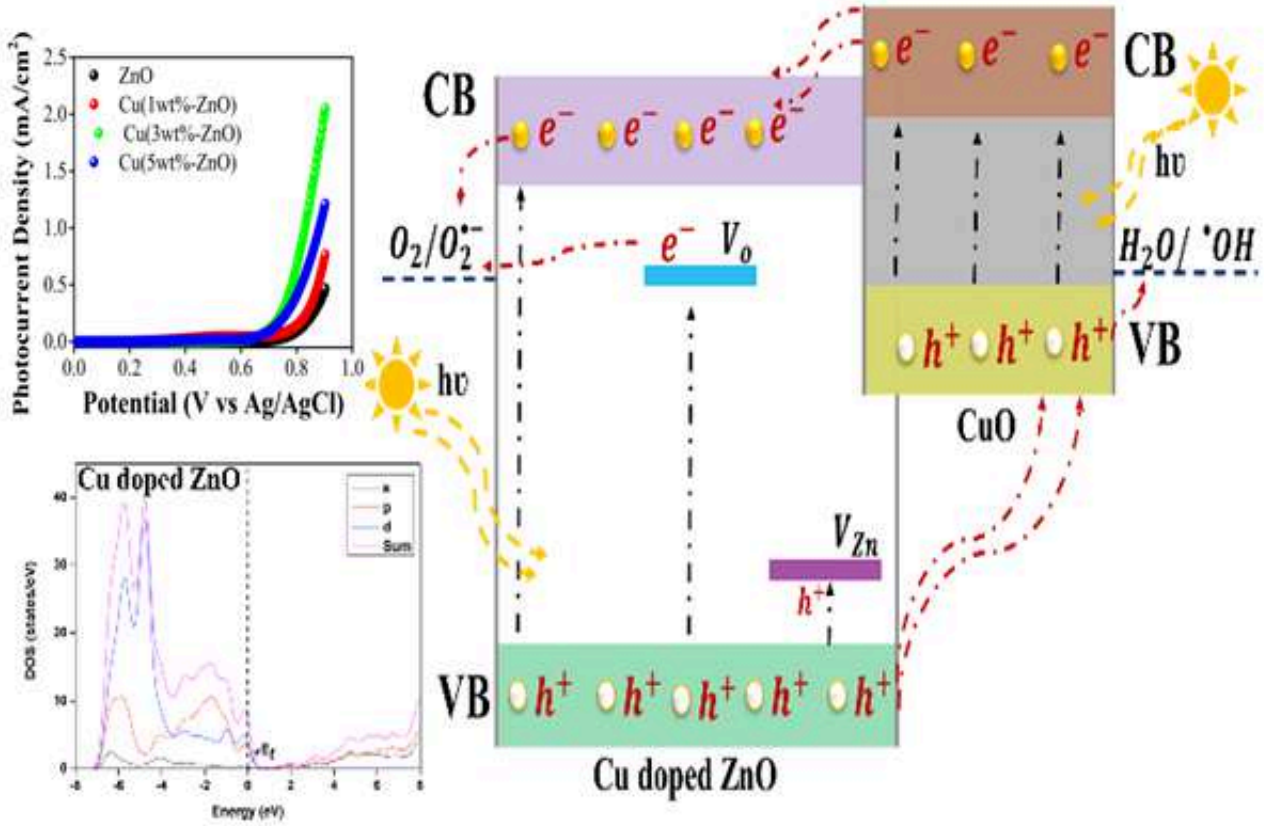
sts are synthesized as tiny nanoparticles. While they have a huge surface area for reactions, they are incredibly difficult to recover from the water once the job is done. There is also the issue of photocorrosion. Some of the best performing materials actually begin to dissolve or degrade under prolonged exposure to light and water. Creating a material that is both highly reactive and incredibly rough.

Despite our progress, several fundamental questions still remains:

- We know the general process, but mapping the exact active sites on a complex heterostructure surface in real time is still difficult.
- Can we design a material that is equally effective against pesticides, plastics, and pathogens?
- Plants perform photosynthesis with near-perfect efficiency using very common elements. We are still struggling to match the elegant charge-transfer mechanisms found in a simple leaf.

The Road Ahead: Looking forward, the future of photocatalysis lies in scalability and integration. We are trying to upgrade from dispersed powders in dye solution to immobilized systems growing our copper-doped heterostructures onto large, flexible substrates. This allows water to flow through the system while the catalyst stays fixed, ready to be used again and again. We are also exploring green approach: using bio-waste materials to create these catalysts. If we can harvest zinc from green waste or copper from bio-source to build our energy-saving materials, the environmental payoff is doubled. We are moving closer to a world where polluted water purification is possible allowing remote communities to clean their water using nothing but a plastic bottle coated with a specialized film and the midday sun. Thus our aim is to build the tools for a cleaner, self-sustaining planet.

Dr. Das's contribution to this field is reflected in his recent publication in The Journal of Physical Chemistry Letters (2026), titled "Optimal Design of Copper-Doped ZnO Heterostructures for Photocatalytic and Photoelectrochemical Performance: A Combined Experimental and DFT Study" (DOI: 10.1021/acs.jpclett.6c00528). This work provides valuable insights into the design of advanced photocatalytic nanomaterials for efficient energy and environmental applications.



EMERGING INSIGHT

BIOBASED COMPOSITE PACKAGING: REVOLUTIONIZING SHELF-LIFE EXTENSION AND POST-HARVEST MANAGEMENT

Dr. Nishant Kumar
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AREAS OF EXPERTISE
Functional Food • Food Packaging • Nano formulations • Value Addition • Edible coating/Films

The maintenance postharvest shelf life of fruits and vegetables throughout the supply chain is the biggest challenges around the world. Postharvest losses are accounted around 30-40% due to various factors including physical, mechanical, chemical and biologicals. The postharvest losses may be depending on the type and nature of the commodity; it occurs higher in highly perishable fruits and vegetables. The postharvest not only affected the economy but also contributed to the degradation of environmental due to emission of green house gases such as CO2 and other. According to the Food and Agriculture Organization (FAO) of the United Nation, the food losses including postharvest losses and wastage are mainly responsible for the emission of 4.4 giga tonnes of greenhouse gases in the environment and direly affected the food safety, food security, economic value and environmental conditions. The major cause of postharvest losses includes the poor temperatures, oxidation/respiration rate, mechanical damage, microbial contamination, poor packaging and higher water losses, which factors reduced the shelf life of produces. To overcome the postharvest losses, various technology such as cold chain transport and packaging can be used. However, the packaging is one of the important factors that protect the produced from external and internal factors. Various types of packaging i.e. plastics, synthetic polymers have been used to maintained quality characteristics and shelf life of produces. Despite, the advantages of the plastic and synthetic based packaging, the encounters the environmental degradation due to their synthetic nature, non-biodegradability, non-toxicity and lack of biocompatibility. However, edible coating made from the natural derived biopolymers such as polysaccharides, protein and lipid/wax are good alternatives to plastic and synthetic packaging for the postharvest shelf-life extension of fresh produce by retarded the weight loss, enzymatic browning, oxidation and quality loss throughout the supply chain and storage period. These biopolymers derived from natural resources such as plants and animals, are biodegradable, non-toxic, and safe for consumption. The edible packaging can be applied on the produces in form of liquid (coating) and solid wrapping materials (films) by various deposition methods. The various type of enhancer such as plasticizers, crosslinkers, emulsifiers, active agents such as plant extract and essential oil encapsulated in the edible coating and films to improve their mechanical, flexibility, thermal, functional and antimicrobial properties, which helps to maintain the integrity of the coating and film for a longer period on the produces. Howbeit, the several advantages of alone polysaccharide, protein and wax based coating, they are poor in water barrier, gas barrier, thermal stability and brittle in structure, resulted off flavour of produce and less effective in preservation.

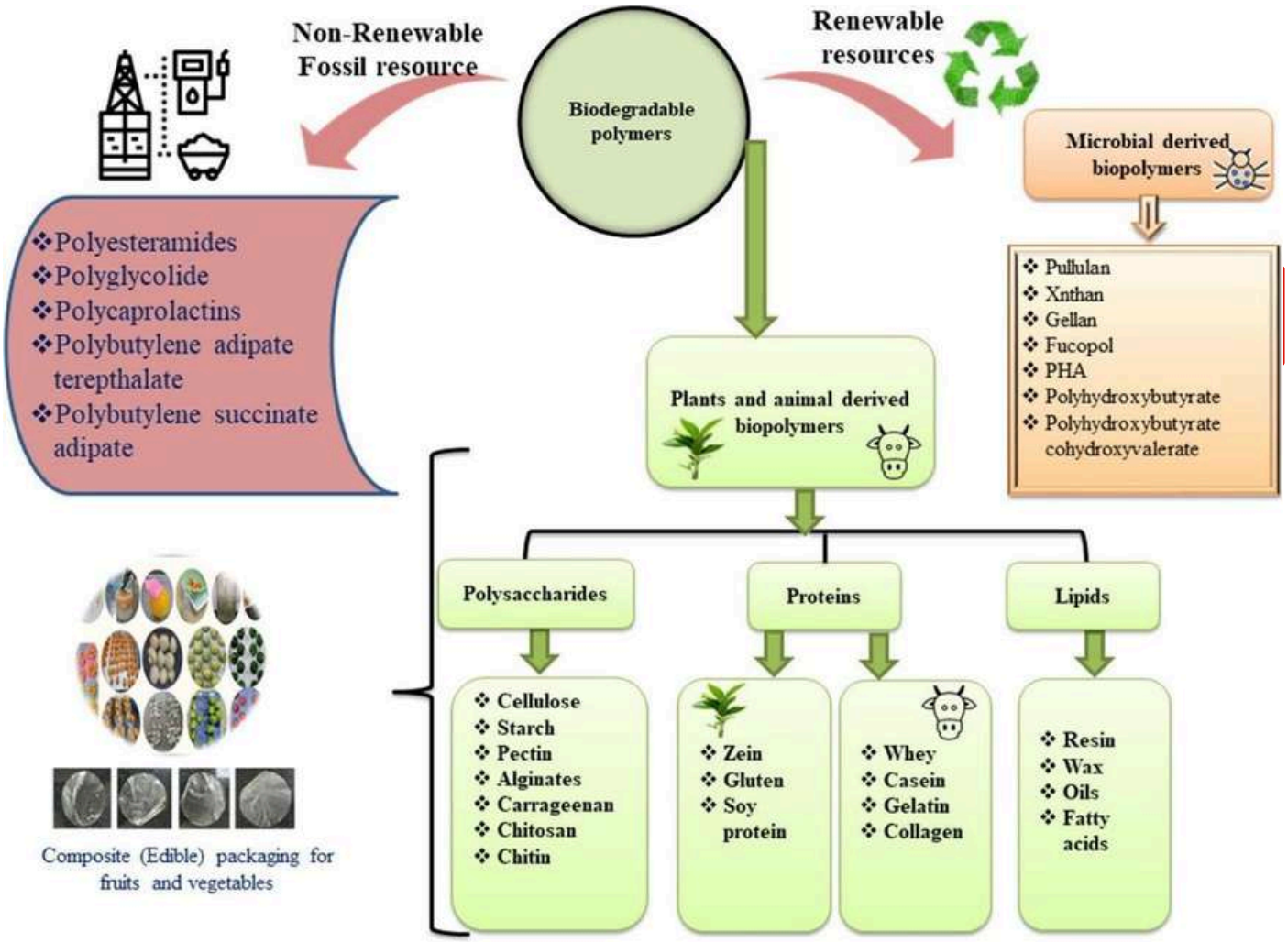
To thwart alone biopolymer-based coating and films issues, the composite of these biopolymers is possessing excellent functional, mec-

hanical, thermal, structural antimicrobial and UV/water & gas barrier properties due to molecular interaction and microphase separation between the biopolymer matrixes, which resulted in increasing surface area of matrix and showed higher functionality. The biopolymer based composite packaging (coating and films) can be developed in binary or ternary complex including polysaccharide - polysaccharide, polysaccharide - protein, protein - protein, polysaccharide-wax, protein-wax and combination of all these matrixes to achieving excellent protection efficiency of packaging from microbial spoilage, water loss and oxidation.

Different types of renewable and non-renewable biopolymers found in nature and their applications in the formation of composite packaging (coating/films) and deposition methods of composite coating on fruits & vegetables and applications of composite films as a wrapping material.

The application of composite coating and films significantly prolonging the shelf life of fruits and vegetables due to retarded the weight loss, microbial loads, TSS, acidity, TSS: TA ratio, oxidation, respiration, ethylene production, enzymatic browning with maintained color attributes, and consumer acceptability in comparison with alone biopolymer-based coating. This may be due to higher water and gas barrier properties (hydrophobic nature) of the composite packaging achieved due to molecular interaction between matrix and encapsulation of active and other texture enhancer such as plasticizers, active agents and nanomaterial etc. In addition, the agro waste can be also utilized to extract and isolates biopolymers for development of composite packaging for postharvest management.

The biopolymer based composite packaging is aligned with the sustainable development goal (2030) such as 2, 3, 12 and 13, which are stands for good health and wellbeing



economic growth, responsible consumption and production and climate action, respectively and helps in enhancing bio-circular economy due to valorization of agro waste to extraction of starch, protein and other valuable compounds for composite packaging application.

The composite packaging challenges such as interfacial tension, mechanical integrity, adhesion, solubility, durability, application uniformity, anaerobic respiration in fruits and vegetables, cracking/flaking, sensory impacts, allergenicity, cost of matrix, consumer acceptability, life cycle complexity and regulatory aspects limits their applications. The further study should be required to address the challenges of composite packaging formation and applications. The high-pressure methods such as ultrasonication, microfludization and ultrasound could be used to improving the structure and integrity of the composite formulations.

Dr. Nishant Kumar's contributions to this field are reflected in his publications in the Journal of Food Measurement and Characterization (https://doi.org/10.1007/s11694-025-03887-2), Applied Food Research (https://doi.org/10.1016/j.afres.2025.101211), the International Journal of Postharvest Technology and Innovation (https://doi.org/10.1504/IJPTI.2024.144956), and in a book chapter published by Springer (https://doi.org/10.1007/978-3-032-13199-7_5). His research focuses on food processing, quality assessment, and innovative postharvest technologies to improve food preservation, safety, and nutritional quality.

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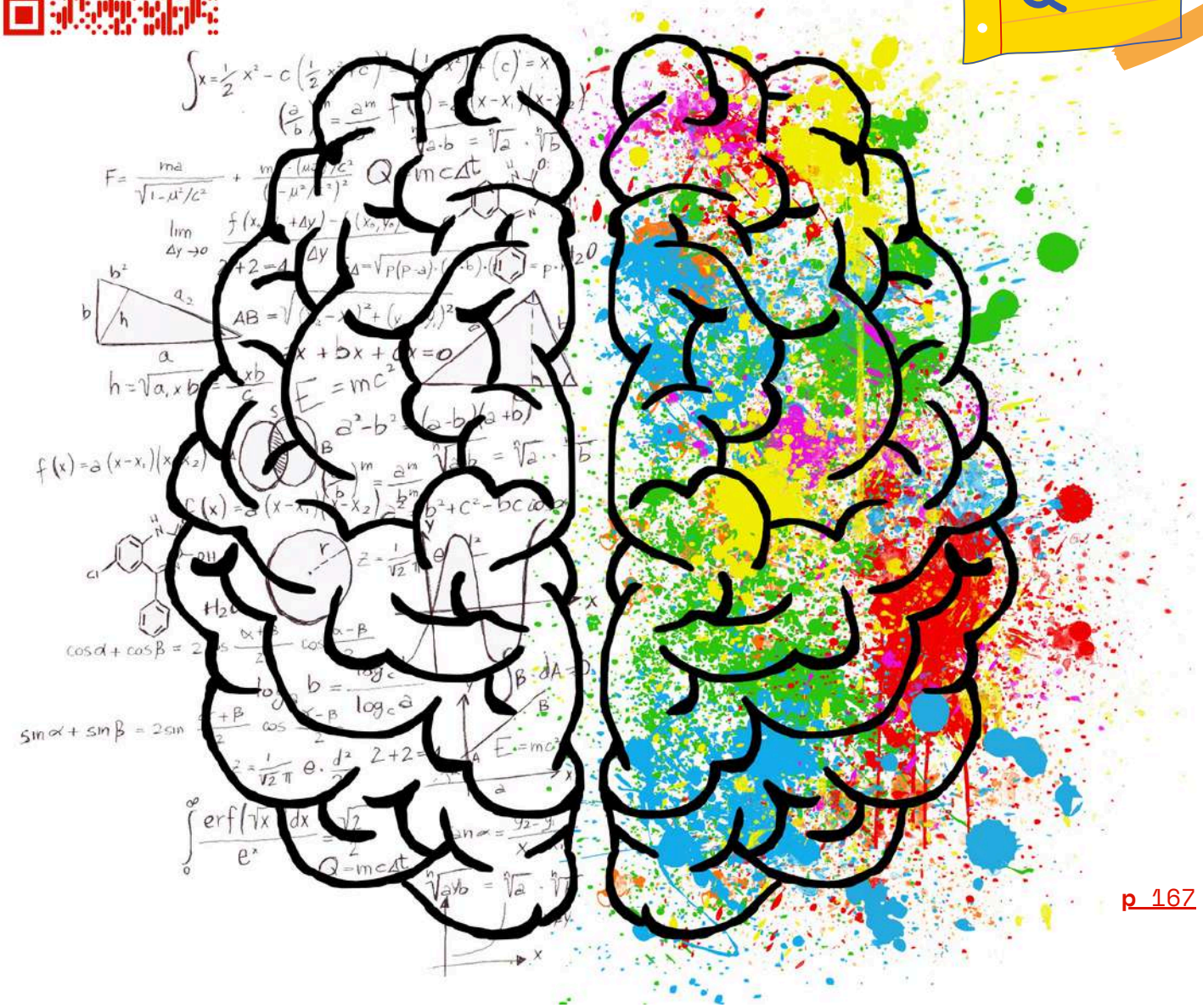
RESEARCHERS LIFELINE RESEARCH HEALTH



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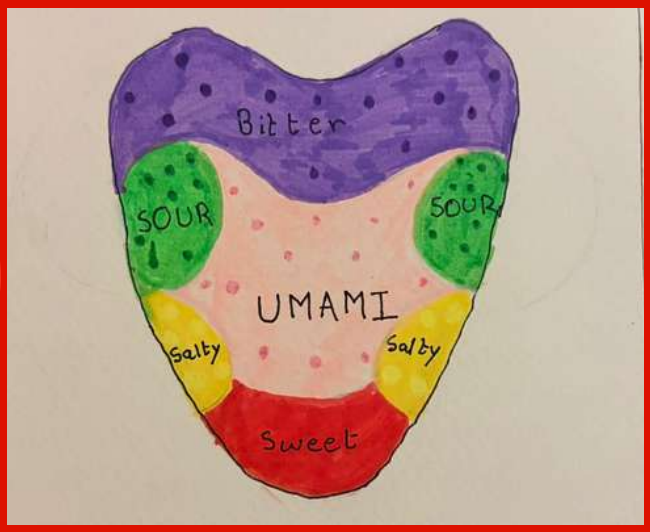
back to school

CURIOUS KID'S



NAME: **Chitrakshi Hota**

Grade: **4**

SCHOOL: **VIBGYIOR High International School**

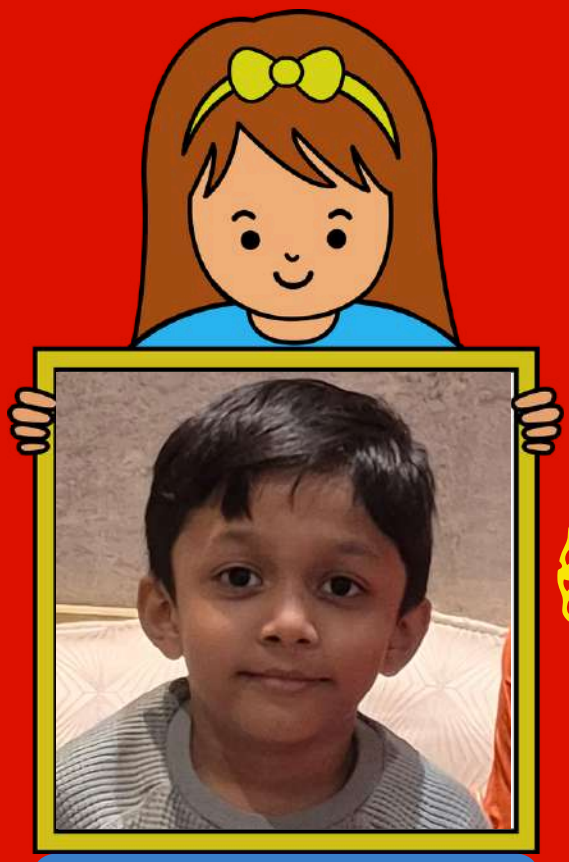
FOCUS:

How Does My Tongue Know What I'm Eating?

Have you ever wondered how your tongue can tell the difference between ice cream, lemon, chips, and vegetables? My painting explores the five basic tastes sweet, salty, sour, bitter, and umami. Tiny taste buds on our tongue act like little scientists, detecting these flavors and sending messages to the brain. Together, they help us enjoy food, stay safe from harmful substances, and discover the amazing science hidden in every bite!

🎨✨ Give your child a chance to shine! Submit their artwork for an opportunity to be featured in Scientific Kids. Send an image along with a brief explanation or inquiry to hello@rfcsr.org

back to school



CURIOUS KID'S

NAME: **Parth Shreyas**

Grade: 1

SCHOOL: **DAV UNIT VII Kindergarten Rakefet, Rehovot, Israel**

FOCUS:

How Fast Does Sunlight Travel?

Have you ever wondered how sunlight reaches us from so far away? My drawing shows the Sun shining light toward Earth. Light travels incredibly fast about 300,000 kilometers every second! Even at this amazing speed, sunlight takes about 8 minutes and 20 seconds to travel the 150 million kilometers between the Sun and Earth. This means when we look at the Sun, we are actually seeing it as it was more than 8 minutes ago. My painting reminds us that light connects distance, time, and life on Earth in a fascinating way.

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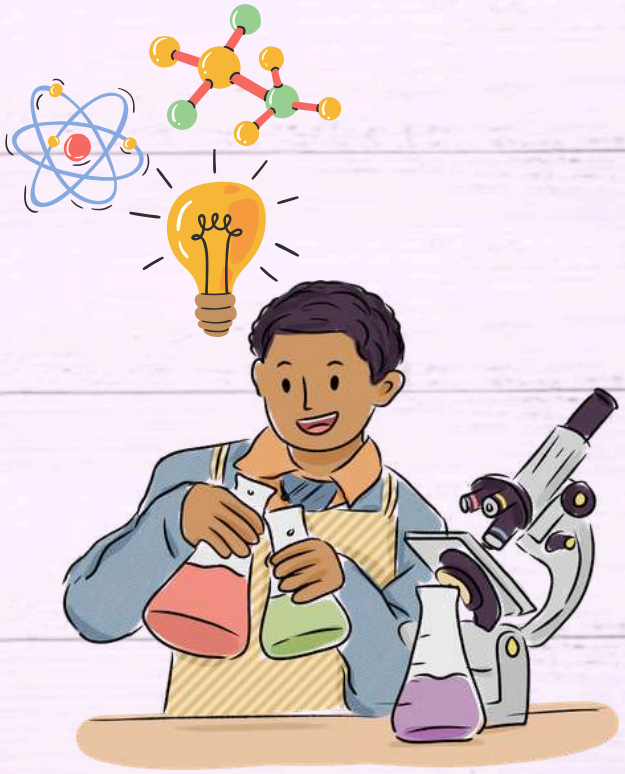

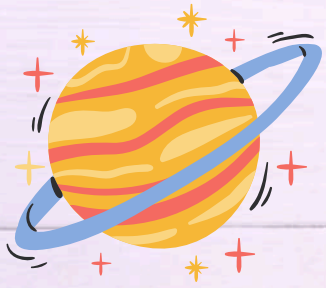

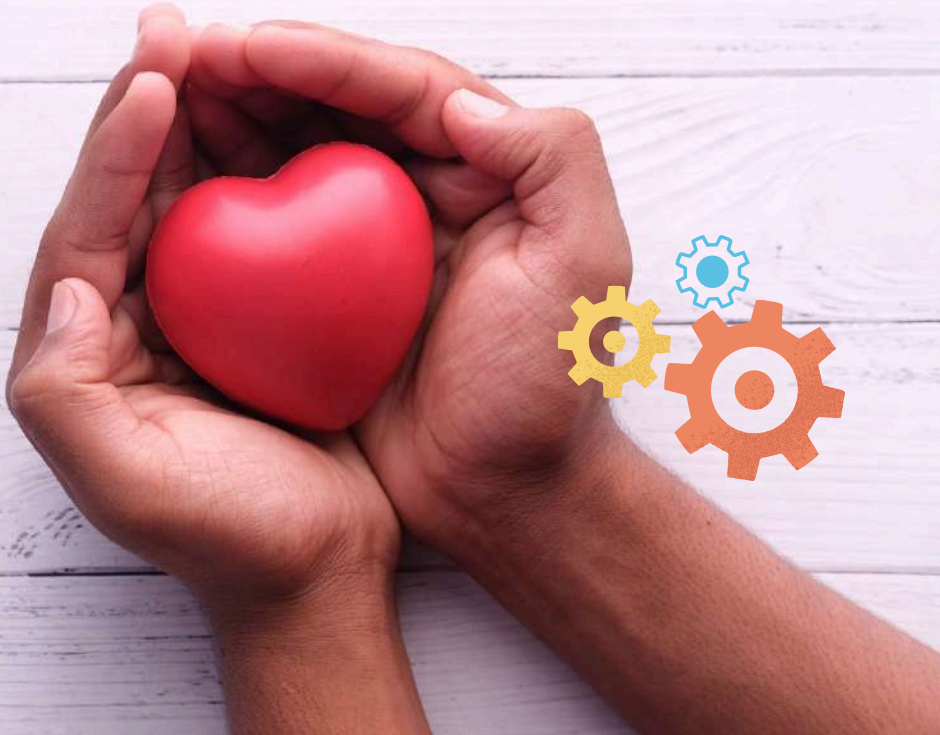

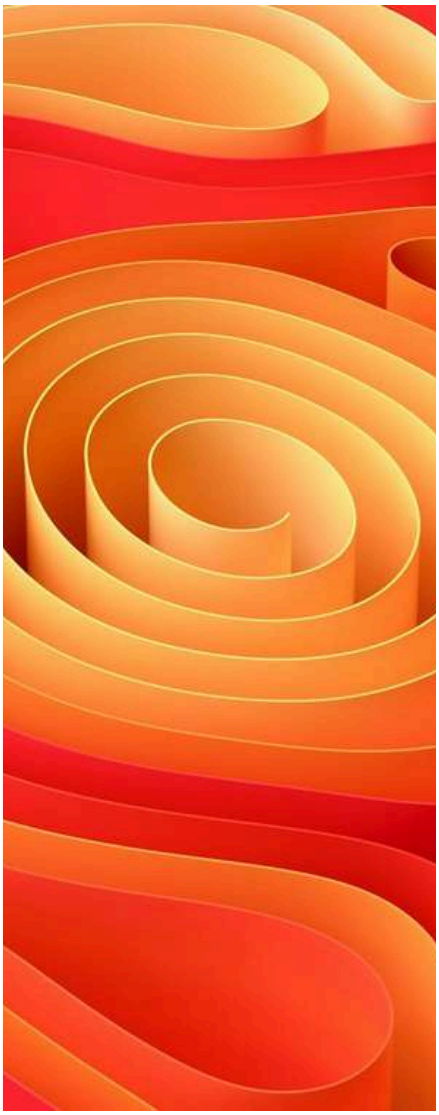

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