SCIENCE FACTORS.

INSIGHT, DISCOVERY, LEARNING, INNOVATION, AND IMPACT

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

Earth's Secret Fuel

The future lies beneath

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Listening to the Gut: The Hidden Clues of Parkinson's Disease | p15

A New Weapon Against Superbugs | p17

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."

Scientific Research Empowers Social Progress !

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from the LETTER EDITOR

Dr. Animesha Rath
The Editor-in-Chief

Dear Readers,

Sometimes, the most important things are not easy to see.

Deep beneath our feet, the Earth holds a vast source of heat that may help power our future. Inside our cells, tiny structures quietly control health and disease. Viruses interact with their hosts in ways we are still trying to understand. And in laboratories around the world, scientists continue to find new possibilities in molecules, materials, medicines, and technologies.

This July issue of Science Factors is about looking deeper. Our cover story takes us beneath the Earth's surface to explore the hidden promise of geothermal energy. But the journey does not stop there. Across this issue, we look inside cells, explore new ways to fight disease, understand how vaccines and biological systems work, and see how simple scientific ideas can lead to meaningful solutions. The issue also shows that scientific progress is not only about discovery; it is about turning knowledge into better healthcare, useful technology, and real-world change. These themes can be seen across the magazine's research, Expert Opinion, public-health, and Science Tomorrow content.

We also celebrate the people behind science, the researchers who ask difficult questions, the innovators who turn ideas into action, and those whose work continues to inspire the next generation.

What connects all these stories is curiosity.

Science asks us to look beyond what is obvious. To look beneath the ground. Inside a cell. Between two interacting organisms. Within a molecule. And sometimes, within a problem, we thought we already understood.

Perhaps the future is not always far away.

Sometimes, we simply need to look deeper to find it.

Welcome to the July 2026 issue of *Science Factors*.

Happy reading!

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SCIENTIFIC RESEARCH EMPOWERS SOCIAL PROGRESS !

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Fuel discovery, inspire the future.

FEATURED RESEARCH

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

| By Dr. Poulami Chakraborty

EARTH'S SECRET FUEL

FEATURED

Once upon a time, in the snowy province of Ontario, Canada, a young geologist named Claire worked deep underground in one of the deepest mines in North America. Every day, she traveled nearly three kilometers below the Earth's surface, descending into a world of darkness, ancient rocks, and silent tunnels. Claire wasn't searching for gold, silver, or diamonds. Instead, she was part of a team studying mysterious underground waters trapped inside rocks for millions of years. Most people thought the mine held only minerals, but Claire often wondered whether the Earth still had secrets waiting to be discovered. One winter morning, while examining water flowing from a borehole drilled into ancient rock, she noticed bubbles rising steadily from the water. Curious, she collected samples and sent them to the laboratory. When the results arrived, everyone was surprised. The bubbles were rich in hydrogen a gas known as a clean fuel. At first, the finding seemed strange, but nobody realized they had stumbled upon a discovery that could change how people think about energy.

Over the following months, Claire and her colleagues began investigating the mystery. They tested more boreholes and found hydrogen almost everywhere they looked. Some gas streams contained large amounts of hydrogen, and many continued flowing month after month without slowing down. The team wondered where it was coming from. Deep inside the Earth, water was reacting naturally with iron-rich rocks. These slow chemical reactions, happening silently for millions and even billions of years, were splitting water molecules and creating hydrogen gas. The ancient rocks were acting like giant natural factories. Claire imagined the Earth as a patient craftsman, producing fuel long before humans built power plants or invented engines. What amazed her most was that nobody had designed this system. Nature had been doing it on its own all along. The deeper the team looked, the more hydrogen they found hidden inside fractures and tiny spaces within the rocks, as though the Earth had been

| By Dr. Poulami Chakraborty

storing away a secret energy reserve.

As the years passed, the researchers continued monitoring the hydrogen. To their surprise, the gas kept flowing. One borehole released hydrogen steadily for more than a decade. This showed that the underground supply was not disappearing quickly. Claire's team calculated how much energy this hidden hydrogen could provide. The numbers were astonishing. A single mining site could release enough hydrogen each year to generate millions of kilowatt-hours of energy. Suddenly, the discovery was no longer just an interesting scientific observation. It became a practical question: Could communities use this natural hydrogen as a clean energy source? Claire imagined remote towns where fuel had to be transported over long distances.

What if the energy people needed was already beneath their feet? Instead of importing fuel from far away, perhaps they could tap into local underground hydrogen reserves. The idea felt almost magical, yet the measurements showed it was real.

But the story did not end with energy. Deep underground, Claire discovered another mystery. Living in the darkness were tiny microorganisms that survived without sunlight. These microbes depended on hydrogen as their food source. While humans used electricity and gasoline to power their lives, these microscopic organisms relied on hydrogen created by the Earth itself. The discovery fascinated Claire. If life could survive deep underground using hydrogen, perhaps similar life could exist elsewhere in the universe. She thought about Mars and the icy moons orbiting distant planets. Could hidden hydrogen reservoirs beneath their surfaces support life too? The mine became more than a workplace. It became a window into some of humanity's biggest questions. How does life survive in extreme places? And are we alone in the universe?

Years later, Claire stood beside the same borehole where the story had begun. The hydrogen was still flowing. Looking at the bubbles rising through the water, she smiled. For generations, people had searched the Earth for coal, oil, and natural gas. Yet beneath their feet was another resource, one they had largely overlooked. The Earth had quietly been producing clean fuel for ages, hidden within ancient rocks. Claire realized that the greatest discoveries are not always about finding something entirely new. Sometimes they are about seeing something familiar in a different way. The hydrogen had always been there, waiting patiently in the darkness. Humanity simply had not noticed it. Now, thanks to years of careful research, the world was beginning to understand that the Earth might hold a remarkable gift a natural source of energy that could help power the future while also teaching us about the hidden life of our own planet and perhaps even worlds beyond it.

Yet Claire knew that discovery was only the beginning. Scientists would still need to learn how much hydrogen existed, how quickly it formed, and how it could be collected safely without harming underground ecosystems. If those questions could be answered, the quiet bubbles rising from ancient rocks might one day become part of a cleaner and more sustainable energy future.

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| By Dr. Preeti Sharma

LISTENING TO THE GUT: THE HIDDEN CLUES OF PARKINSON'S DISEASE

FEATURED

Once upon a time in the busy city of London, a retired schoolteacher named Margaret enjoyed a simple life. Every morning, she walked through the park, greeted her neighbors, and shared tea with friends. At sixty-two, she felt healthy, but she had noticed a few small changes. She was often constipated, her sense of smell was not as sharp as it once was, and she sometimes felt unusually tired. Nothing seemed serious enough to visit a doctor. After all, growing older came with its share of inconveniences. Yet deep inside her body, a quiet story was unfolding one that neither Margaret nor anyone around her could see. Hidden in her gut lived trillions of tiny microbes, and some scientists had begun to suspect that these microscopic residents might be whispering clues about her future long before any disease could be diagnosed.

Across the city, a group of researchers were trying to solve a mystery that had puzzled doctors for decades. Parkinson's disease, a condition that slowly affects movement and many other body functions, often begins years before the first visible symptoms appear. By the time a person develops a tremor or difficulty walking, much of the damage inside the brain has already occurred. The scientists wondered whether the answer to earlier detection might not be found in the brain at all, but in the gut. They collected samples from hundreds of people some with Parkinson's disease, some carrying a gene that increased their risk, and others who appeared completely healthy. When they examined the bacteria living in these samples, they discovered something remarkable. The gut communities of people at risk looked neither completely healthy nor completely diseased. Instead, they seemed to sit somewhere in between, as though they were standing on a bridge connecting health and illness.

Margaret would have been fascinated by what the researchers found. Certain bacteria that are normally considered helpful were becoming less common, while others linked to inflammation were quietly increasing. It

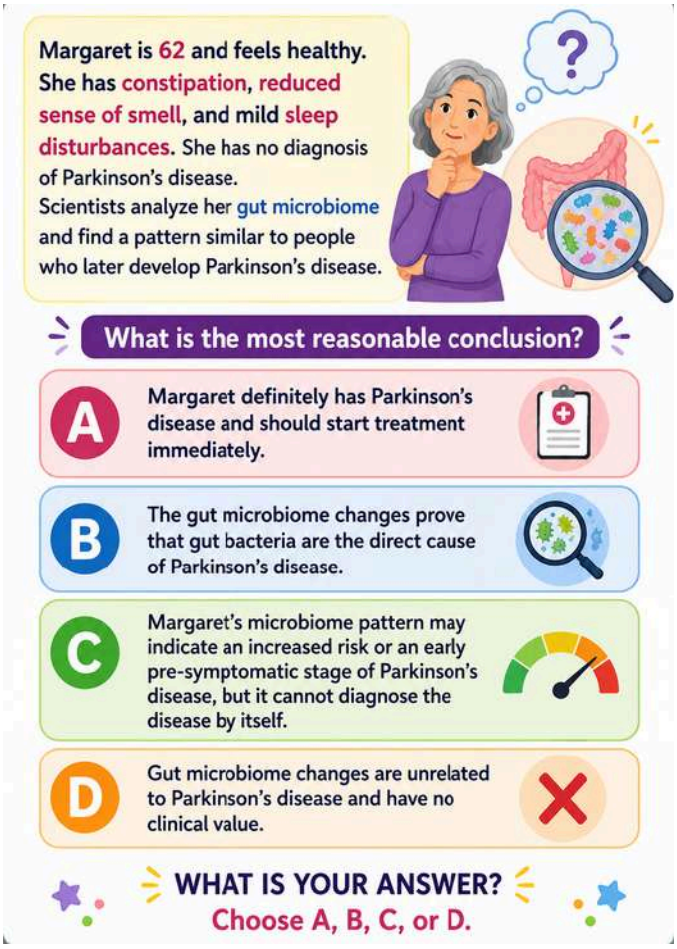
| By Dr. Preeti Sharma

was as if a healthy garden was slowly losing its strongest flowers while weeds began to spread. The surprising part was that these changes were not limited to people who already had Parkinson's disease. Some healthy individuals showed the same pattern, though to a lesser extent. Even more interesting, those people often had subtle signs that doctors now recognize as possible early warnings constipation, sleep disturbances, mild mood changes, or difficulties with smell. None of these symptoms alone could predict Parkinson's disease, but together they painted a picture. The gut microbiome seemed to be acting like an early messenger, sending signals years before the brain revealed obvious problems.

As the researchers continued their work, they noticed another pattern. People whose gut bacteria looked more "Parkinson-like" often had more severe symptoms if they already had the disease. They also found that these microbial changes appeared in people carrying a high-risk gene, even when they had never been diagnosed. It was as though the microbiome was keeping a record of where someone stood on a long journey toward illness. To make sense of this information, the scientists developed a simple score based on a small group of bacterial species. This score could distinguish individuals whose gut communities resembled those of Parkinson's patients from those whose microbiomes appeared healthier. The researchers did not claim that bacteria cause Parkinson's disease, but they believed these tiny organisms might serve as warning lights on a dashboard indicators that something important could be happening beneath the surface.

Years from now, Margaret imagined a future visit to her doctor. Instead of waiting for symptoms to appear, perhaps a simple stool sample could reveal hidden risks. A test based on gut microbes might help identify people moving toward disease long before serious damage occurs. Doctors could monitor them more closely, recommend lifestyle changes, or one day even offer treatments designed to restore a healthier microbial balance. The study did not provide all the answers, but it offered hope and a new way of thinking about disease. Sometimes the earliest signs of trouble are not found where we expect them. In the case of Parkinson's disease, they may be hidden among trillions of tiny organisms living quietly in our intestines, sending messages that science is only now beginning to understand. The greatest surprise of all may be that the road to understanding the brain begins in the gut.

Yet the promise of this research lies not in predicting an individual's future with certainty, but in recognising biological change earlier and more precisely. The microbiome may eventually become one layer of a broader risk assessment, interpreted alongside genetics, symptoms, environment, and clinical history. Such an approach could transform Parkinson's care from responding to established disease toward observing, understanding, and perhaps interrupting its earliest stages.



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| By Dr. Avijit Das

A NEW WEAPON AGAINST SUPERBUGS

FEATURED

Once upon a time, in the bustling Canadian city of Hamilton, a young scientist named Asha spent her days chasing a mystery that worried doctors across the world. Hospitals were fighting a growing army of superbugs bacteria that had learned how to survive many of the medicines designed to kill them. Every year, these microscopic enemies became stronger, while the discovery of new antibiotics slowed to a trickle. Some experts even feared that humanity was running out of options. To many researchers, it seemed that nature had already given up most of its secrets. After all, scientists had spent decades studying the bacteria living in soil. Surely, they thought, the easy discoveries had already been made.

But Asha was not convinced. She believed that nature often hides its greatest treasures in places people stop looking. One rainy afternoon, she and her colleagues returned to an old scientific favorite: a soil bacterium called Streptomyces rimosus. This microbe was already famous. More than seventy years earlier, it had helped scientists discover oxytetracycline, one of the world's important antibiotics. Because of that success, researchers assumed they knew almost everything about it. Yet Asha wondered whether the bacterium might still be hiding something valuable. Instead of focusing on the major chemicals it produced, she carefully searched through tiny molecules that previous scientists had ignored. It felt like exploring an old attic where generations had searched before. Most people expected dust and forgotten boxes. Asha hoped for treasure.

Weeks passed. Then something unusual appeared. Hidden among hundreds of known compounds was a strange molecule unlike anything the team had seen before. At first, nobody knew whether it was important. But as they purified and studied it, excitement began to spread through the laboratory. The molecule seemed completely new. The team named it manikomycin, inspired by the word manik, meaning a precious gem. The name felt perfe-

Reference: Kaur, M., Travin, D. Y., Berger, M. J. et al. A natural depsipeptide antibiotic binds the E-site of the bacterial ribosome. Nature (2026). https://doi.org/10.1038/s41586-026-10589-2

| By Dr. Avijit Das

ct. Like a gemstone buried deep underground, this discovery had been hidden in plain sight for decades. Yet finding a new molecule was only the beginning. The real question was whether it could help solve one of the biggest medical challenges of our time.

The answer came when the researchers tested manikomycin against dangerous superbugs. To their amazement, bacteria that could resist many existing antibiotics suddenly stopped growing. The results seemed almost too good to be true. Most antibiotics attack familiar targets, such as bacterial cell walls or membranes. But manikomycin appeared to be doing something entirely different. Determined to uncover its secret, Asha traveled to Hamburg, Germany, where powerful cryo-electron microscopes could reveal molecular structures in extraordinary detail. There, scientists captured images showing exactly what was happening inside bacterial cells. The pictures revealed a surprising scene. Manikomycin was not attacking the usual targets at all. Instead, it was slipping into the ribosome the tiny protein-making factory that every bacterium depends on for survival. Without proteins, bacteria cannot grow, repair damage, or reproduce.

As the team looked even closer, they discovered something remarkable. Inside the ribosome was a small region known as the E-site. For years, scientists had paid little attention to this area when searching for antibiotics. To understand its role, imagine a crowded train station. Passengers move from platform to platform before finally leaving through an exit gate. The E-site functions much like that exit. During protein production, molecular workers constantly move through the ribosome. Manikomycin quietly parked itself at this exit and blocked the way. Suddenly, everything stopped. The molecular workers could no longer move forward. The bacterial factory became jammed. Protein production ground to a halt. The superbugs had developed defenses against many drugs, but they had never faced an attack at this hidden location. For the first time, scientists had discovered a way to strike bacteria where they were least prepared.

Months later, Asha stood before an audience of scientists, doctors, and students. She explained that the most astonishing part of the discovery was not simply the new antibiotic itself. It was where it had been found. The breakthrough had emerged from a bacterium that researchers thought they understood completely. The treasure had been there all along, waiting for someone curious enough to look more carefully. Although manikomycin still requires years of testing before it could become a medicine, its discovery offers hope in the battle against antibiotic resistance. More importantly, it reminds us of a powerful lesson about science. The world still holds hidden wonders, even in familiar places. Sometimes the greatest breakthroughs are not found by searching somewhere new, but by looking at something old with fresh eyes. As Asha left the stage, she smiled. Nature had revealed another secret and perhaps many more were still waiting to be discovered.

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Kaur, M., Travin, D. Y., Berger, M. J., et al. (2026). A natural depsipeptide antibiotic binds the E-site of the bacterial ribosome. Nature. https://doi.org/10.1038/s41586-026-10589-2.

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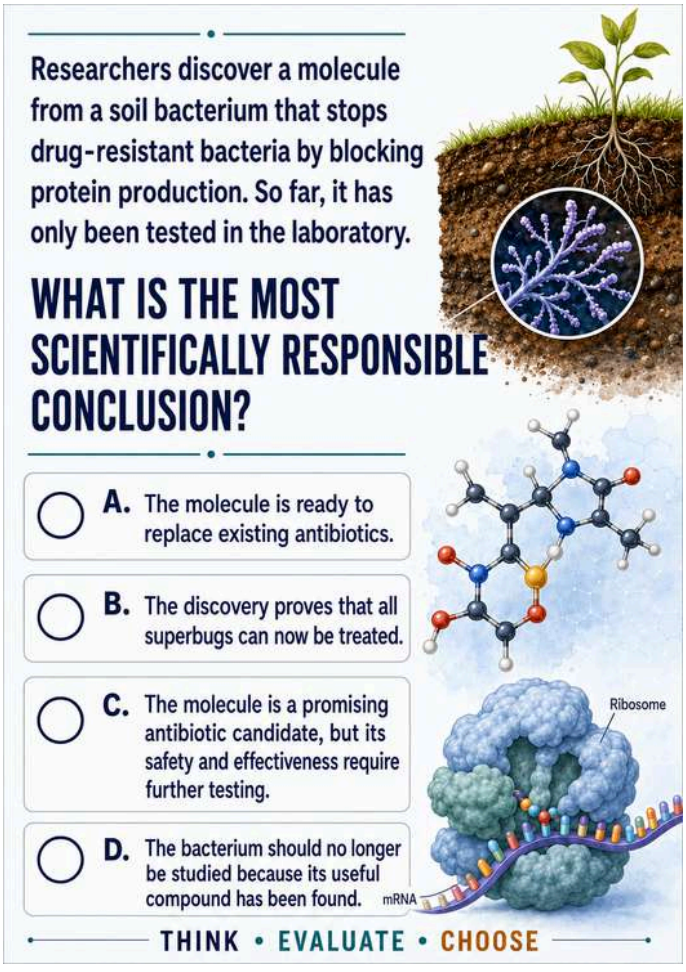

| EXPERT OPINION |

Simple Salt, Smart Reactivity: The Emerging Story of Sodium Thiosulfate

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

Areas of Expertise: Medicinal Chemistry | Heterocyclic Compound Synthesis | Antimalarial | Anticancer Drug Discovery

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Areas of Expertise: Synthetic Organic Chemistry | Heterocyclic Chemistry | Reaction Development | Catalysis

Sulfur is among the most intriguing elements in chemistry. It quietly resides in antibiotics, pharmaceuticals, agrochemicals, functional materials, and even in molecules essential for where sulfur functionalities often govern molecular properties and biological activity. Molecules such as proton-pump inhibitors (e.g., omeprazole), sulfur-containing antibiotics, sulfonamide drugs, anticancer agents, and various agrochemicals derive essential functionality from sulfur-based structural motifs. Beyond medicinal chemistry, sulfur-containing architectures have also found broad applications in materials science and advanced technologies, highlighting the remarkable versatility of sulfur in modern chemical science (Figure 1).

Yet sulfur chemistry has long carried a paradox. While sulfur-containing compounds possess enormous biological and synthetic importance, the chemistry used to construct them is frequently associated with unpleasant odor, challenging reagent handling, sensitivity issues, and limitations in selectivity.

Despite their importance, the synthesis of sulfur-containing architectures often remains a challenging task. Conventional sulfur-transfer methodologies frequently rely on reagents associated with unpleasant odor, oxidation sensitivity, difficult handling, and the requirement of expensive catalysts or harsh reaction conditions. Such limitations often increase synthetic complexity and reduce operational simplicity.

As chemistry increasingly moves toward sustainable and environmentally responsible practices, the development of greener sulfur-transfer methodologies has become particularly important. Green chemistry principles encourage replacing hazardous reagents with environmentally benign alternatives capable of minimizing waste generation while maintaining efficiency and practicality. Consequently, identifying cleaner and operationally simple sulfur-transfer systems has emerged as an important challenge in contemporary synthetic chemistry.

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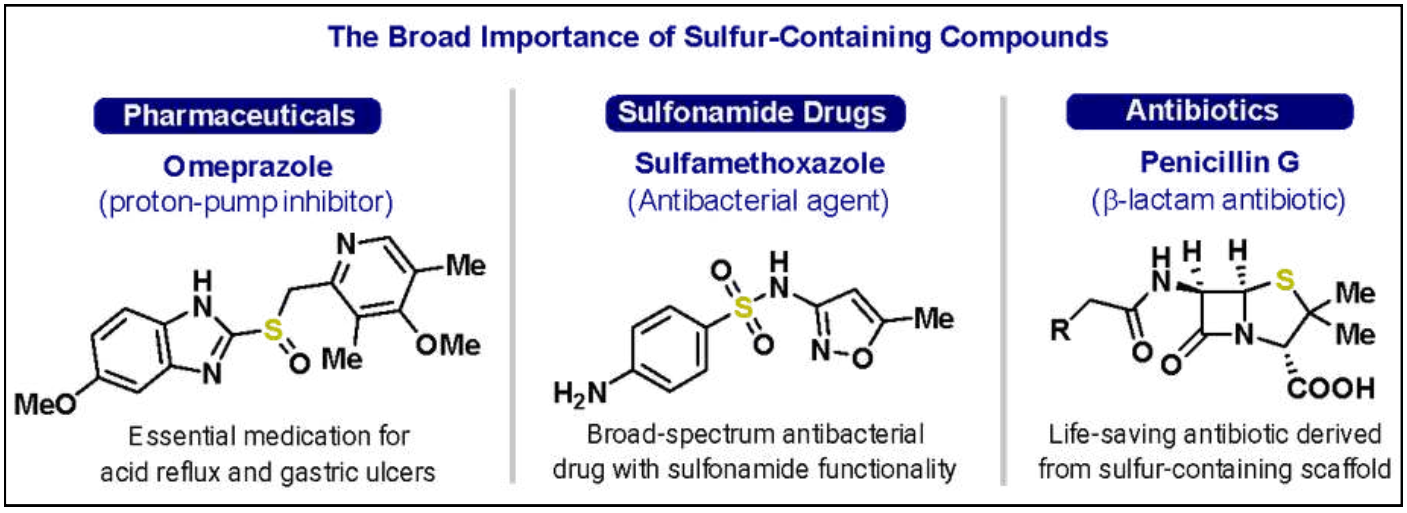


Figure 1. Broad importance of sulfur-containing compounds and challenges associated with traditional sulfur chemistry approaches.

on reagents associated with unpleasant odor, oxidation sensitivity, difficult handling, and the requirement of expensive catalysts or harsh reaction conditions. Such limitations often increase synthetic complexity and reduce operational simplicity.

As chemistry increasingly moves toward sustainable and environmentally responsible practices, the development of greener sulfur-transfer methodologies has become particularly important. Green chemistry principles encourage replacing hazardous reagents with environmentally benign alternatives capable of minimizing waste generation while maintaining efficiency and practicality. Consequently, identifying cleaner and operationally simple sulfur-transfer systems has emerged as an important challenge in contemporary synthetic chemistry.

As chemists, we often accept these practical limitations as unavoidable. But science progresses precisely when we challenge assumptions that have become too familiar. What if sulfur transfer could be achieved through a cleaner, simpler, and more sustainable pathway? What if a common, inexpensive salt could reveal entirely new behavior when placed in the right chemical environment?

Such questions formed the scientific curiosity behind our recent work on stereoselective thiosulfonylation of alkynes. The conceptual evolution of this strategy, moving from traditional sulfur sources toward a greener sulfur-transfer paradigm, is illustrated in Figure 2.

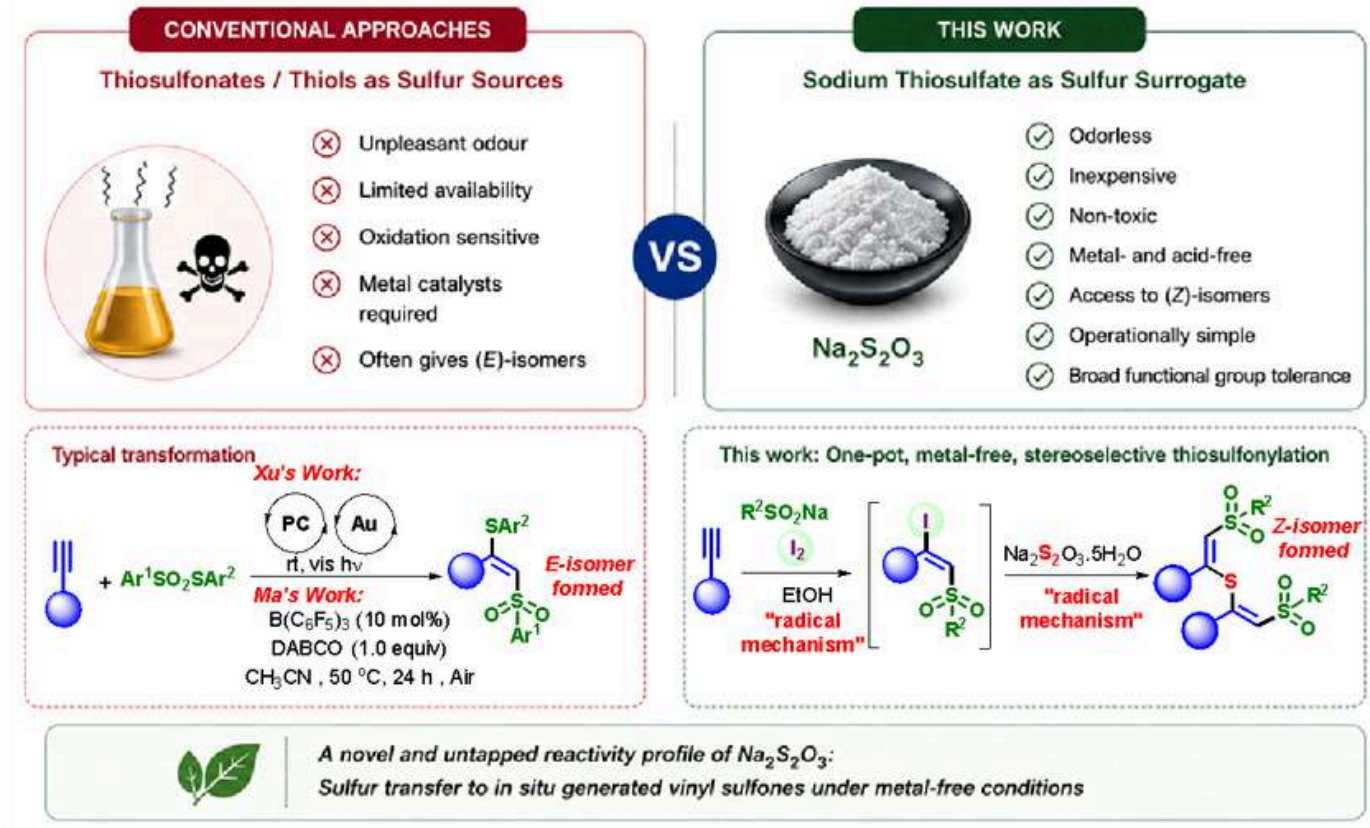
> *The most fascinating discoveries in chemistry often emerge not when we search for new molecules, but when we learn to ask new questions from familiar ones.*

Alkynes represent highly versatile building blocks, carbon-carbon triple bond stores substantial chemical potential and can be transformed into structurally sophisticated molecules. Among the valuable products accessible from alkynes are vinyl sulfones, compounds that have attracted significant interest because of their broad utility in medicinal chemistry, chemical biology, and materials science.

However, synthesizing these molecules with precise stereochemical control remains challenging. Nature often favors the thermodynamically stable pathway, whereas ch-

| EXPERT OPINION |

Figure 2



emists frequently seek access to less accessible and synthetically valuable alternatives. Controlling such outcomes requires not merely carrying out reactions, but understanding and directing molecular behavior itself.

Our study explored an unexpected role for sodium thiosulfate, a simple, inexpensive, non-toxic, and odorless reagent commonly used in laboratories for entirely different purposes. Instead of behaving according to conventional expectations, this reagent exhibited a previously unexplored reactivity profile and functioned as an efficient sulfur transfer agent under metal-free and acid-free conditions.

The excitement in research rarely comes from observing expected behavior. It comes when molecules behave in ways they were never anticipated to. A reaction flask may appear quiet externally, but at the molecular level an extraordinary sequence of events unfolds, bonds break, radicals emerge, intermediates form and disappear within fractions of a second, ultimately constructing new architectures with remarkable precision.

Perhaps this is one of the most beautiful aspects of chemistry: molecules possess their own language, and our responsibility as scientists is to learn how to listen.

Beyond the immediate synthetic achievement, the broader implications are equally important (Figure 3). Modern chemistry increasingly demands sustainability alongside efficiency. Green chemistry is no longer an optional direction; it has become a scientific necessity. Developing reactions that reduce hazardous reagents, avoid expensive catalysts, and improve operational simplicity contributes not only to laboratory convenience but also toward a more responsible future for chemical science.

For young researchers, sulfur chemistry presents a remarkably fertile landscape for exploration. The field sits at the intersection of synthetic chemistry, mechanistic understanding, medicinal science, materials development, and sustainable technologies. Questions remain everywhere: Can sulfur-centered radicals reveal entirely new reactivity? Can we design smarter sulfur transfer systems? Can sustainable sulfur chemistry transform mole-

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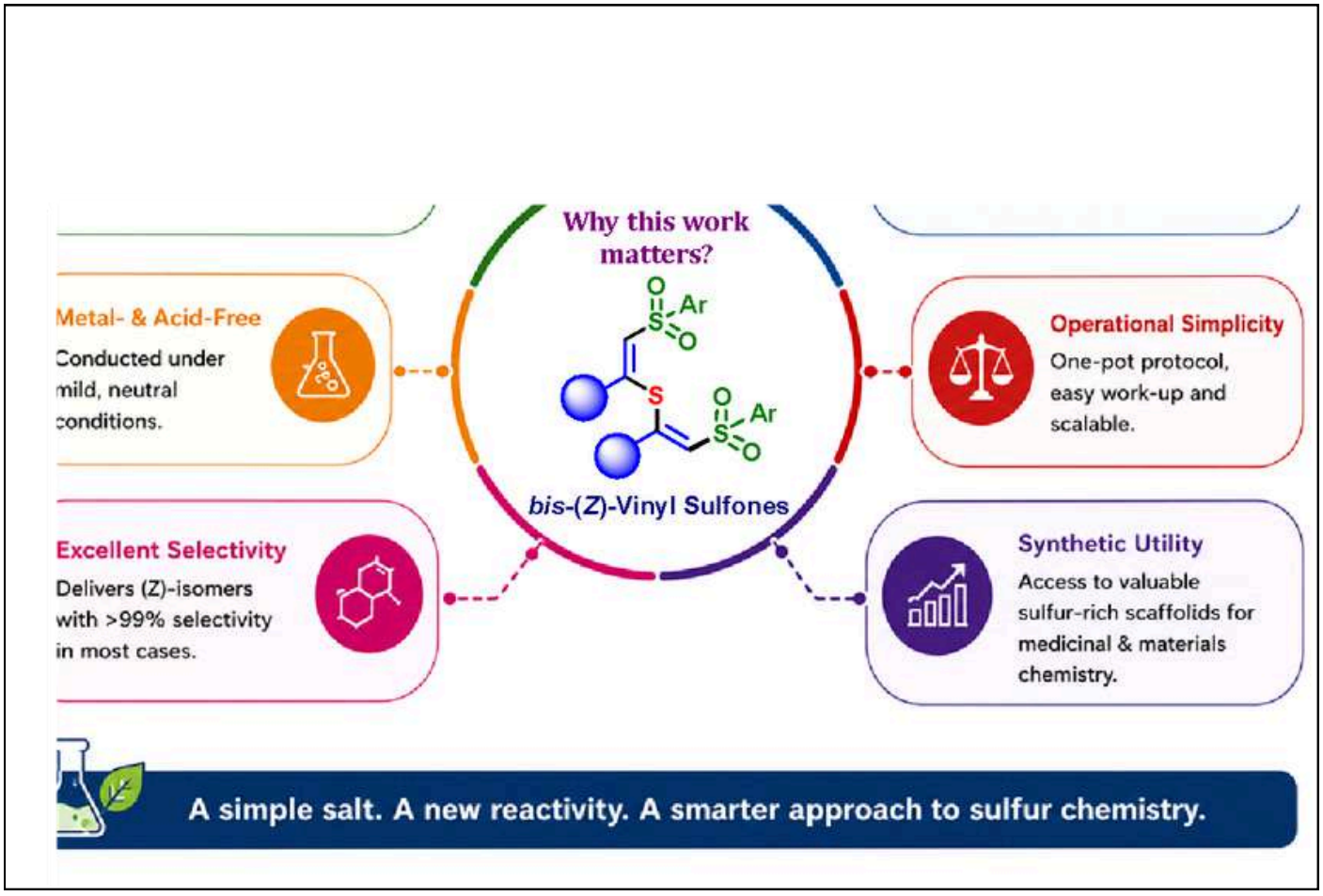


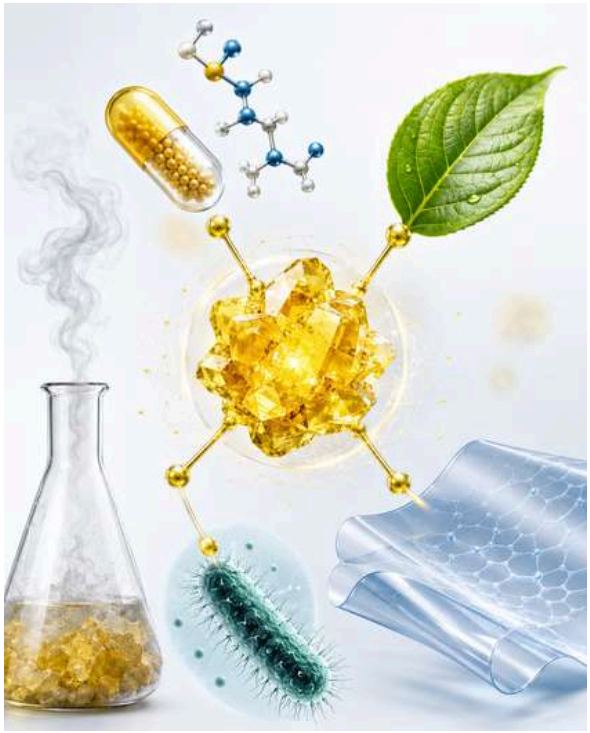
Figure 3. Highlights of the developed methodology emphasizing green chemistry, selectivity, operational simplicity, and synthetic utility.

cular design itself?

These questions remain unanswered, and that is precisely why the field remains exciting. Looking back, I believe chemistry has always rewarded curiosity more than certainty. Reactions that initially seem routine sometimes become gateways toward entirely new concepts. Often, the difference between an ordinary observation and an important discovery lies only in asking one additional question.

After all, chemistry is not simply about making molecules. It is about uncovering possibilities hidden within them.

Prof. Rawat and Dr. Tiwari's contributions to synthetic organic chemistry are highlighted in their recent Chemical Communications (2026) publication (https://doi.org/10.1039/D5CC07298K), which reports a sustainable, metal- and acid-free method for the stereoselective thiosulfonylation of alkynes using sodium thiosulfate as a green sulfur-transfer reagent, providing efficient access to valuable sulfur-containing molecules.



| EXPERT OPINION |

The Secret Connection Between Diabetes And Memory Loss

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

Areas of expertise: Super-resolution microscopy | nanomaterials | biosensors | fluorescence imaging | chemical biology

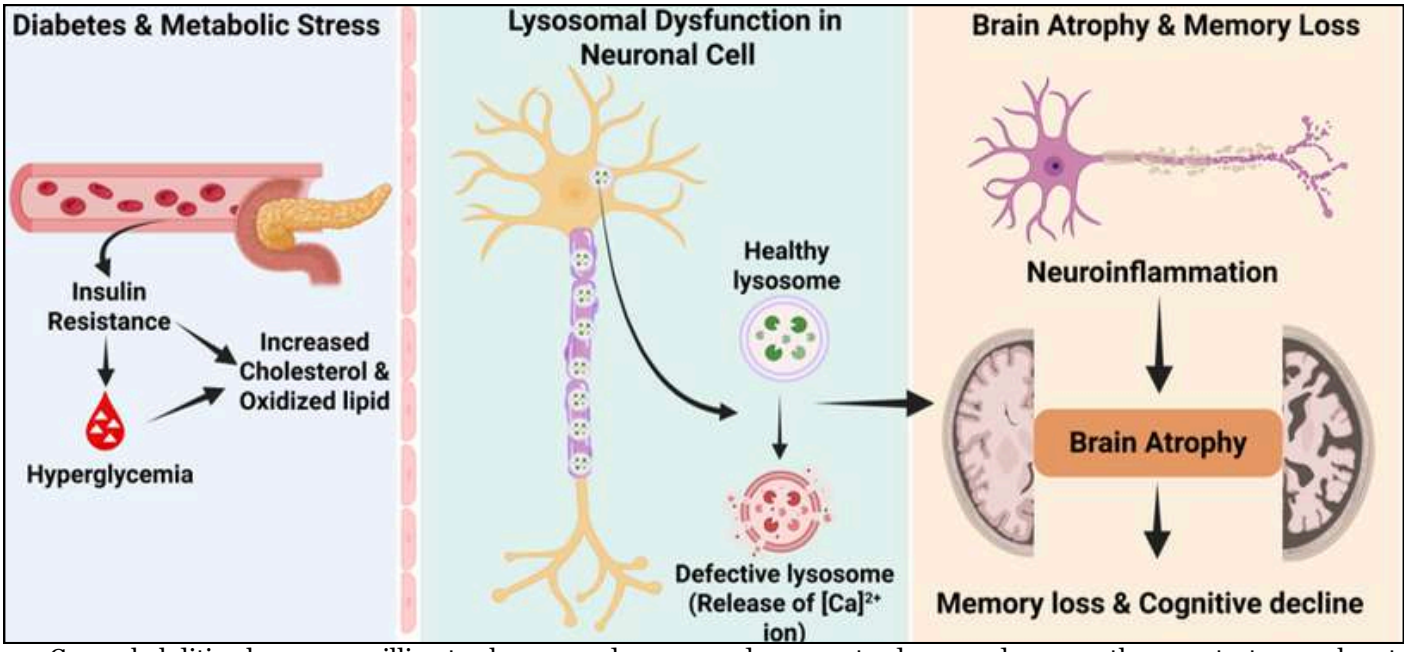
Adam had managed her diabetes for almost twenty years. She counted her carbs, took her insulin, and checked her sugar every morning without fail. What she never expected was that the disease quietly reshaping her blood sugar might also be reshaping something else entirely, the tiny machinery inside her brain cells that keeps memories intact. "Doctor, my sugar is under control," she told her physician one afternoon. "So why do I keep forgetting where I put things?" It's a question more families are asking every year. And it turns out, the answer may be hiding somewhere no one thought to look: inside a cell's tiniest recycling bin.

THE CELL'S GARBAGE DISPOSAL AND WHY IT MATTERS: Every cell in the body has a built-in cleanup crew called the lysosome. Think of it as a combination of a recycling center and a garbage disposal, breaking down old proteins, damaged parts, and cellular debris so the cell can stay healthy. For decades, scientists paid little attention to this humble organelle. It seemed like a background player, quietly doing its job while flashier molecules took the spotlight. But our research told a different story. Working with a specially designed fluorescent probe, a molecule we built to light up and change color depending on how "thick" or viscous its surroundings are, we found something unexpected. When blood sugar levels rise, as they do in diabetes, the fluid inside lysosomes doesn't stay the same. It thickens. It becomes syrupy, almost sluggish, like honey left in a cold refrigerator instead of flowing like water. This thickening is called an increase in lysosomal viscosity, and it turns out to be far more than a mere curiosity. It's a warning sign.

> *"Diabetes didn't just touch Adam's blood sugar, it may have reached his memory."*

WHEN THE GARBAGE DISPOSAL GETS CLOGGED: Lysosomes don't just break down waste. They also store calcium, a mineral your cells depend on to send signals, regulate energy, and keep countless internal processes running on time. When lysosomes swell and thicken under high-sugar conditions, this delicate calcium balance breaks down. Calcium that should stay locked inside the lysosome leaks out into the surrounding cell fluid, throwing the cell's internal signaling into disarray. To watch this unfold, we studied liver and cervical cancer cells exposed to high glucose, and used a technique called super-resolution imaging, essentially a way of zooming in far closer than a normal microscope allows, to catch lysosomes in the act of swelling in real time. We then turned to a small but powerful ally in biolo-

| EXPERT OPINION |



gy, Caenorhabditis elegans, a millimeter-long roundworm that, despite its size, shares a surprising number of biological pathways with humans, including ones involved in aging and neurodegeneration.

We fed one group of worms a high-glucose diet, mimicking the hyperglycemia seen in diabetes, and compared them to worms engineered to model Alzheimer's disease. The result was striking: the same rise in lysosomal viscosity and calcium imbalance we saw under high sugar also appeared alongside the clumping of amyloid-beta, the sticky protein fragment long associated with the plaques found in Alzheimer's brains.

In other words, the same cellular traffic jam that diabetes creates looks remarkably similar to what happens in a brain sliding toward memory loss.

A COMMON THREAD, NOT A COINCIDENCE: For years, doctors have noticed that people with type 2 diabetes face a higher risk of developing Alzheimer's disease, so much so that some researchers have nicknamed Alzheimer's "type 3 diabetes." But noticing a pattern and understanding its cause are two very different things. Our findings offer a possible thread connecting them: a breakdown in the cell's own cleanup system, triggered by chronically high blood sugar, that leaves calcium signaling in disarray and creates conditions in which harmful protein aggregates can take hold. This doesn't mean every person with diabetes will develop Alzheimer's, nor does it mean memory loss always has a metabolic cause. But it does suggest that keeping blood sugar steady may do more than protect your heart, kidneys, and eyes; it may also protect the quiet, unglamorous machinery inside your brain cells that keeps them clean, balanced, and functioning.

WHY A GLOWING MOLECULE MATTERS: The probe we developed, a zinc-based fluorescent complex, is not a treatment. It's a window. Because it lights up specifically within lysosomes and changes its glow with viscosity, it lets researchers watch, for the first time in living cells and animals, exactly when and where this cellular traffic jam begins. Tools like this one could eventually help scientists test whether new drugs can restore healthy lysosomal function before memory loss ever sets in, turning an invisible warning sign into something we can actually see, measure, and, one day, treat.

Adam's forgetfulness may never be fully explained by any single study. But research like ours adds one more piece to a puzzle that touches millions of families: the idea that diabetes and memory loss may not be two separate battles, but two symptoms of the same quiet struggle happening inside our cells.

Prof Nandi's contribution t this filed is reflected in his recebt publication from his group on Chemical & Biomedical Imaging, 2026, https://doi.org/10.1021/cbmi.5c00170 which explores how changes in lysosomal viscosity under high blood sugar conditions may contribute to Alzheimer's disease.

| EXPERT OPINION |

How Cells remember Stress and Adapt to Change

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

Areas of expertise: Epigenetics | Chromatin biology | Genomics | Synthetic biology

An essential component of evolution is adaptation of cells to changing environment. Changes in environment constitute stress conditions. Cells survival under stress conditions has entailed development of pathways that maintain and adapt the structure and function of proteins that are essential for survival.

Since environmental stress can be deleterious to protein structure and function and thus affect cell viability, cells have evolved diverse pathways, like chaperones, that restore their structure and function. Conversely, the altered protein structure may impart new traits that help yeast cells to survive environmental stress. Thus, changes in the protein sequences that help adapt the structure to environment may get selected during evolution. Prions exemplify an altered form of protein structure that carries a structural memory and ability to convert the normal form of protein into its own altered shape and loss of function. This epigenetic role is dominant over the function of the normal protein and is inherited in a non-Mendelian manner in yeast.

In the fission yeast, *Schizosachharomyces pombe*, centromeres, telomeres and mating type regions are assembled into heterochromatin via epigenetic mechanism. This involves di/tri-methylation of Lys9 in histone H3 (H3-K9-me2/me3) by the histone methyltransferase Clr4/Suv39, followed by binding of H3-K9-me2/me3 by the heterochromatin protein Swi6/HP1. This binding spreads into the neighbouring region to generate a transcriptionally inactive, heterochromatin structure. The integrity of the heterochromatin structure is critical for proper chromosome segregation during mitosis and meiosis, since mutations in Swi6 cause chromosome segregation defects.

> *"The components of heterochromatin assembly and APC/C not only interact with but also regulate each other."*

APC/C, a multiprotein complex, plays a pivotal role in an orderly cell cycle progression in all eukaryotes from yeast to humans. Its functions are mediated through its biochemical activity of ubiquitination of key regulatory proteins and the orderly degradation. One such pathway leads to separation of sister chromatids during mitosis. Mutations in these pathways can perturb orderly cell cycle progression.

Rather surprisingly, APC/C also ensures chromosome integrity and segregation as well as heterochromatin structure. This function is performed through direct interaction between the APC/C subunits like Cut4/Apc1 and Swi6/HP1 and Clr4/Su-

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v39 (Dubey et al J. Biol Chem 284, 7165 (2009)). This property links the two pathways involved in heterochromatin assembly and cell cycle regulation.

Further, the components of heterochromatin assembly and APC/C not only interact with but also regulate each other. This regulation may occur at the level of ubiquitination of specific proteins of heterochromatin and RNAi pathway. Ubiquitination, in turn, may regulate the activity and levels of the heterochromatin proteins. In turn, heterochromatin proteins can possibly regulate the activity of the APC/C subunit/s. This interaction would ensure that heterochromatin assembly and cell cycle progression are closely coordinated. This coordination is likely to be conserved during evolution and its disruption may lead to chromosome segregation defects, aneuploidy and dysregulation of cell cycle, conditions associated with diseased states.

A recent study showed that Cut4/Apc1, the largest subunit of the Anaphase Promoting Complex/Cyclosome (APC/C), adopts a prion form in yeast strains either due to mutations or overexpression of Cut4/Apc1 (Sharma et al, Nucleic Acids Research, 52, 13792 (2024); Reviewed in Sharma and Singh mBio 17, 1 (2026)).

An observable characteristic of the cells harbouring a prion form of Cut4/Apc1 is the presence of variable level of aggregates. These aggregates not only lack the normal function of the protein but they also block the activity of the normal protein. Thus, in case of an essential protein, prion formation can be deleterious to cell function and survival. Surprisingly, while the prion form of Cut4/Apc1 also forms aggregates and it abrogates several pathways, like cell cycle progression, heterochromatin assembly and chromosomal integrity and segregation, it confers enhanced resistance to stress: such cells exhibit better survival under conditions of stress – like, oxidative stress, osmotic stress, high ethanol concentration, exposure to high temperature, etc. Pertinently, cancer cells also display similar characteristics: aneuploidy, cell cycle defect and enhanced stress survival.

> *Thus, the IDR regions allow for better adaptation of function to changing cellular environment in response to stress.*

These apparently opposing effects suggest a role of the prion variant of Cut4 in evolution as well as disease. Changes in sequences of proteins help to adapt to changing environment during evolution. One of the significantly regions within proteins that are associated with adaptation are known as Intrinsically Disordered Regions (IDRs). These regions lack the canonical secondary structures like a-helix and b-sheet or tertiary structures, but have an intrinsic flexibility to adopt conformations that facilitate their interaction with different proteins under different environments. Interestingly, the IDRs show greater level of sequence variation among the homologous proteins even in related species as compared to the remaining parts of proteins, indicating reduced evolutionary pressure and allowance for greater sequence variation. These amino acid changes may perform a dual function: exploration of suitable structures in the conformational space and selection of those conformations which have functions better suited for cell survival.

Notably, IDRs have been found in a large number of proteins especially in metazoans. The greater complexity of cells in metazoans combined with limited protein coding capacity of their genome, requires additional functional diversification of proteins. The conformational flexibility of IDRs allows for multiple regulated interactions with diverse sets of proteins to meet the increased cellular requirements of the organism. Thus, the IDR regions allow for better adaptation of function to changing cellular environment in response to stress.

In a seminal study a transient overexpressio-

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n of about 50 proteins elicited beneficial traits in yeast cells, including enhanced resistance to stresses. Importantly, these traits persisted even after the expression levels of proteins was restored to normal level (Chakrabortee et al, Cell 167, 369 (2016)). The overexpressed proteins shared the presence of IDRs and traits caused by their overexpression exhibited prion-like inheritance pattern. However, these traits were not necessarily associated with formation of amyloids. Indeed, a comparison of sequences of Cut4/Apc1 from different species of the genus *Schizosachharomces* reveals conserved location of two IDRs. Sequence comparison shows significantly lower level of sequence similarity in the IDR regions as compared to the complete sequence of Cut4 protein of four species.

In this regard, our recent findings about Cut4/Apc1 and its prion variant may carry broader significance. The Darwinian evolution involves variation in DNA sequence and selection of the organisms with proteins that enhance greater fitness. While protein structure and functions may have inherent malleability to adopt altered conformations that allow functional diversification and adaptation in response to changing environment. These changes are facilitated by the conformational flexibility of the IDRs. Mutations in the IDRs may further help proteins to explore different conformations that are more adapted to maintain the protein functions in response to stress (Wickner and Kelly Cell Mol Life Sci 73, 1131 (2016)).

Prof. Singh's contributions to the field of epigenetics and prion biology are reflected in his pioneering research on the interplay between prions, heterochromatin regulation, and cell cycle control in fission yeast. His work has uncovered a novel prion-based mechanism underlying the non-Mendelian inheritance of heterochromatin silencing and provided new insights into the roles of Cut4/Apc1 in chromatin organization, RNA interference, stress responses, and evolution. These findings have been published in leading journals, including Nucleic Acids Research (2024; DOI: 10.1093/nar/gkae1136), mBio (2026; DOI: 10.1128/mbio.00837-25), and The Journal of Biological Chemistry (2009; DOI: 10.1074/jbc.M806461200).

| EXPERT OPINION |

Ice, Water, and the Future of Chemistry: A Molecule Connecting Stars, Life, and Sustainable Technologies

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

Areas of expertise: Molecular & nanoscale materials | Microdroplets | Water purification | Molecular surfaces | Scientific instrumentation

Chemistry has traditionally advanced through the discovery of new molecules, reactions, and materials. Despite centuries of investigation, water continues to surprise us. We still do not fully understand its behavior under confinement, at interfaces, in extraterrestrial environments, or within complex biological systems. Water exists in interstellar clouds, on distant moons, and within living cells, linking environments separated by vast differences in scale and complexity. Water may have participated in the chemistry that preceded life, and continues to sustain biology and may help define chemistry of the future. As humanity enters a new era shaped by planetary exploration, artificial intelligence, and sustainable technologies, water and its frozen forms remain at the center of scientific investigations.

Among the many mysteries connected to water, perhaps the most profound is the origin of life itself. In 1953, Stanley Miller and Harold Urey demonstrated that exposing simple molecules such as CH_4, NH_3, H_2, and H_2O vapor to energy sources resembling lightning could produce amino acids, suggesting that biological building blocks might arise through abiotic chemical processes. However, as our understanding of the Solar System expanded, scientists began to ask a broader question: What if some of the molecular ingredients required for life were not produced solely on Earth?

> *"Understanding how molecules behave within ice may help answer one of science's oldest questions: How did life begin?"*

Modern astronomical observations strongly support this possibility. More than 300 molecular species have been identified in interstellar and circumstellar environments, including H_2O, CO, CO_2, CH_4, NH_3, alcohols, aldehydes, and a growing inventory of complex organic molecules. Many of these species accrete onto microscopic dust grains, forming ice-rich mantles in which water is typically the dominant component. Although temperatures in these regions can be as low as 10 K, they are far from chemically inactive. Ultraviolet radiation, cosmic rays, and energetic particles continuously process these icy materials, driving reactions that increase molecular complexity over astronomical timescales. In this sense, space itself functions as a vast chemical laboratory, where water plays a significant role. The resulting molecules may have been incorporated into comets and meteorites, delivering some of the chemical ingredients of life to the early Earth (Figure 1).

Laboratory simulations inspired by these

discoveries have shown that irradiation of simple molecules trapped in water-rich ice can produce amino acids and other prebiotic compounds. Yet major questions remain unresolved. These experiments generally produce racemic mixtures containing equal amounts of left- and right-handed molecules, whereas life on Earth exhibits a remarkable preference for a single chirality. Understanding how this chiral enrichment or homochirality emerged remains one of the central challenges in origin of life research. One intriguing possibility is that confinement within ice matrices or porous molecular structures may influence molecular organization and symmetry breaking. Besides, such confinements could act as reaction vessels for photon/ion/electron-induced chemistry in space.

Water is uniquely suited for exploring this question because it exists in multiple solid forms. Under astrophysical conditions, water predominantly exists as amorphous solid water, a highly disordered phase that forms at extremely low temperatures. Upon heating, it can transform into crystalline cubic and hexagonal ice. Water can also organize into clathrate hydrates, cage-like crystalline structures capable of trapping small molecules such as CH_4 andCO_2 within their cavities. These different phases provide distinct chemical environments that influence how species are stored, transported, concentrated, and transformed. Understanding their formation, evolution, and reactivity is therefore crucial for deciphering chemical processes in space and assessing the role of ice in the emergence of prebiotic molecules and, ultimately, the origins of life.

Motivated by this broader vision, we designed a unique custom-built ultrahigh vacuum (UHV) instrument to mimic key aspects of interstellar chemical events targeting ice. Equipped with infrared spectroscopy, multiple mass spectrometric techniques, and an ultraviolet irradiation source, the setup operates at pressures approaching 10^{-10} mbar and temperatures as low as 10 K, enabling the study of molecular processes under conditions similar to those found in molecular clouds, comets, and icy planetary bodies. Over more than a decade, this instrument has become a center of attraction for systematically investigating the behavior of molecular solids, including water ice and clathrate hydrates, under such extreme (10 K, 10^{-10} mbar) conditions.

> *Water-based materials may contribute to future technologies for carbon capture, clean energy storage, and sustainable resource management.*

The first major breakthrough from this lab came in 2019 with the experimental observation of CH_4 and CO_2 clathrate hydrates under these conditions studied by infrared spectroscopy (Ghosh et al., Proc. Natl. Acad. Sci. U. S. A., 2019). Although the existence of such hydrates in the interstellar medium had been proposed for decades, direct experimental evidence was lacking. The study demonstrated that water molecules could self-assemble into cage-like structures capable of trapping guest molecules even under extremely low-temperature and low-pressure conditions. This observation opened a new direction in laboratory astrochemistry. Subsequently, we have also demonstrated the growth of the clathrate hydrates under similar conditions using electron diffraction (Bijesh et al., J. Phys. Chem. Lett. 2024).

Building on this discovery, subsequent studies demonstrated that a plethora of molecules, such as tetrahydrofuran, acetaldehyde, acetone, formaldehyde, ethane, dimethyl ether, trimethylene oxide, and nitrous oxide, can be trapped in the form of hydrates under UHV conditions. We further demonstrated the formation of several binary and ternary hydrates and revealed dynamic guest migration processes within hydrate frameworks, providing new insights into molecular redistribution in multicomponent icy environments. These

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investigations also established that thermal annealing and guest desorption transformed hydrates into different forms of crystalline ice. Hydrate dissociation forms hexagonal and cubic ices depending upon the guest molecules. Even non-hydrate-forming volatile species such as acetonitrile present in mixed ices can affect this process and ultimately govern the emergence of specific crystalline ice phases.

Additional intriguing chemistry emerged when these hydrates were exposed to ultraviolet (UV) radiation. CO_2, acetaldehyde, and dimethyl ether hydrates demonstrated cage-controlled photochemistry, where confinement altered reaction pathways and product selectivity in the presence of UV irradiation. For instance, acetaldehyde hydrate retains significantly larger fractions of photoproducts, primarily CO and CH_3CH_2OH, whereas mixed acetaldehyde-H_2O ice favors CO and CH_4 formation during UV photolysis (Gaurav et al., J. Phys. Chem. Lett. 2026). Complementary photolysis studies of simple astrophysical molecules such as CO, CO_2, methyl chloride, and N_2O generated a variety of complex organic products of prebiotic relevance.

> *"Water microdroplets can break minerals!"*

These studies provide compelling experimental evidence that water, existing as amorphous ice, crystalline ice, and clathrate hydrates, can influence molecular storage, transport, reactivity, and photochemistry under interstellar conditions. Although the puzzle of the origin of life remains unresolv-

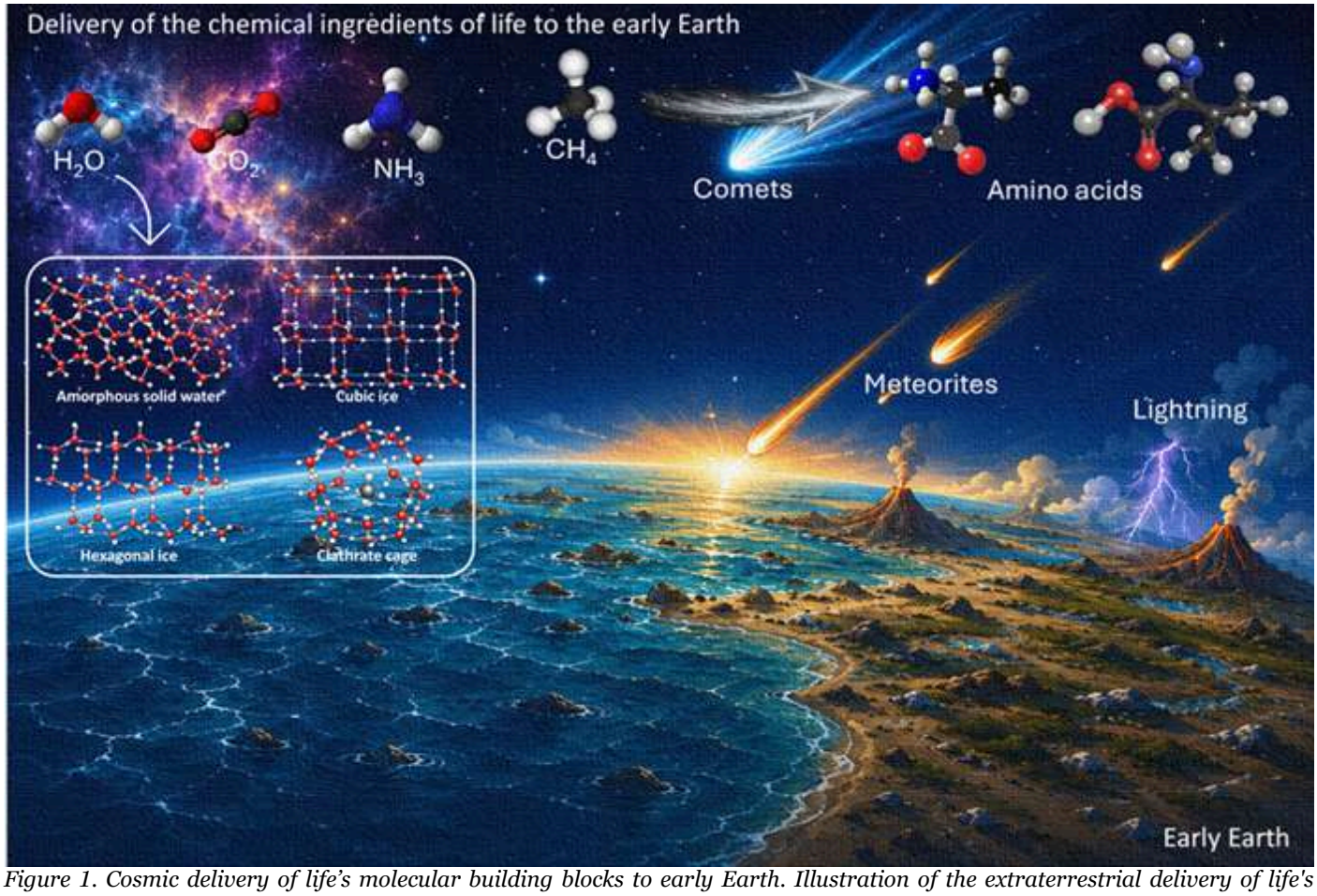

Figure 1. Cosmic delivery of life's molecular building blocks to early Earth. Illustration of the extraterrestrial delivery of life's molecular ingredients to the early Earth. Complex molecules formed in interstellar environments were trapped within icy bodies, incorporated into comets and meteorites, and transported to the young Earth, where they may have contributed to the inventory of prebiotic compounds available for the origin of life.

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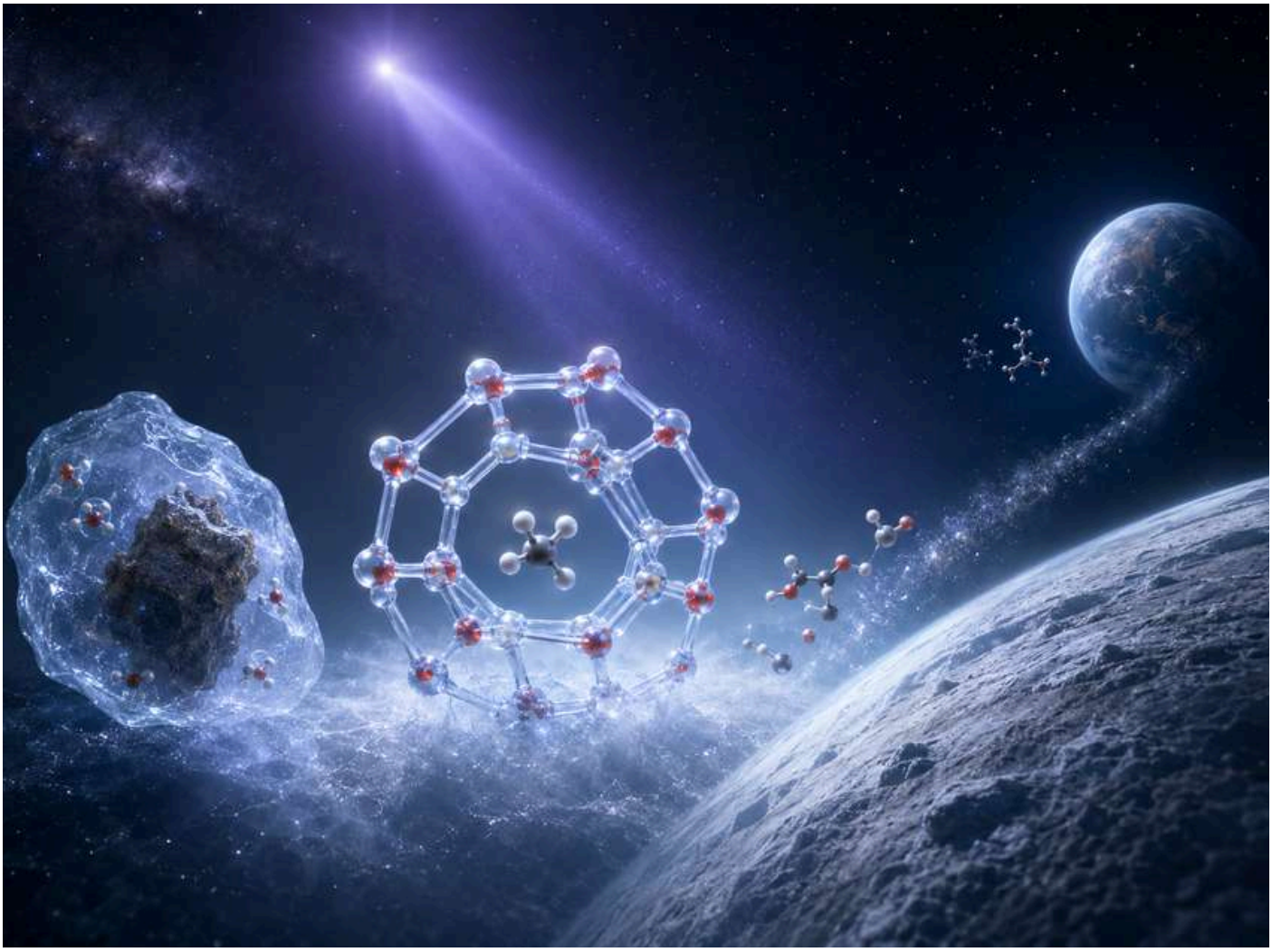
ed, significant progress has been made toward understanding how molecular complexity emerges in icy environments. Future advances will come from integrating laboratory astrochemistry, space missions, astronomical observations, artificial intelligence, and molecular simulations. As these fields converge, water is increasingly recognized as a key driver of chemical evolution, linking the chemistry of interstellar space to the emergence of life and potentially to habitable worlds beyond Earth.

Beyond ice and hydrate chemistry, terrestrial water also presents new phenomena of relevance to the origin of life. We showed that charged water microdroplets break natural minerals spontaneously into nanoparticles within milliseconds. Usually, weathering of rocks and minerals occurs over millennia. The active surfaces of minerals formed in water droplets can contribute to chemistry of relevance to life. In a different but equally important context, clathrate hydrates are also being explored as sustainable materials for the capture of CO_2 and the storage of gases such as CH_4 and H_2, offering potential routes for carbon management and clean energy. Looking ahead, advances in these areas may enable new approaches to cooling, energy storage, and resource utilization.

Prof. T. Pradeep and his team's contributions to this field are reflected in a series of influential studies that have advanced our understanding of clathrate hydrates, from their formation under interstellar conditions to their nanoscale growth and unique photochemical behavior. Their work has been published in leading journals, including Proceedings of the National Academy of Sciences (2019; DOI: 10.1073/pnas.1814293116) and The Journal of Physical Chemistry Letters (2025; DOI: 10.1021/acs.jpclett.4c03106; 2026; DOI: 10.1021/acs.jpclett.6c00885)



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Can Peppermint Oil Help Fight Harmful Bacteria?

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

Areas of expertise: Chemical Nanotechnology | Nanobiology | Biomaterials

Taking inspiration from the nature's own remedial mechanism to counter bacterial infection: the tale of Peppermint Oil Nanoemulsion.

The use of antibiotics for the management of bacterial infection has long been relied; however, the widespread and uncontrolled use of these drugs have resulted to an alarming rise in the antibiotic-resistant bacteria. It has been observed that even the common bacteria have also become resistant towards these drugs, making the once manageable disease increasingly difficult to control.

It is in this context that the search for newer alternatives has led the scientists to focus on nature's own arsenal: plant-derived essential oils. Amongst the many essential oil studied, peppermint essential oil (PEO) has shown impressive antibacterial, antioxidant and anti-inflammatory properties. The PEO is generally being isolated from the hybrid plant Mentha piperita and has been found to be rich in several bioactive compounds including menthone, menthol and methyl acetate. Though its biological effects are promising, several challenges restrict the practical use of PEO in day to day life. The major bottlenecks arises from their strong aroma, high volatility, poor water solubility and also due to their low stability when exposed to heat, light or through aerial oxidation which all effect PEO's biological efficacy. Hence scientific interventions are required to not only maintain the biological potency of PEO but also to deliver it in a form that helps to overcome these drawbacks.

> *"Peppermint essential oil nanoemulsion (PEONE) was synthesized via ultrasonication method."*

After studying several delivery systems, it was found that nanoemulsification process could successfully be used to enhance PEO's stability and bioefficacy. The process of nanoemusion formation involves simultaneous use of water and oil in the presence of appropriate surfactant which allow formation of tiny droplets that encapsulates the active ingredients. Our proposed idea was to use such tiny droplets to prevent the degradation of PEO from the external stimuli and maintain its biological activity. To achieve this, our research team developed an optimized ultra-sonication assisted PEO nanoemulsification process comprising of a blend of two non-ionic surfactants viz., Brij®58 and Span®80. The choice of such surfactants was made to maintain adequate hydrophilic –lipophilic balance during the synthesis. Such careful

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control of the process led us to obtain ultra-small droplets (averaging about 40 nm) PEO nanoemulsion (PEONE). The developed oil-in-water PEONE demonstrated marked colloidal and physical stability for a prolonged period of time, resisting separation of two different immiscible phases with an extremely low creaming index.Next, we studied the anti-bacterial efficacy of the developed PEONE. When tested against common bacterial pathogens viz., Staphylococcus aureus and Escherichia coli, which are the common cause of hospital-acquired infections, skin infection, urinary tract infection etc. PEONE demonstrated ~ 2.4 – to 3.3 fold increased anti-bacterial activity compared to unformulated PEO.Further, PEONE was also able to inhibit the matured biofilms of both the bacteria, indicating its much stronger applications. The potency of the PEONE was quantitatively measured and it was found that it's Minimum Inhibitory Concentration (MIC) and Minimum Biofilm Inhibitory Concentration (MBIC) values were significantly lower compared to bare PEO. The mechanistic studies suggested that PEONE, due to its small size, penetrates the bacterial cell membrane more effectively compared to unformulated PEO and eventually leads to the oozing out of the cytoplasmic content of the bacteria. We predicted that the small droplet size of PEONE allowed the PEO to penetrate more deeply and also allowed slow and sustained release of PEO, hence maintain its anti-bacterial activity for longer period of time. We expect that such nanoemulsification process will allow deeper penetration of PEO in layers of skin or within bacterial membrane and hence the practical utility of this process may find its applications in cosmeceuticals or other healthcare applications. In practical terms, PEONE could easily be incorporated into topical creams, gels, or hydrogels for use as antibacterial agents.

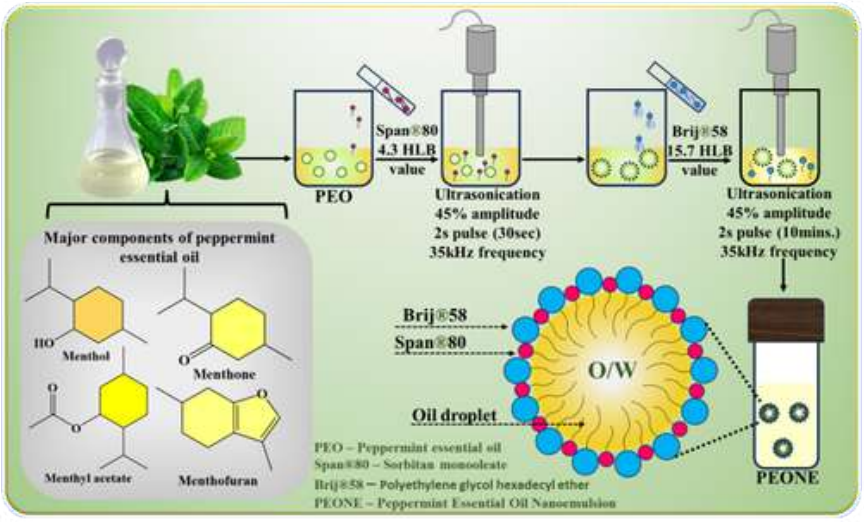

Figure 1. Schematic illustration of the synthesis process for oil-in-water (O/W) peppermint essential oil nanoemulsion (PEONE). © 2026 Elsevier Ltd. All rights are reserved.

However, before its practical use, several key questions related to PEONE formulation needs to be addressed.The design and development of an ideal surfactant system that allow stable and ultra-small droplet formation of essential oils is challenging task. Additionally, even though in vitro results are encouraging, the efficiency of any developed formulation is better tested under in vivo condition, which allow a proper mimic of biological milieu. The stability of the developed formulation should also be tested under complex biological environment including living samples. Further, studies on antibiotic resistant strains should also be carried out to confirm the effectiveness of the formulations.

In conclusion, the development of peppermint essential oil nanoemulsion marks an important step towards the progress of "green antibiotics" using natural antibacterial therapies. The nanotechnological intervention provided an alternative to the inherent limitations of essential oils and initial results suggested this approach to be effective one.

Dhiman R, Kaur H, Thakur A, Pal PK, Yadav SK, Acharya A. Oil-in-water nanoemulsification of peppermint oil enhances its antibacterial and antibiofilm activity. Microbial Pathogenesis. 2026 May 19:108568.

> *Mechanistic studies show PEONE disrupts bacterial membranes, highlighting therapeutic potential.*

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The Future of Vaccines: From Traditional Shots to mRNA Technology

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Areas of expertise: Immunology | Vaccines | Vaccine Adjuvants

The Rise of mRNA Vaccines.

Vaccination remains inevitable in modern medicine, having prevented millions of deaths and significantly reduced the burden of infectious diseases worldwide. The vaccine technology has evolved from the early development of live-attenuated and inactivated vaccines to the introduction of recombinant protein and viral vector platforms to address emerging public health challenges (Figure 1). Today, the remarkable success of messenger RNA (mRNA) vaccines, which were recently introduced, marks a new era in vaccinology (Figure 1), demonstrating unprecedented speed, flexibility, and efficacy in responding to global health emergencies.

The COVID-19 pandemic, although chaotic, highlighted the potential of mRNA technology as a rapid-response platform capable of accelerating vaccine development from sequence identification to clinical deployment within months Unlike conventional vaccines, which require pathogen propagation or large-scale protein production and/or adjuvant combinations, mRNA vaccines leverage the body's own cellular machinery to produce target antigens, enabling a highly adaptable and scalable manufacturing process. This platform not only shortens development timelines but also offers significant opportunities for addressing emerging infectious diseases (pandemic preparedness), seasonal pathogens, and even non-infectious conditions such as cancer. That being said, the mRNA is highly unstable and requires delivery technology to succeed. Lipid nanoparticles (LNPs) have emerged as the gold-standard delivery system, protecting fragile mRNA molecules from degradation while facilitating efficient cellular uptake and antigen expression. Continuous improvements in LNP composition, tissue targeting, and safety profiles are expected to further enhance vaccine performance. Unlike conventional vaccines, which often require separate adjuvants, mRNA–lipid nanoparticle (mRNA-LNP) vaccines possess intrinsic adjuvant properties. The LNP carrier (based on its composition) can stimulate innate immune pathways, leading to the production of cytokines and chemokines that enhance antigen presentation and adaptive immune responses. The LNP components, particularly ionizable lipids, promote the recruitment and activation of antigen-presenting cells such as dendritic cells, facilitating robust T-cell and antibody responses. However, the level of innate immune activation must be carefully balanced. Excessive stimulation can reduce mRNA translation, increase reactogenicity,

> *"The future of vaccines is no longer limited to prevention; it is becoming a powerful platform for personalized, adaptable, and globally accessible healthcare solutions."*

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Figure 1. Evolution of vaccine technologies and enabling delivery platforms. A) This schematic illustrates the progression of vaccine development from the late 18th century to the present day. B) Scalable and thermostable mRNA-LNP platforms. C) Vaccine adjuvants that enhance the magnitude and durability of immune responses. Figure created with biorender.com.

and compromise vaccine efficacy. Conversely, controlled immune activation serves as a self-adjuvanting mechanism, eliminating the need for additional adjuvants in many mRNA vaccine formulations. This property has been a key contributor to the success of mRNA-LNP vaccines against infectious diseases, including COVID-19. Ongoing research aims to optimize lipid composition and mRNA design to fine-tune adjuvant activity, thereby maximizing immunogenicity while minimizing adverse effects. The ability to precisely modulate innate and adaptive immune responses remains one of the major advantages of the mRNA-LNP vaccine platform.

Challenges of mRNA-LNP Technology and Strategies to Overcome

Despite these notable advances, mRNA-LNP technology platforms have several limitations. However, significant advances are rapidly overcoming many of the limitations. One of the major concerns has been the cold-chain requirements. The cold-chain requirements associated with mRNA-LNP formulations are being addressed through the development of more stable lipid compositions, improved formulation strategies, the incorporation of novel cryoprotectants and the selection of suitable storage buffers (Figure 2).

These innovations are expected to enhance product stability and facilitate global distribution. The liver tropism of conventional LNPs, which restricts delivery to other tissues, is another limitation. Emerging technologies such as Selective Organ Targeting (SORT) nanoparticles are now enabling tissue-specific delivery to organs beyond the liver, expanding the therapeutic potential of mRNA medicines. Similarly, Innate immune activation remains an intricate aspect of mRNA therapeutics. While excessive immune stimulation can compromise efficacy and safety, particularly in applications such as cell therapy and protein replacement therapy, controlled or optimal innate immune activation can serve as a powerful adjuvant effect in vaccine development, enhancing protective immune responses. Advances in manufacturing technologies, including scalable in vitro transcription processes and microfluidic-based platforms for continuous nanoparticle production, have significantly improved the feasibility of large-scale mRNA-LNP production. Moreover, the cost of key reagents, including cap analogues, polymerase enzymes, NTPs (with or without modifications), and other materials, has significantly decreased compared with prices

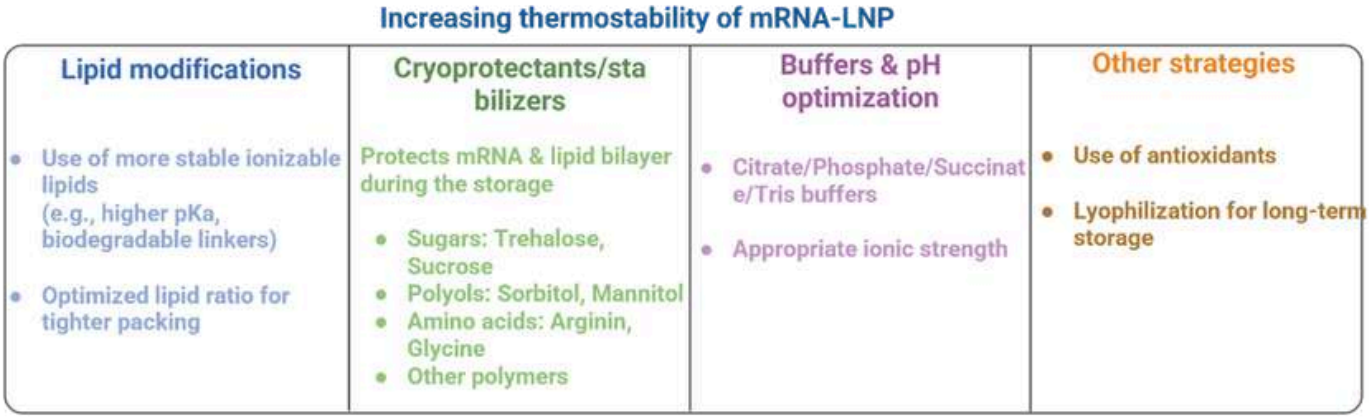

Figure 2. Thermostable mRNA-LNPs. Formulation optimization through lipid engineering, cryoprotectants, and buffer systems to enhance the stability, storage, and global distribution of mRNA therapeutics and vaccines. Figure created with biorender.com.

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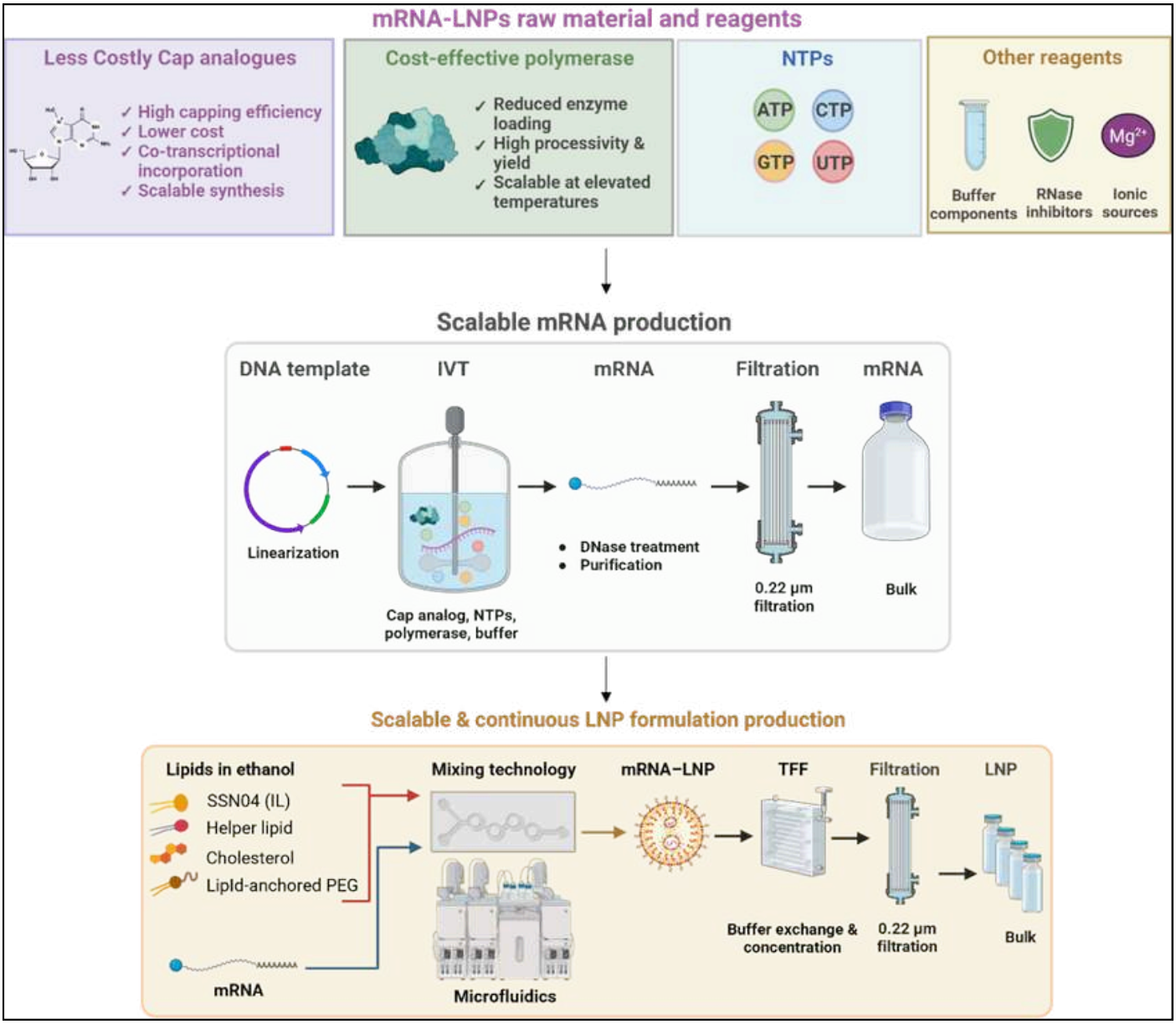

Figure 3. Strategies to enable cost-effective, scalable, and thermostable mRNA-LNP manufacturing. Key approaches include the use of low-cost cap analogues, polymerases, NTPs, and reagents for large-scale mRNA production, as well as continuous microfluidics-based lipid nanoparticle (LNP) formulation. Figure created with biorender.com.

during the COVID-19 pandemic (Figure 3).

These developments have transformed mRNA therapeutics from an experimental concept into a commercially viable platform. Another critical focus area is improving endosomal escape, which remains a major bottleneck for intracellular mRNA delivery. Chemists and formulation scientists (including our group) worldwide are actively designing next-generation ionizable lipids and novel nanoparticle architectures to enhance cytoplasmic release of mRNA. Continued innovation in lipid chemistry, delivery technologies, and manufacturing platforms is expected to drive the next generation of mRNA therapeutics, broadening their applications far beyond vaccines and opening new possibilities for treating a wide range of diseases.

> *We are witnessing a paradigm shift in vaccine development.*

Future Perspectives

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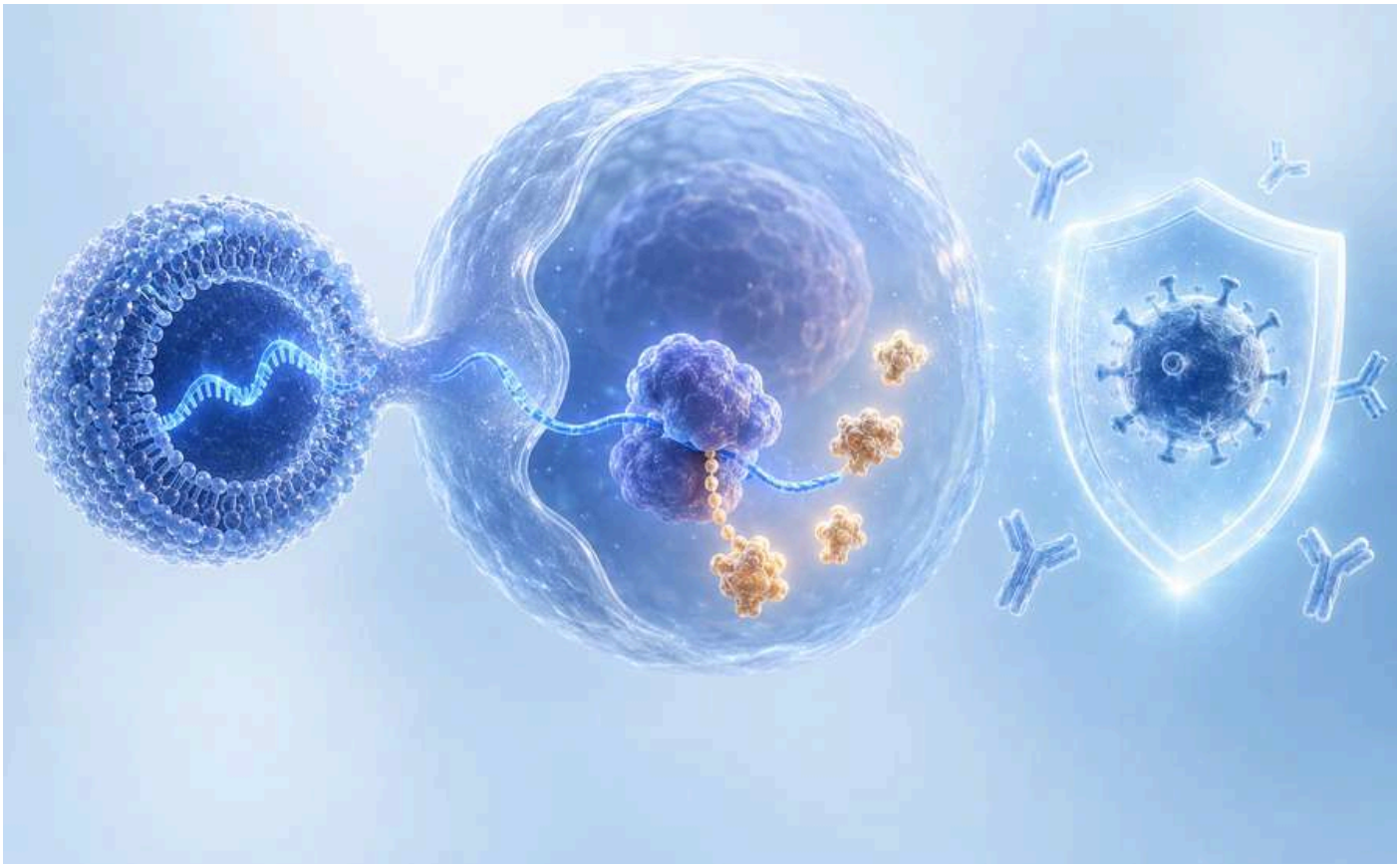
Looking ahead, the future of vaccines extends beyond infectious disease prevention. Personalized cancer vaccines, therapeutic vaccines for chronic diseases, and mucosal vaccines are poised to expand the boundaries of immunization science. Moreover, technology platforms are being rapidly explored for cell and gene therapies, gene editing, protein replacement therapies, biologics production, and more. The recent success of mRNA-LNP-based gene editing (NTLA-2001 [Intellia Therapeutics] and VERVE-101 and VERVE-102 [Verve Therapeutics]) in advanced preclinical and clinical trials has attracted considerable attention. In addition, other mRNA modalities, such as self-amplifying RNA platforms, circular RNA platforms, trans-amplifying RNAs, and others, are being explored for various ailments. Advances in AI/ML, systems biology, and genomic surveillance will further accelerate antigen discovery, lipid design, and vaccine optimization, enabling more proactive responses to future pandemics and emerging health threats.

Conclusion

In our opinion, we are witnessing a paradigm shift in vaccine development. The convergence of mRNA technology, advanced delivery systems such as LNPs, novel adjuvants, and precision immunology is redefining what vaccines can achieve. As scientific invention continues to accelerate, the next generation of vaccines will not only provide faster and more effective protection against infectious diseases but also open new therapeutic avenues for some of humanity's most challenging health conditions. The future of vaccines is no longer limited to prevention; it is becoming a powerful platform for personalized, adaptable, and globally accessible healthcare solutions.

Dr. Bonam's contributions to this field are reflected in a series of influential publications that have advanced our understanding of vaccine immunology, mRNA vaccine development, and host immune responses. His work has appeared in leading journals, including Vaccines (Basel) 2024, 10.3390/vaccines12050543, Proc Natl Acad Sci U S A 2023; https://doi.org/10.1073/pnas.2311752120, NPJ Vaccines 2024; https://doi.org/10.1038/s41541-024-00957-2, Sci Transl Med 2022; DOI: 10.1126/scitranslmed.abq1945 Science 2024; DOI: 10.1126/science.adn4955, J Virol 2026: 10.1128/jvi.01897-25, Am J Reprod Immunol 2024; DOI: 10.1111/aji.13861.



| EXPERT OPINION |

Beyond the Bite: The Double Life of Chikungunya Virus

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

Areas of expertise: Arbovirus biology | host–pathogen interactions | Mosquito (Aedes) immunity | vector biology | Proteomics | Transcriptomics | Metabolomics of virus–host interfaces | Host-directed antiviral strategies

Every time an Aedes mosquito takes a blood meal, it does more than leave an itchy welt. If the mosquito carries an arbovirus such as chikungunya virus (CHIKV) or Dengue virus (DENV), it deposits the pathogen into human skin, triggering a cascade of immune responses that the virus must evade to establish itself.

What is remarkable is how differently the virus behaves in the two hosts it depends on: in the mosquito, it persists silently for life without causing harm, while in the human body, it replicates aggressively across multiple tissues. My laboratory at the Vector Borne Diseases Group, ICGEB New Delhi, has spent several years examining both sides of this double life succeeding in two biologically distinct organisms through a conserved set of host–virus interactions.

The tolerant host: Persistent infection without pathology

When CHIKV enters Aedes aegypti, the mosquito mounts an innate immune response centred on reactive oxygen species (ROS). Transcriptomic profiling of infected Aag2 cells showed that early ROS spikes activate the Imd immune pathway through its transcription factor Rel2 — silencing Rel2 increased viral titres approximately 14-fold. However, the escalating ROS also induces antioxidant gene expression — glutathione metabolism, ascorbate synthesis, and cytochrome P450-dependent redox homeostasis — that progressively quenches the very ROS that drive immunity. As oxidative stress decreases, Rel2 signalling declines, relieving the virus of immune pressure and allowing replication to peak around 24 hours post-infection. The mosquito's own antioxidant self-preservation inadvertently provides the window the virus needs.

> *"In Aedes mosquitoes, CHIKV exploits the vector's own antioxidant response to silence innate immunity — explaining why mosquitoes remain lifelong viral reservoirs despite mounting a genuine immune defence."*

A complementary study in whole Aedes aegypti mosquitoes showed that dietary L-cysteine supplementation restricted CHIKV infection, coinciding with elevated glutathione S-transferase activity and reduced oxidative damage. Silencing genes in the taurine and hypotaurine biosynthetic pathway further altered viral loads and redox biology — confirming the cysteine–antioxidant metabolic axis as a genuine determinant of how much virus a mosquito harbours and transmits.

Viral non-structural proteins: Master host manipulators

CHIKV encodes four non-structural proteins (nsP1–nsP4) that form the replication complex, but each also recruits and repurposes host proteins. Our group

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systematically mapped the interactomes of nsP2 and nsP3 across human liver cells (Huh7), macrophages (THP-1), and Aedes albopictus cells, producing the most comprehensive cross-host interaction dataset for any CHIKV non-structural protein. In human cells, these viral proteins engage host networks enriched for TCA cycle enzymes, translation regulators, proteostasis machinery, and immune signalling through NF-κB and cGMP-PKG pathways. For nsP2, a direct comparison across human Huh7 and Aedes U4.4 cells identified six conserved interactors shared between both hosts — DEAD-box helicase, eIF3, succinate dehydrogenase, isocitrate dehydrogenase, glutathione S-transferase, and peptidyl-prolyl isomerase. This conserved core defines the pan-host dependencies CHIKV exploits in organisms as different as a mammal and a mosquito.

The infected cell: metabolic reprogramming across tissues

In human liver cells, argininosuccinate synthase 1 (ASS1), an enzyme of the urea cycle, emerged as an unexpected proviral factor. ASS1 sits at a metabolic fork where arginine can either feed nitric oxide synthase (NOS) to generate antiviral nitric oxide, or be converted by arginase 1 (ARG1) to ornithine and polyamines that support viral replication. CHIKV shifts this balance in its favour: ASS1 and ARG1 are upregulated during infection, polyamine levels rise, and nitric oxide falls. Silencing ASS1 reversed these changes and reduced viral titres by over 95%. ASS1 also suppresses STAT3, a key antiviral signalling protein, during infection — a suppression restored upon ASS1 silencing. Notably, succinate dehydrogenase and isocitrate dehydrogenase also appear as conserved nsP2 interactors across human and mosquito cells, suggesting convergent targeting of the TCA cycle is a signature of how CHIKV manages energy metabolism in every host.

In the joint, chikungunya disease causes arthritis that can outlast the acute infection by months or years. Standard rodent models fail to recapitulate this chronicity. Our group developed a three-dimensional spheroid system from primary human chondrocytes that sustains productive CHIKV infection for up to seven days. Global proteomics of infected spheroids revealed activation of interferon-stimulated genes, NF-κB inflammatory signalling, elevated IL-6, TNF-α, and IL-1β, and perturbation of arginine and proline metabolic pathways — echoing the liver findings. The sustained inflammatory response, with matrix metalloprotease activity maintained over days, appears to precisely drive extracellular matrix remodelling and chronic joint damage. The enemy is partly the virus, but partly the cell's own prolonged attempt to fight it.

> *"Comparative interactome mapping of CHIKV nsP2 in human and mosquito cells uncovered six conserved host proteins spanning TCA cycle enzymes, translation factors, and redox regulators — defining pan-host dependencies the virus exploits across species."*

Across the two hosts: Conserved host dependencies

Across every system studied — mosquito cells, human liver, joint, and macrophages — CHIKV converges on the same molecular themes: TCA cycle enzymes, redox homeostasis, and translation initiation machinery. This convergence is encouraging therapeutically, because it suggests a small set of host-directed interventions could interrupt CHIKV replication across tissues and potentially in the vector. Unlike direct antivirals, host-directed strategies targeting metabolic enzymes or redox pathways are inherently harder for a fast-evolving RNA virus to escape through mutation.

Challenges and the road ahead

Significant challenges remain. Pharmacological inhibitors suitable for clinical use do not yet exist for key host targets such as ASS1. The in vitro systems used, however sophisticated, do not fully capture immune cell crosstalk and systemic metabolism in a living organism. Validation in in vivo models and functional perturbation of conserved interactors are

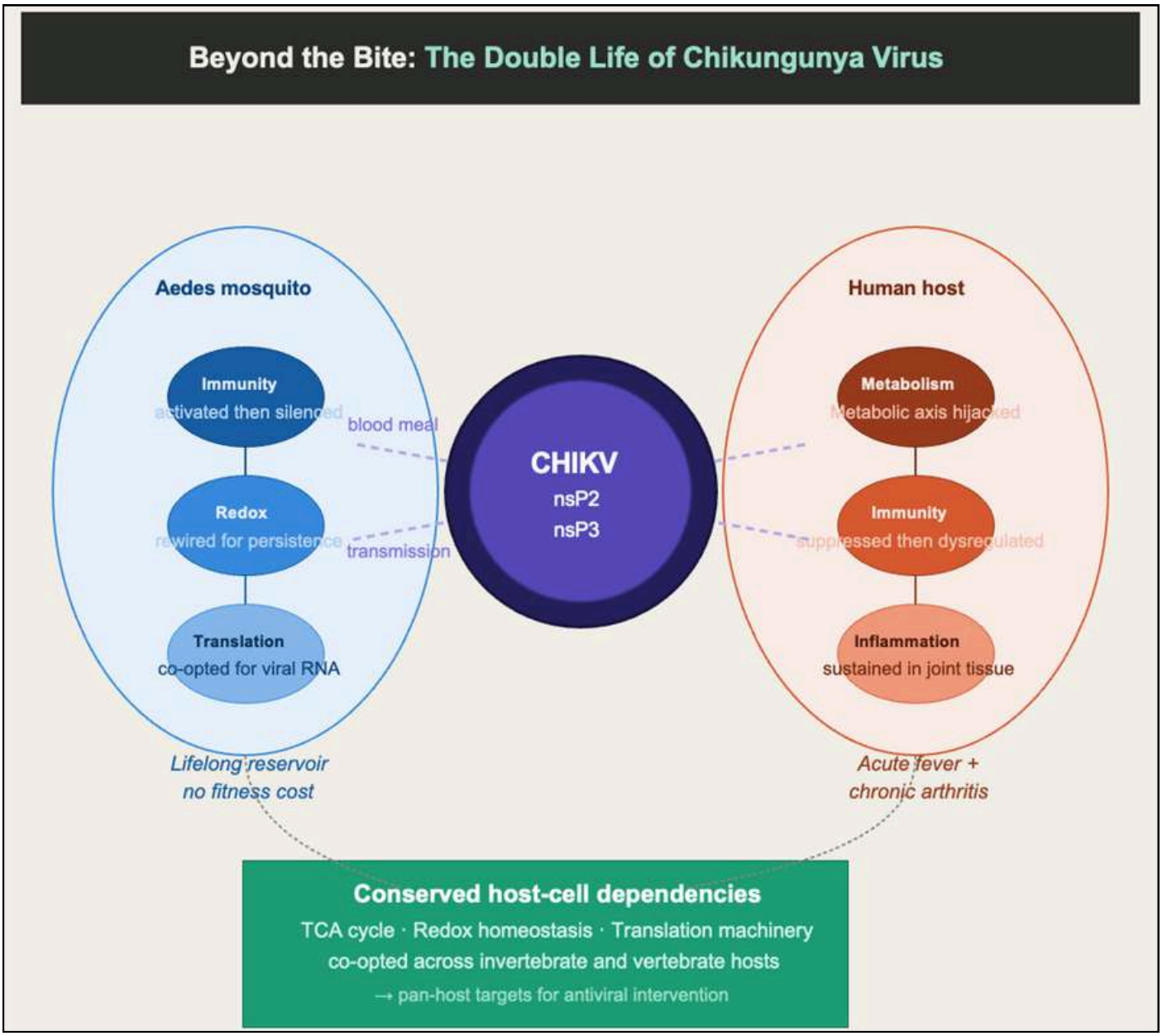

Figure 1. CHIKV exploits conserved host-cell dependencies in both the Aedes mosquito vector and the human host, driving persistent infection in the vector and acute and chronic disease in humans, mediated through the viral non-structural proteins nsP2 and nsP3.

important next steps. Extending the interactome approach to nsP1 and nsP4 would complete the replication complex map. On the vector side, translating the redox and taurine–cysteine findings into strategies that reduce mosquito vector competence is a long-term goal with direct public health impact.

Looking forward

Our findings suggest CHIKV infection is better understood as a sequence of tissue-specific negotiations, each conducted using a similar vocabulary of metabolic and immune signalling molecules shaped by the virus's two-host evolutionary history. The mosquito is not merely a syringe; it is a co-evolutionary partner that has shaped which host vulnerabilities CHIKV exploits. Understanding both sides of this relationship simultaneously may be the most efficient path to interventions that work at the source — in the vector — as well as at the site of disease in the human patient.

A concluding message

Chikungunya virus is a master of metabolic persuasion. In the mosquito, it outwits immunity by letting the vector's an-

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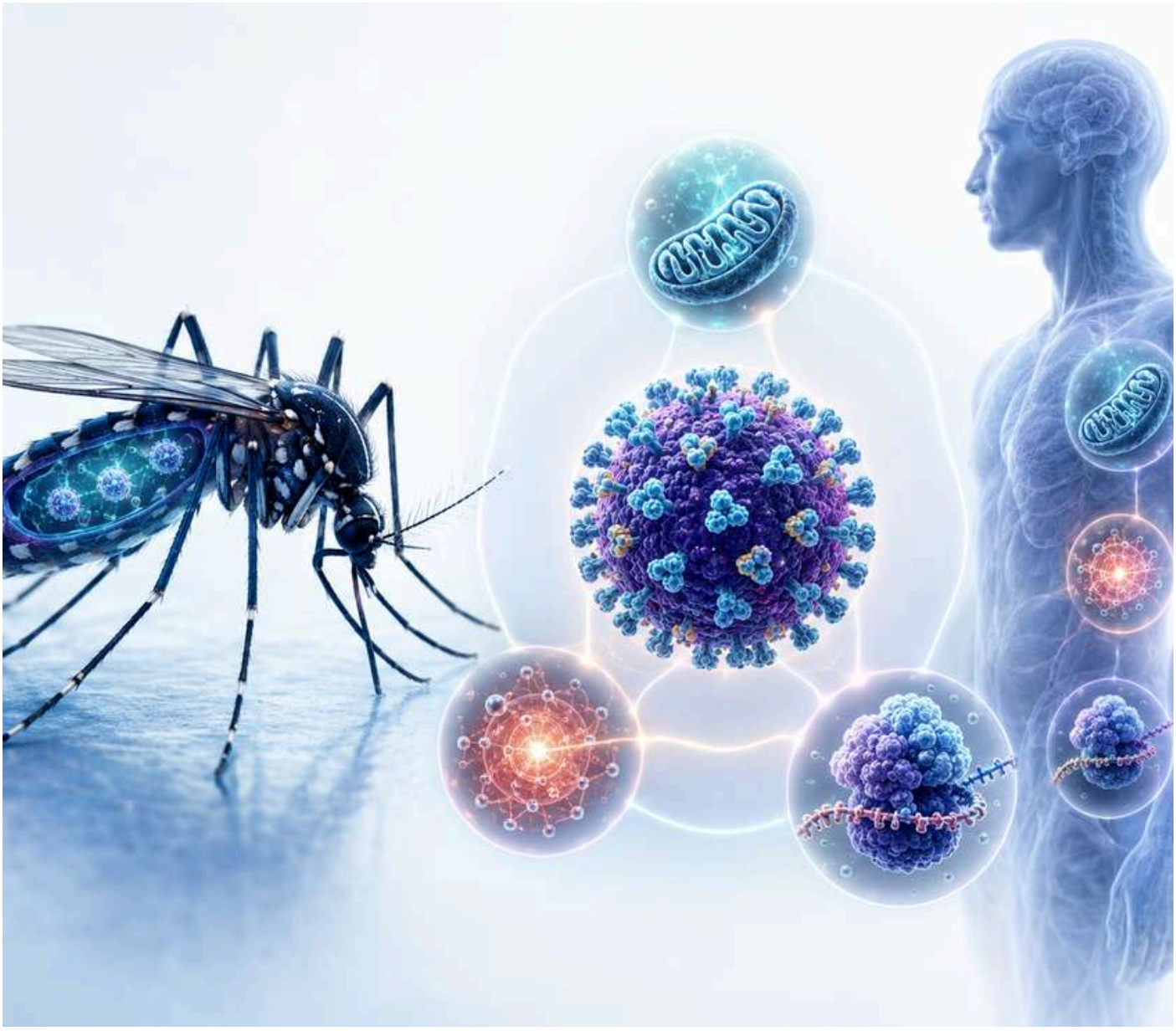
tioxidant defences suppress the very signals that would clear it. In humans, it hijacks arginine metabolism, redirects TCA cycle energy, co-opts translation machinery, and sustains inflammatory signalling in joints long after active replication has waned. The same non-structural proteins accomplish all of this across both hosts — a finding that points toward shared therapeutic targets and a more unified vision of arboviral biology.

Dr. Sujata's contributions to the field of chikungunya virus (CHIKV) biology, host–virus interactions, and vector-pathogen dynamics are reflected in her recent publications in Journal of Virology (2026; DOI: 10.1128/jvi.02098-24), ACS Omega (2025; DOI: 10.1021/acsomega.5c02832), VirusDisease (2025; DOI: 10.1007/s13337-025-00941-x), International Journal of Molecular Sciences (2025; DOI: 10.3390/ijms26146832), Frontiers in Virology (2024; DOI: 10.3389/fviro.2024.1310161), Journal of General Virology (2024; DOI: 10.1099/jgv.0.001966), and PLoS Neglected Tropical Diseases (2023; DOI: 10.1371/journal.pntd.0011280). These studies provide important insights into the molecular mechanisms of CHIKV infection, including viral protein–host interactions, metabolic regulation, oxidative stress responses, proteomic profiling, immune signaling, and the factors that govern virus replication in both human and mosquito cells.



| EXPERT OPINION |

How Cells Manage Fat and Why It Matters for Health

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

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Areas of Expertise: Neuroscience | Neurophysiology | Retinal diseases

The global prevalence of metabolic syndrome (MetS) has reached alarming proportion with ~30% of the world's adult population being affected marking a significant public health crisis driven by obesity, sedentary lifestyle, and ageing. Our group is investigating obesity at the molecular level by studying lipid droplets (LDs), an organelle dedicated to fat storage. LDs are found in all cell types, including skeletal muscles, heart muscles, kidney, liver and brain cells. However, in adipocytes LDs are strikingly large, unilocular and they fill the entire volume of the cell. Though, LD biogenesis occurs in virtually all cell types, and an incremental progress has been made in recent years towards an understanding in the molecular mechanisms of this pathway, our knowledge is far from complete. Dysregulated lipid metabolism manifests in various pathological conditions such as obesity, type-2 diabetes, insulin resistance, fatty liver, lipodystrophy, cancer and neuronal diseases. A more detailed understanding of how LDs are formed is thus important to apprehend the etiology of these syndromes.

> *"Biogenesis of sterol ester-rich lipid droplets employ distinct molecular factors from those involved in triacylglycerol-rich lipid droplet formation."*

LD biogenesis occurs in the endoplasmic reticulum (ER), a membranous labyrinth within the cytoplasm where enzymes catalyzing production of storage fats/neutral lipids (NLs), triglycerides (TAG) and sterol (cholesterol) esters (SE) resides. Previously we have demonstrated that LD formation in response to metabolic cues is restricted to few highly defined and specialized ER subdomains demarcated by ER transmembrane protein seipin. Cryo-electron microscopy studies have revealed how seipin assemble into oligomeric complex at LD biogenesis sites. Interestingly, seipin is a non-enzymatic protein defects in which results in lipodystrophic syndrome characterized by selective loss of adipose tissue, along with neurological problems collectively known as seipinopathies. Seipin at LD biogenesis sites

collaborates with several LD biogenesis factors to establish the machinery of droplet formation. Seipin performs a decisive role in initiating LD biogenesis, absence of which results in ectopic TAG packaging, resulting in abnormally small or oversized LDs that cannot function properly, thereby affecting overall fat metabolism. However, how these sites are selected and regulated remains largely unknown. Most of the studies by far have focussed on the assembly of TAG-rich LDs, where critical role of seipin has been established, however, the mechanism of biogenesis of SE-rich LDs remains largely unknown. In mammals, steroidogenic tissues such as the testis, ovary, and adrenal glands specialize in storing SE-rich LDs, that undergo rapid degradation upon demand for steroid hormone production. Hence, better understanding of SE-rich LD biogenesis and its turnover will provide molecular insights into flux of sterols for steroid hormone biosynthesis.

We used specially engineered baker's yeast, Saccharomyces cerevisiae, to investigate the origins of TAG-rich/SE-rich LDs. Since both yeast and humans store excess fats into LDs, yeast serves as an excellent model to elucidate the molecular details of this pathway. Remarkably, most of the findings in yeast is conserved in mammals and mammalian orthologues can functionally complement yeast mutants. For example, human seipin can rescue yeast seipin (Sei1) deletion. We have elegantly shown that seipin defined ER sites exist even in cells that have no LDs, and that upon initiation of either TAG or SE biosynthesis using genetic mutants, cells begin to produce droplets that contain exclusively TAG-rich or SE-rich LDs respectively at the seipin-complex (Figure 1A, B).

Surprisingly, we found that a truncated form of seipin, Fld1-ΔLR in yeast, and the human equivalent hSeipin-ΔLR, mutants devoid of the conserved luminal domain region (LR) can functionally complement the role of wild-type seipin. Remarkably, truncated seipin containing the transmembrane domains and lacking the LR mimics functional wild-type seipin in defining ER sites that recruits the full LD biogenesis machinery resulting in de novo LDs being born at these locations. Interestingly, we demonstrate that Fld1-ΔLR can oligomerize independently of the LR facilitated by protein-protein interaction between Fld1-ΔLR monomers. We found that yeast seipin mutants expressing Fld1-ΔLR/hSeipin-ΔLR had markedly increased steady state TAG levels, indicating important regulatory role of the luminal domain in seipin. Our data suggests that luminal domain in seipin is dispensable in defining functional LD biogenesis sites in the ER, thus providing mechanistic insights into the process of LD assembly.

> *"The luminal domain region of seipin is dispensable in defining functional sites of lipid droplet biogenesis in the ER."*

More recently, we have shown that similar to TAG-rich LDs, biogenesis of SE-rich LDs also occur at seipin marked ER sites. This has allowed us to investigate this process in greater detail to uncover which proteins are selectively recruited at seipin defined ER sites when cells are actively making TAG-rich vs SE-rich LDs. We provide evidence that several key factors and/or lipid that localize at Sei1 sites during biogenesis of TAG-rich LDs fail to do so when cells are engaged in the production and assembly of SE-rich LDs. We found that deletion of Nem1, Yft2 or Pex30, factors previously known to be crucial for the biogenesis and growth of TAG-rich LDs, were dispensable for the biogenesis of SE-rich LDs. Moreover, neither Pah1, the mammalian lipin homolog, nor diacylglycerol (DAG), a product of Pah1 enzyme and a substrate for TAG synthesizing enzymes accumulated at Sei1 sites upon induction of SE-rich LD formation. This indicates that TAG vs SE production is uncoupled by means of factors that get recruited at seipin sites (Figure 1C). The findings suggest that specialized pathw-

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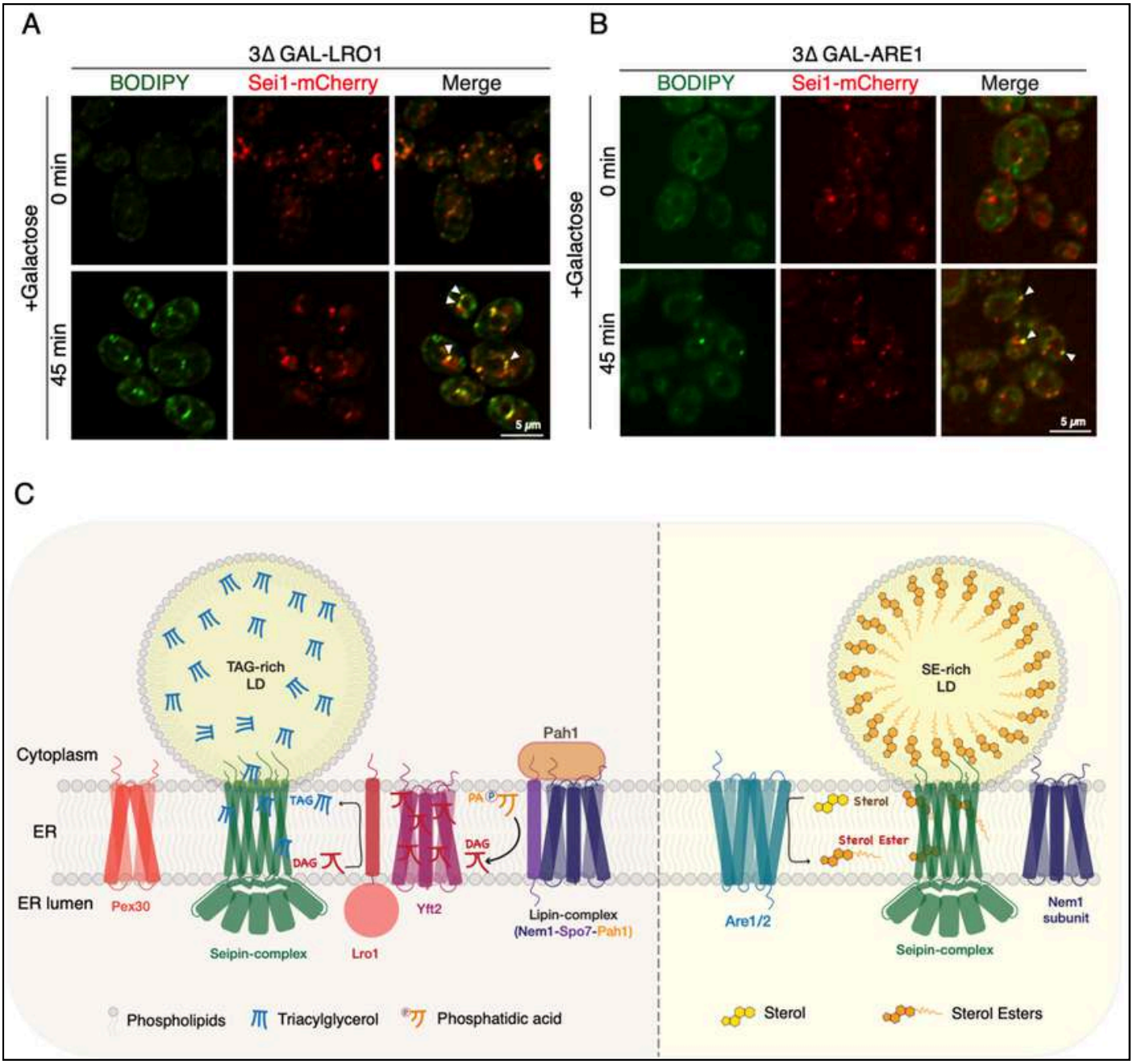

Figure 1. De novo lipid droplet biogenesis at Seipin-complex in the ER. A, B) Stimulation of de novo LD production. Yeast genetic mutants that can produce de novo TAG-rich LDs (A) or SE-rich LDs (B) expressing mCherry tagged Seipin (Sei1), an ER protein shows distinct punctate localization when cells do not contain LDs (0 min time point). Transcriptional induction of either TAG synthesis (A) or SE synthesis (B) results in very first LDs to be born at Seipin sites revealed by BODIPY staining, a green fluorescent LD dye (45 min time point). White arrowheads denote colocalization of LDs with Seipin foci. C) Model of LD biogenesis. Seipin-complex localizes to distinct ER subdomains. Induction of either TAG-rich or SE-rich LD biogenesis results in recruitment of distinct factors to facilitate droplet assembly. Assembly of TAG-rich LDs drives recruitment of factors such as Nem1, Pah1, Yft2, Pex30, and TAG-synthase Lro1 at these ER sites. Upon stimulation of SE-rich LD formation, SE synthesizing enzymes Are1, and Are2 become enriched at Seipin sites. Remarkably, Pah1, Yft2, and Pex30 failed to get recruited when cells were engaged in SE-rich droplet assembly. Although Nem1 colocalized with Seipin, however, deletion of Nem1 did not abrogate SE-rich LD formation at Seipin-complex suggesting dispensable role in the assembly of SE-rich LDs.

ay exist for storage of different class of lipids via recruitment of distinct molecular factors during birth of LD. Identifying novel leads to fine tune this process will have far reaching implications for therapeutic interventions

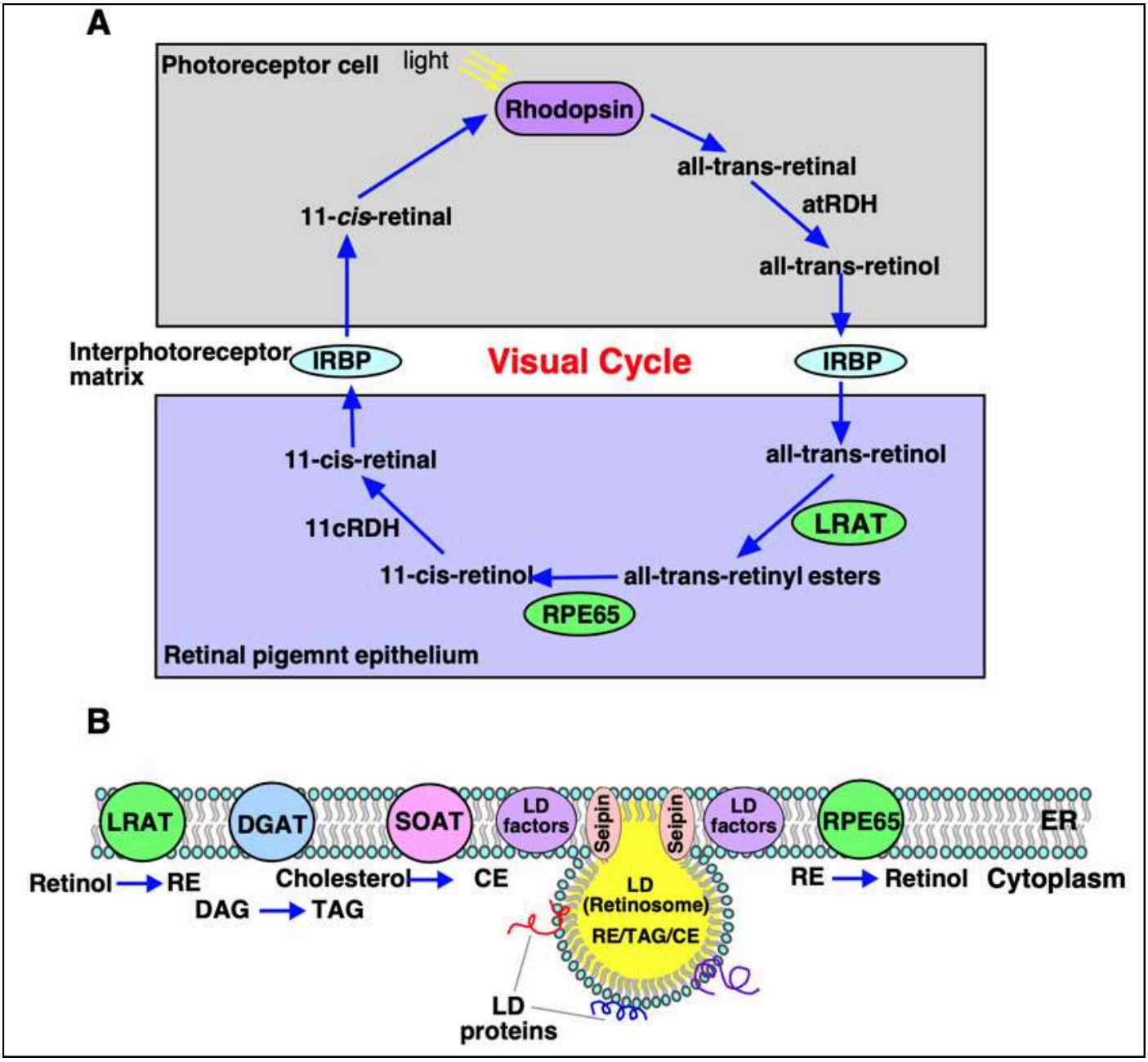

Figure 2. Classical visual cycle. A, B) Schema depicting visual cycle homeostasis (A). The cycle begins with the transport of all-trans-retinol in the RPE cells. Interphotoreceptor retinol binding protein (IRBP) binds and solubilizes all-trans-retinol within the interphotoreceptor matrix and directs it to the endoplasmic reticulum (ER) of RPE cells where lecithin:retinol acyltransferase (LRAT) converts it into all-trans-retinyl esters (RE), a storage form of vitamin A that is deposited into retinosomes/lipid droplets (LDs) together with other neutral lipids, triacylglycerol (TAG) and cholesterol esters (CE) (A, B). Diacylglycerol:acyltransferase (DGAT) produce TAG, whereas sterol O-acyltransferase (SOAT) synthesize CE. TAG and CE are sequestered by ER membrane protein Seipin resulting in nucleation of nascent LD that grows and emerges towards the cytoplasm. Various molecular factors assist in the biogenesis of LDs at seipin defined ER sites (B). RPE65 catalyzes conversion of RE to 11-cis-retinol, a critical step in the functioning of the visual cycle. 11-cis-retinol is further oxidized by the enzyme 11-cis-retinol dehydrogenase (11cRDH) (A, B). 11-cis-retinal is bound by IRBP and exported to photoreceptor cells where it combines with the protein opsin within the outer segment (OS) disc membrane to form the complex rhodopsin (light sensitive pigment). When light stimulus strikes rhodopsin, the 11-cis-retinal gets converted to all-trans-retinal, thereby triggering a conformation change and activating phototransduction cascade. The formed 11-trans-retinal is released and reduced to all-trans-retinol by atRDH enzyme and is exported to RPE cells by IRBP to continue the visual cycle.

in LD storage disorders.

We further demonstrate that yeast SE acyltransferases, Are1 and Are2, become enriched at seipin defined ER sites during stimulation of SE production indicating that SE synthesis occurs locally, a likely prerequisite for efficient sequestration of SEs and droplet assembly. Consistent with this we have previously shown that TAG producing enzyme, Lro1 gets recruited to seipin sites upon induction of de novo TAG biosynthesis. This indicates that cells have mechanisms in place that control localized accumulation of TAG/SE so as to prevent the detrimental consequences of ectopic NL synthesis throughout the ER membrane. Seipin along with accessory factors would bind to TAG/SE and perhaps act as gatekeepers, thereby allowing growth and maturation of nascent LDs.

In a recent review we highlighted the importance of lipid homeostasis in the retina to ensure proper visual functioning and how dysregulation in this process due to genetic or acquired factors is implicated in the pathogenesis and progression of several retinal diseases. The visual cycle is a continuous biochemical pathway in the retina between the photoreceptor cells (rods and cones) and the retinal pigment epithelium (RPE) that regenerates 11-cis retinal, a light sensitive molecule essential for vision (Figure 2A). Upon light absorption in the photoreceptor cells, 11-cis retinal undergoes step-wise transformation to all-trans retinol (vitamin A) form that translocates to the RPE cells. In the RPE all-trans retinol is esterified by ER localized enzyme lecithin-retinol acyltransferase (LRAT) to retinyl-esters (RE) that are deposited into morphologically unique lipid droplet (LD) structures called retinosomes (Figure 2A, B). Apart from RE, retinosomes store TAG, SE, and cholesterol. Upon demand REs are hydrolyzed by an ER localized isomerohydrolase, RPE65 generating 11-cis retinol that upon oxidation forms 11-cis retinal that moves back to photoreceptor cells, combines with opsin and rebuilds rhodopsin thereby completing visual cycle (Figure 2A, B). Several mutations in RPE65 have been implicated in retinal pathologies including Leber's congenital amaurosis (LCA), and retinitis pigmentosa (RP), underscoring the important role of RPE65 in the visual cycle. Hence LDs/retinosomes in the retina play a crucial role in visual chromophore homeostasis for maintaining normal vision. How seipin might promote sequestration and formation of RE-rich LDs and what factors are involved in this process awaits future investigation. In pathological retina, dysregulated lipid metabolism results in extracellular deposition of aggregated lipids and proteins known as "drusen" that slows down trafficking of nutrients and removal of waste materials between RPE and blood vessels resulting in dysfunctional RPE thereby impairing vision.

> *"Retinosomes in the retina play a crucial role in visual chromophore homeostasis for maintaining normal vision."*

The most perplexing question is what determines localization of seipin. Whether it is mediated by protein or lipid cues, or a combination of both remains to be determined. Knowing more about how these ER subdomains are formed will pave the way forward in deciphering the mechanism of LD biogenesis. Mature LDs interact with several organelles via membrane contact sites to facilitate bidirectional lipid transfer. Although several tethering factors have been identified, the dynamics of LD-membrane contact association and its release in response to environmental cues is poorly understood. Although our studies provide insights into distinct mechanisms for storage of TAG vs SE containing LD, it remains to be determined how SE packaging is coordinated with TAG filling into LDs. Moreover, whether seipin plays a role in the biogenesis of RE containing LDs/retinosomes remains largely unexplored.

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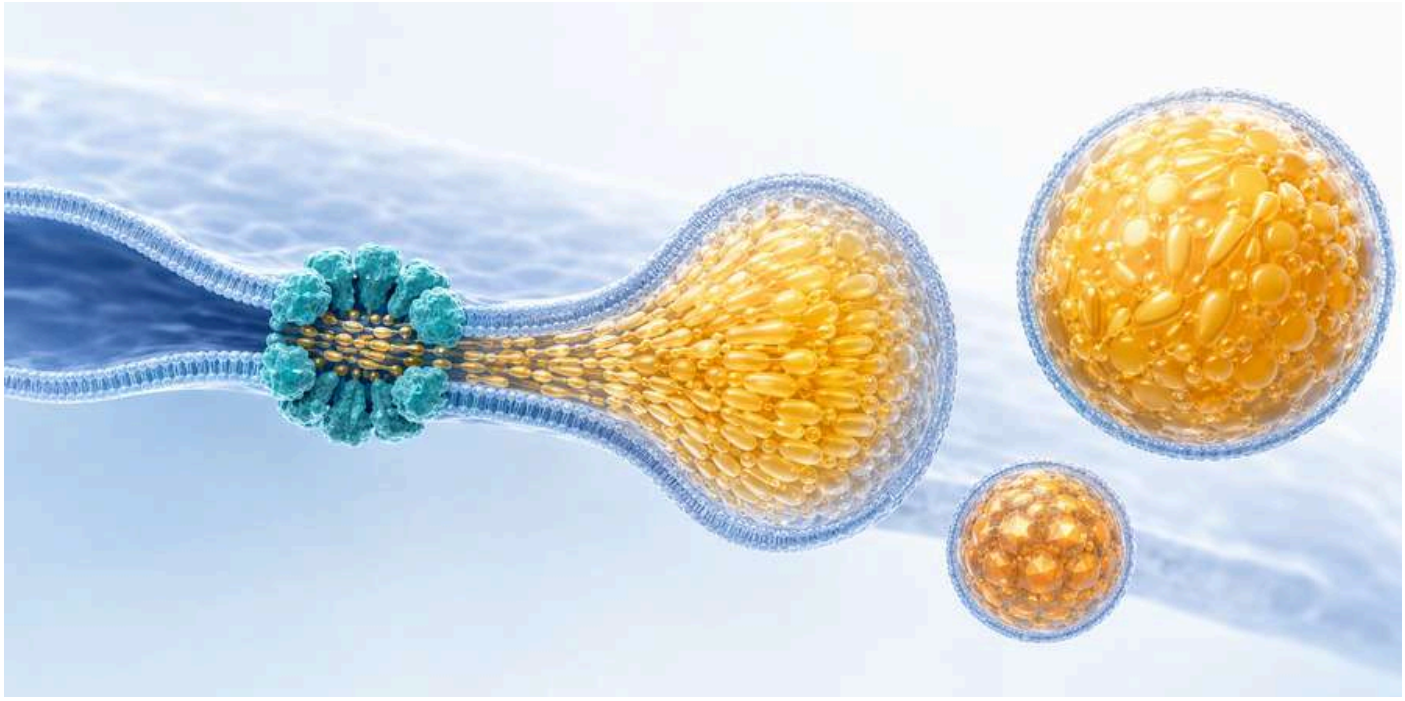
What we have learnt is that LD biogenesis is an intricately regulated process. Absence of LD biogenesis factors, due to genetic mutation or deletion impairs droplet formation, resulting in ectopic NL production and deposition of aberrant LDs, manifesting in ER stress and lipotoxicity, thereby impacting cell physiology and metabolism. Elucidating how this process maintains energy homeostasis, provides key insights into metabolic disorders such as obesity, diabetes, insulin resistance, and lipodystrophy.

Moving forward, we would like to characterize this process in mammalian cells to better understand how cells handle sudden influx of fatty acids for efficient storage into LDs in a regulated manner thereby preventing lipotoxicity. It would be interesting to determine how different domains in seipin might be orchestrating an organized filling of TAG/SE into LDs. It remains to be determined if mammalian SE-acyltransferases SOAT1/SOAT2 would also localize at seipin sites for the synthesis of SE-rich LDs. How does the Sei1-complex concentrate SEs/REs? Knowing how seipin interacts with its partner proteins during lipogenesis or lipolysis will likely reveal how sites for LD biogenesis are selected and what role LDs play in energy metabolism homeostasis at cellular, tissue and whole organism's level. Findings in the coming years will bring novel insights into the pathological conditions that results due to impaired LD biogenesis and/or its defective intracellular trafficking and thus opening new avenues for developing therapeutic leads for lipid storage disorders.

Dr. Vineet Choudhary's contributions to the field of lipid biology are reflected in his research on lipid droplet biogenesis, endoplasmic reticulum organization, and lipid homeostasis. His work has uncovered key mechanisms regulating lipid droplet formation and highlighted the role of lipid homeostasis in retinal diseases. These findings have been published in leading journals, including Nature Communications (2025; DOI: 10.1038/s41467-025-65645-8), iScience (2026; DOI: 10.1016/j.isci.2026.115655), and Communications Biology (2026; DOI: 10.1038/s42003-026-10025-1).3.

Acknowledgement
This work was supported by an Indo Swiss Joint Research Programme of Department of Biotechnology (Grant: IC-12044(11)/6/2021-ICD-DBT awarded to VC), an Extramural Grant of the Indian Council of Medical Research (ICMR), New Delhi (Grant: IIRPSG-2025-01-01895 awarded to VC) and DBT/Wellcome Trust India Alliance Fellowship (Grant IA/I/20/2/505191 awarded to VC). AB is supported by Ramanujan Fellowship of Science and Engineering Research Board (SERB), Department of Science and Technology (DST), Government of India (Grant: RJF/2019/000040), and the Core Research Grant (CRG) of SERB, DST (CRG/2021/003472).



| EXPERT OPINION |

Making Private TB Care Visible: Lessons from Quality Improvement in Public Health Notification Systems

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Areas of expertise: Tuberculosis Control | Implementation Research | Quality Improvement | Community Medicine | Physical Chemistry of macromolecules

Tuberculosis (TB) remains one of the world's leading infectious diseases and continues to be a major public health challenge in India. Although significant progress has been made in diagnosis, treatment, and programme implementation, India still accounts for the largest share of the global TB burden. Eliminating TB requires more than providing quality treatment. It also requires timely notification of every diagnosed patient to the public health system. TB notification is much more than a reporting requirement. It forms the foundation of disease surveillance. It helps health authorities understand where TB is occurring, monitor treatment, trace contacts, and allocate resources effectively. Without complete notification, patients become invisible to the programme, making it difficult to achieve the goal of TB elimination.

The private healthcare sector plays a critical role in India's health system. A large proportion of patients with symptoms suggestive of TB first seek care from private practitioners, hospitals, diagnostic laboratories, or pharmacies. These providers diagnose and treat thousands of TB patients every year. Their active participation is therefore essential for strengthening surveillance and improving programme performance. Recognizing this, the Government of India has introduced several initiatives to improve private-sector engagement. Mandatory TB notification, the Ni-kshay digital platform, Public–Private Mix (PPM) activities, and provider incentives have all strengthened reporting. Nationally, these efforts have increased private-sector notifications. However, progress has not been uniform across districts. Many areas continue to face operational challenges that limit private-sector participation.

> *"Quality improvement transforms policy into practice by making existing health systems simpler, stronger, and more responsive."*

Our experience from the Akot Tuberculosis Unit highlighted an important reality. The biggest barriers were rarely related to policy. Instead, they were practical problems encountered during routine clinical practice. Busy outpatient clinics, limited familiarity with digital reporting, technical difficulties, and infrequent communication with programme staff affected notification practices. These challenges could not be solved by regulations alone. They required continuous support and collaboration.

From Policy to Practice

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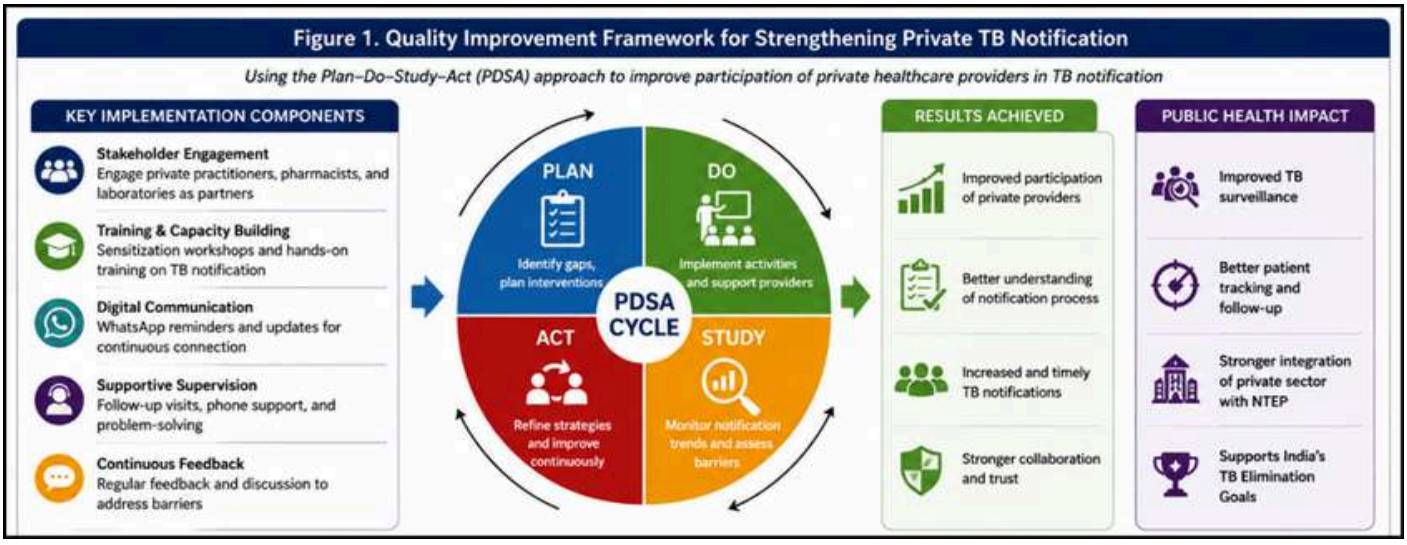

Figure 1. Quality Improvement Framework for Strengthening Private TB Notification. The quality improvement framework illustrates how the Plan–Do–Study–Act (PDSA) cycle was used to strengthen private TB notification through stakeholder engagement, capacity building, digital communication, supportive supervision, and continuous feedback. The framework highlights the progression from identifying local barriers to improved surveillance and stronger public–private collaboration.

To address these challenges, we adopted a quality improvement approach. The objective was not to introduce a new programme but to strengthen the existing one. We worked closely with private practitioners, pharmacists, laboratory personnel, and district TB programme staff. Rather than assuming the causes of poor notification, we first tried to understand them. The solutions were intentionally simple. Sensitization meetings improved awareness of TB notification. Regular WhatsApp communication kept providers informed and connected. Technical support helped resolve problems related to the Ni-kshay platform. Follow-up visits created opportunities to answer questions and address operational difficulties. Every intervention was designed to fit within routine programme activities. One important observation was that healthcare providers were willing to participate when the reporting process became easier and support was readily available. Most providers did not oppose notification. They simply needed practical guidance and confidence in the system. This finding reinforces an important principle of implementation research: improving systems often depends more on reducing operational barriers than introducing new technology.

Our quality improvement initiative demonstrated that district-level TB notification can be strengthened without introducing new reporting systems or major financial investments. By combining stakeholder engagement, digital communication, supportive supervision, and continuous feedback within the existing NTEP framework, the initiative provided a practical model that can be replicated in similar programme settings. The experience reinforces the growing importance of implementation research in translating public health policies into routine practice.

The Value of Partnership

Perhaps the greatest achievement of this initiative was not the increase in notification alone. It was the stronger partnership that developed between the public health programme and private healthcare providers. Regular interaction created trust. Private practitioners became more comfortable discussing their concerns. Programme staff gained a better understanding of the realities of private clinical practice. Communication became more open, and problems were solved more quickly. This partnership changed the way notification was perceived. It was no longer viewed as an administrative obligation. Instead, it became a shared responsibility for improving patient care and strengthening public health. These experiences demonstrate that successful programmes depend as much on relationships as they do on technology. Digital platforms can simplify reporting, but they cannot replace regular communication, mutual respect, and supportive supervision.

Remaining Challenges and Knowledge Gaps

Although India has made substantial progress in strengthening private TB notification, important challenge-

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s remain. The success of quality improvement initiatives depends on sustained engagement with healthcare providers and continued support from programme teams. Maintaining these efforts over time can be difficult, especially in resource-constrained settings. Evidence on the long-term sustainability of quality improvement interventions is still limited. More implementation research is needed to identify strategies that work across different districts, urban and rural settings, and diverse private healthcare systems. Future studies should also evaluate the cost-effectiveness of these interventions, the role of digital technologies, and innovative approaches to strengthen long-term engagement of private healthcare providers. Addressing these knowledge gaps will help develop scalable and sustainable models that can support TB elimination not only in India but also in other high-burden countries.

Lessons Beyond Tuberculosis

The lessons from this work extend well beyond TB control. Many public health programmes depend on collaboration between public agencies and private healthcare providers. Immunization, maternal and child health, non-communicable disease screening, antimicrobial resistance surveillance, and outbreak preparedness all require timely reporting and coordinated action. Quality improvement offers a practical framework for strengthening these programmes. It encourages teams to identify local barriers, test simple solutions, evaluate outcomes, and refine interventions over time. This approach allows programmes to adapt to local needs without requiring major structural changes or additional resources. One important lesson is that small improvements can have a large cumulative impact. A phone call, a follow-up visit, a WhatsApp message, or timely technical assistance may appear simple, but together they create a system that is easier to use and more responsive to healthcare providers.

> *"Strong public–private partnerships are as important as digital innovations for improving tuberculosis notification and strengthening disease surveillance."*

Looking Ahead

India has made remarkable progress in engaging the private sector for TB control. The next phase should focus on improving the quality of engagement rather than simply expanding reporting mechanisms. Digital innovations, including user-friendly reporting systems, artificial intelligence-assisted decision support, and mobile health technologies, may further strengthen programme performance. However, technology should complement, not replace, strong partnerships between healthcare providers and public health teams.

Future implementation research should focus on identifying strategies that are sustainable, scalable, and adaptable across different healthcare settings. More evidence is needed on long-term provider engagement, integration of digital tools into routine practice, and cost-effective models that can be implemented across districts with different resource levels. Sharing successful district-level experiences will help accelerate learning across programmes and strengthen national TB elimination efforts. Making private TB care visible ultimately means making every patient visible to the health system. When healthcare providers, programme managers, researchers, and policymakers work together, notification becomes more than a reporting exercise. It becomes a vital step towards better surveillance, better patient care, and ultimately, a TB-free India.

Dr. Kawalkar's contributions to the field of tuberculosis control, quality improvement, and public health implementation research are reflected in her recent publication in PLOS Global Public Health (2026; 10.1371/journal.pgph.0006480), which demonstrates how a Plan–Do–Study–Act (PDSA) quality improvement approach can enhance tuberculosis case notification from the private healthcare sector.

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Nanoscale Confinement: How Molecular Barrels are Unlocking Fullerene-Driven Green Photocatalysis in Water

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Nature has spent billions of years refining chemical processes. Within living systems, enzymes carry out complex transformations with remarkable efficiency and selectivity. Crucially, the enzymes execute these transformations under incredibly mild conditions, entirely in water. How do the enzymes achieve such precision? Their performance does not arise solely from the intrinsic properties of their catalytic centers. Equally important is the highly specific, confined microenvironment surrounding these active sites. This allows enzymes to position substrates precisely, protect reactive intermediates, suppress undesired pathways, and control the movement of molecules into and out of their catalytic pockets.

> *Unlike closed cages that suffer from product inhibition, the open-ended design of molecular barrels balances robust guest confinement with smooth, continuous chemical exchange.*

One of the central goals of supramolecular chemistry has been to replicate these features in artificial systems. Can synthetic molecular architectures be designed to mimic the functional environments of enzymes while offering robustness, tunability, and structural diversity available through modern chemical synthesis?

Building the Molecular Barrels: Self-assembly at the nanoscale

Over the past several decades, coordination-driven self-assembly has emerged as a powerful tool for the construction of well-defined, discrete three-dimensional metal-organic architectures. Through the spontaneous organization of metal ions and organic ligands, it is possible to generate complex molecular structures in high yield with precise control over shape, size, and functionality. Importantly, the internal cavities of these architectures provide confi-

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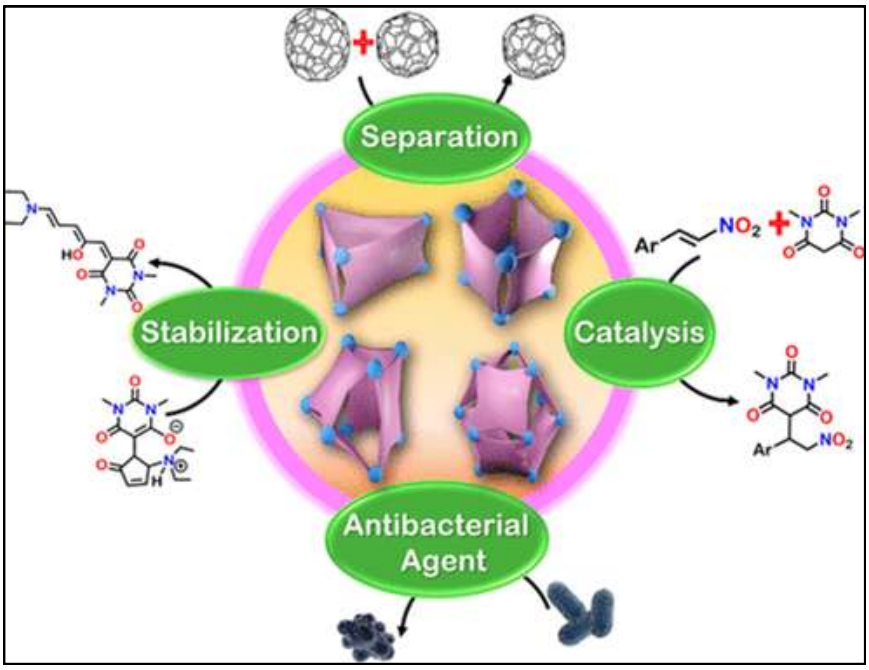

Figure 1. Molecular Barrels: From Design to Applications. Design of self-assembled molecular barrels and its applications. Reproduced from American Chemical Society, Copyright © 2023 American Chemical Society, https://doi.org/10.1021/jacs.3c01084.

ned reaction spaces that can emulate key features of enzyme active sites by organizing substrates, stabilizing reactive intermediates, and influencing chemical transformations. Historically, many synthetic molecular cages were designed as closed architectures with small openings. While these systems proved highly efficient for guest encapsulation, they often suffered limitations in catalysis. Reactants could enter the cavity and undergo transformation, but the resulting products sometimes remained trapped inside the host. This leads to product inhibition, reducing catalytic efficiency by preventing continuous turnover.

To address this challenge, our group has focused on developing molecular barrels. These self-assembled architectures possess elongated internal cavities enclosed by continuous aromatic walls and large open windows at both ends. Such a design combines two essential features required for efficient host–guest chemistry. The confined cavity provides a protected environment capable of stabilizing reactive species and pre-organizing substrates, while the open ends allow the efficient exchange of reactants and products. As a result, molecular barrels represent attractive platforms for developing artificial enzyme-like reaction vessels.

Fullerene Chemistry and Challenges

Among the many molecular guests that can benefit from supramolecular confinement, fullerenes occupy a special position. The cage-like carbon allotropes C_{60} and C_{70} possess exceptional photophysical and electronic properties, making them highly effective photosensitizers. Upon light absorption, they can generate reactive oxygen species that drive a wide range of oxidation reactions. These characteristics have made fullerenes attractive candidates for applications in photocatalysis, energy conversion, and materials science. Despite their promise, the practical use of fullerenes remains challenging. Their extremely poor solubility in water and strong tendency to aggregate significantly limit their performance in aqueous environments. Aggregation suppresses excited-state processes and reduces the efficiency of reactive oxygen species generation. Consequently, many of the desirable photochemical properties of fullerenes become inaccessible under conditions where sustainable chemical transformations are most desirable.

Various approaches have been explored to improve fullerene solubility. Covalent modification by introduction of solubilizing functional groups can increase aqueous compatibility, but these strategies are often synthetically demanding and may alter the intrinsic properties of the fullerene. An alternative approach is to use supramolecular host–guest interactions to control fullerene behaviour without permanently modifying its structure.

Our group has been interested in exploring how molecular barrels could be used for fullerene binding. In our earlier studies, we observed that fullerene binding could induce significant structural reorganization within self-assembled hosts. The introduction of a fullerene guest triggered the transformation of one cage architecture into another, resulting in enhanced singlet oxygen generation and improved photocatalytic activity. Subsequent studies showed that fullerene confinement within molecular barrels could prevent aggregation and enable efficient photocatalysis under visible and even promote catalysis under

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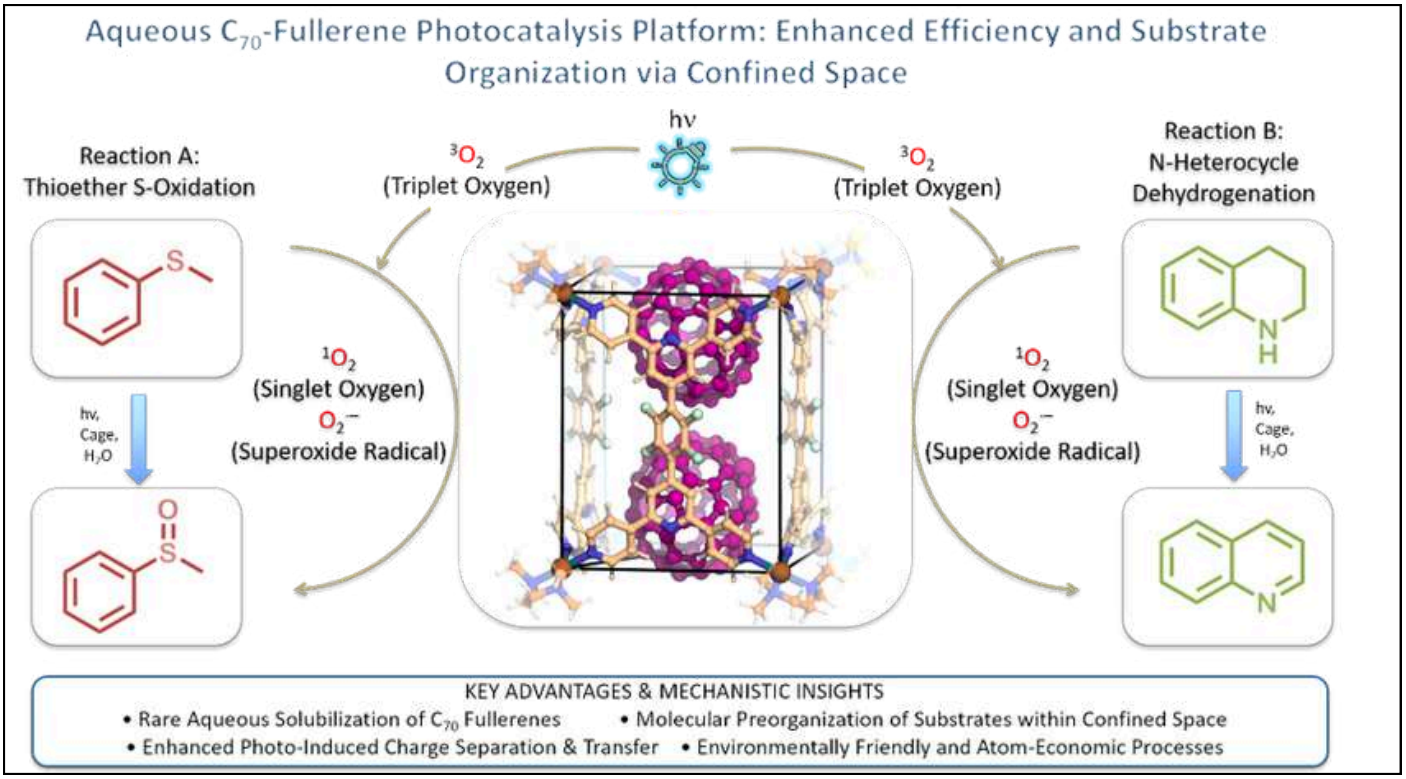

Figure 2. Aqueous C_{70} - Fullerene Photocatalysis Platform: Enhanced efficiency and Substrate Organization via Confined Space. Molecular barrel as a host for two C_{70} fullerene molecules, providing water-compatible fullerene complex for light driven photocatalytic sulfide oxidation and oxidative dehydrogenation of tetrahydroquinolines in an aqueous medium.

low-energy red-light irradiation. These advances highlighted the potential of supramolecular confinement for controlling fullerene photochemistry. However, an important challenge remained unresolved. Most fullerene-containing host systems continued to operate primarily in organic solvents. Achieving efficient fullerene photocatalysis in water remains a significant objective. If we truly want to mimic nature and develop sustainable, green chemistry, we have to make such system operational in water.

Unlocking Fullerene Photocatalysis in Water

Our recent work addresses this challenge by designing a water-soluble, self-assembled Pd8 molecular barrel capable of trapping C_{70} fullerene. The barrel possesses a large rectangular cavity and an overall architecture that combines hydrophobic confinement with excellent aqueous solubility. Upon C_{70} encapsulation, the barrel undergoes subtle structural adjustments that facilitate the binding of two fullerene molecules, reminiscent of the induced fit model forming a stable host–guest complex. The complex effectively disperses fullerene molecules in an aqueous media while preventing their aggregation. As a result, a homogeneous supramolecular photocatalytic system can be generated directly in water.

> *"Confinement of fullerenes within the barrel enhances charge separation, empowering complex to drive complex, light-powered sulfide oxidations and aerobic dehydrogenations in pure water."*

The role of the molecular barrel extends far beyond solubilization. Unlike many host systems, the elongated rectangular cavity of barrels not only accommodates the fullerene photosensitizer but also provides sufficient space for substrate molecules to access the confined environment. By bringing substrates into close proximity to the encapsulated fullerene, the barrel creates a localized reaction space where light harvesting, photoinduced processes and substrate activation can occur more efficiently. In this way, the architecture resembles an enzyme-like reaction chamber that combines guest stabilization with substrate organization. Confinement within

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this well-defined environment also significantly influences the photophysical behaviour of the encapsulated fullerene. Most notably, the host–guest complex exhibits an approximately twelve-fold enhancement in photocurrent response compared with free C_{70}, indicating more efficient charge separation and reduced charge recombination. Together, these effects promote the generation of reactive oxygen species, particularly superoxide radicals, which play a central role in the observed photocatalytic transformations.

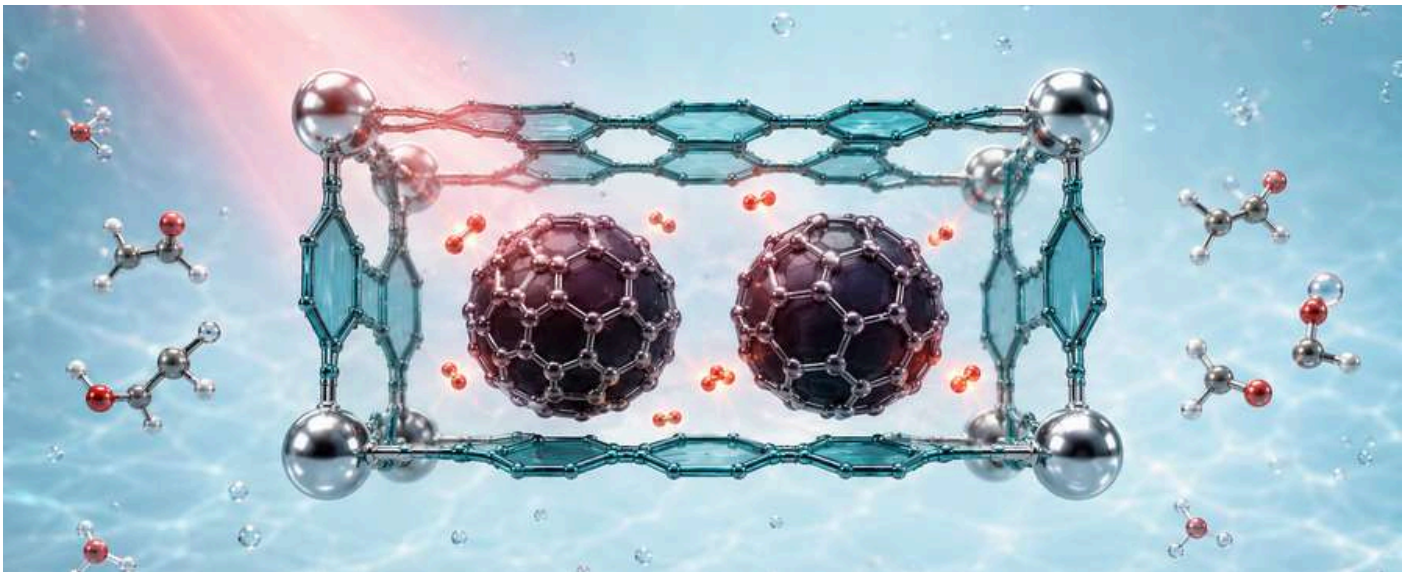
Using this system, we demonstrated two important light-driven oxidation reactions in water. The first involves the selective oxidation of sulfides to sulfoxides, an important transformation in synthetic chemistry. The second is the aerobic oxidative dehydrogenation of tetrahydroquinolines to valuable quinolines. These results illustrate how supramolecular confinement can unlock chemical reactivity that would otherwise be difficult to achieve using free fullerene molecules in aqueous media.

Dr. Mukherjee's contributions to the field of supramolecular chemistry are exemplified by their publication in journals, including Angewandte Chemie International Edition (2025; https://doi.org/10.1002/anie.202504851), Journal of the American Chemical Society (2023; https://doi.org/10.1021/jacs.3c01084), and Chemical Science (2025; https://doi.org/10.1039/D5SC01015B).

Future Perspectives

Supramolecular hosts have officially evolved beyond simple storage vessels. The development of our system demonstrates how molecular confinement can be used not only to solubilize functional molecules but also to enhance and control their behaviour. In this respect, molecular barrels are evolving beyond simple molecular containers into functional nanoreactors capable of regulating photochemical processes. Looking forward, the implications of this work extend far beyond fullerene chemistry. The ability of confined environments to influence charge separation, molecular organization, and catalytic performance suggests new opportunities for the design of advanced supramolecular photocatalysts. Future studies may focus on expanding the range of photoactive guests that can be incorporated within these architectures, developing systems capable of activating more challenging substrates, and improving long-term operational stability under practical reaction conditions.

More broadly, these efforts contribute to a growing vision in which self-assembled molecular architectures perform functions traditionally associated with biological systems. By combining the precision of supramolecular design with the versatility of synthetic chemistry, molecular barrels provide a promising platform for developing sustainable catalytic technologies. While artificial systems are unlikely to match the complexity of enzymes in the near future, advances in molecular confinement are bringing us closer to constructing functional synthetic reactors that emulate some of Nature's most effective strategies for controlling chemical reactivity.



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

THE HIDDEN KINGDOM BENEATH THE ICE

Once upon a time, high in the world's mountains and polar regions, there existed a hidden kingdom that almost nobody knew about. From a distance, glaciers looked like lifeless deserts of ice and snow. The freezing temperatures, fierce winds, and endless white landscapes seemed too harsh for animals to survive. Yet beneath this frozen surface lived an extraordinary community of tiny creatures. For thousands of years, these animals quietly thrived in one of the most extreme environments on Earth. Scientists recently set out to explore this secret world, and what they discovered was astonishing. Far from being barren wastelands, glaciers are home to unique ecosystems filled with life. Their findings revealed that glaciers support at least 152 known animal species, including many that exist nowhere else on the planet. Hidden within the ice was a remarkable kingdom that had remained largely invisible to humanity.

Among the inhabitants of this frozen world were some of nature's toughest survivors. Tiny water bears, known as tardigrades, crawled through microscopic pools of water. Rotifers spun through droplets trapped within the ice, while springtails hopped across snowy surfaces searching for food. There were also worms, insects, spiders, and even a few birds that visited glacier habitats. These creatures had evolved incredible abilities to survive conditions that would kill most forms of life. Some could endure being frozen solid for long periods. Others could dry out almost completely and come back to life when water returned. Food was often scarce, temperatures remained below freezing for much of the year, and strong sunlight reflected from the snow created additional challenges. Yet these animals adapted so successfully that glaciers became their permanent homes. In fact, scientists discovered that at least 73 known species are glacier specialists, meaning they are found nowhere else on Earth.

As researchers explored glaciers around the world, they learned that these icy landscapes are far more complex than they appear. A glacier is not simply a giant block of ice. It contains many different habitats. Some animals live on snow-covered surfaces, while others inhabit tiny meltwater pools called cryoconite holes. These small pools

| By Dr. Sivan Friedman

form when dust and organic matter absorb sunlight and melt pockets into the ice. Other creatures live in streams flowing across glaciers or among rocky debris scattered on their surfaces. Some even inhabit strange moss-covered balls called glacier mice. Different species prefer different parts of this frozen landscape, creating miniature ecosystems within the glacier itself. Scientists found glacier animals in the Arctic, Antarctica, Europe, Asia, North and South America, and New Zealand. Surprisingly, they also realized that many glaciers have never been carefully studied. Less than one-tenth of one percent of the world's glaciers have been examined for animal life, suggesting that many more species may still be waiting to be discovered.

However, while scientists were uncovering this hidden biodiversity, they also found a troubling reality. The icy kingdom was shrinking. Rising global temperatures are causing glaciers around the world to melt at unprecedented rates. Since the beginning of this century, glaciers have already lost vast amounts of ice, and scientists predict much larger losses in the decades ahead. For glacier animals, this presents a serious threat. Unlike many species that can move to new habitats, glacier specialists depend entirely on ice-covered environments. As glaciers retreat, their homes disappear. Researchers used future climate projections to estimate what might happen and found that several glacier species could lose nearly all of their suitable habitat by the year 2100. Some may lose every glacier where they are currently known to live. Particularly vulnerable are species with very limited distributions, such as certain springtails that inhabit only a few glaciers in the European Alps. For them, the loss of ice could mean extinction.

The dangers do not end with climate change. Glacier ecosystems also face pollution from microplastics, black carbon, and heavy metals carried by wind and water. Human activities such as mining, hydropower development, tourism, and skiing place additional pressure on these fragile habitats. Together, these threats make glacier ecosystems among the most vulnerable on Earth. Yet the study offers an important lesson. Glaciers are not merely frozen landscapes; they are living ecosystems that support unique forms of biodiversity. Every glacier that disappears may take with it species that evolved over thousands or even millions of years and exist nowhere else. The hidden kingdom beneath the ice reminds us that life can flourish in the most unexpected pl-

aces. Protecting glaciers is therefore about more than preserving ice. It is about safeguarding an entire world of remarkable creatures whose stories have only just begun to be discovered.

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| By Dr. Priyangana Deb

MYCOELECTRONICS: WHEN FUNGI JOINED THE MACHINE

Once upon a time, in a town surrounded by forests and mountains, there lived a young engineer named Maya. She loved nature as much as technology. Every summer, wildfires threatened nearby communities. A tiny spark hidden deep among the trees could grow into a devastating blaze before anyone noticed. Maya often wondered whether the forest itself could somehow warn people of danger. It sounded impossible. Forests could not speak, and machines could not grow like living things. Yet while exploring the woods one day, Maya noticed delicate white threads spreading beneath a fallen log. A scientist friend explained that these threads were part of a fungus. Together they formed a vast underground network called mycelium, which helps fungi gather nutrients, communicate, and survive. Looking at those hidden threads, Maya had a bold idea: what if living fungal networks could become part of electronic devices?

Maya and her team began studying fungi more closely. They learned that mushrooms are only the visible part of a much larger organism. Most of a fungus exists underground as mycelium, a network of microscopic threads capable of growing, adapting, and even repairing itself. Scientists already knew that fungi respond to changes in temperature, moisture, and other environmental conditions. Inspired by these abilities, the researchers mixed living fungal material with a nutrient-rich gel and used a specialized 3D printer to place it onto soft electronic circuits made from graphene, a highly conductive form of carbon. After printing, the fungus continued growing across the circuit. The result was something entirely new: a hybrid system combining living

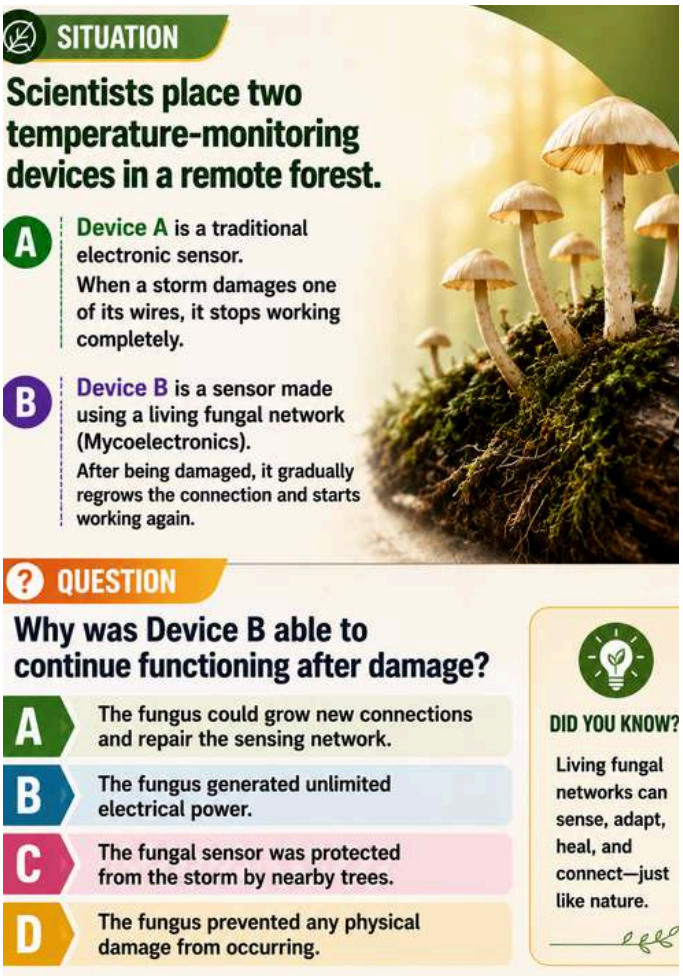
By Dr. Priyangana Deb

biology with modern electronics. The researchers called it Mycoelectronics, a name that combines mycology, the study of fungi with electronics.

The next question was whether this living device could actually sense its surroundings. To find out, the team gently warmed the fungal network and monitored its electrical activity. What they observed was remarkable. Inside fungal cells are tiny liquid-filled compartments called vacuoles. As the temperature increased, these vacuoles began merging together, altering how ions, tiny charged particles, moved through the cells. Because electrical signals depend on the movement of charged particles, the conductivity of the fungal network changed as well. The electronic circuit detected these changes and converted them into measurable signals. In simple terms, the fungus was acting like a living temperature sensor. Even more impressive, dead fungal material showed no response at all. The sensing ability came entirely from the living organism itself. For Maya, it felt as though the forest had found a way to communicate through electricity.

As the project continued, the team uncovered even more surprising abilities. One day, part of the fungal network was accidentally damaged. In a normal electronic device, a broken connection usually means failure. But the fungus responded differently. Within hours, new threads began growing across the damaged area. Soon the electrical pathway was restored, and the sensor worked again. The living circuit had healed itself. Researchers also placed fungal networks inside maze-like structures. Slowly but steadily, the mycelium explored different routes until it connected two distant points, creating a functioning pathway. Unlike traditional electronics that must be carefully assembled, fungal networks could build and repair their own connections. The scientists later connected fungal sensors to robotic systems. In one experiment, the fungus detected heat from a nearby flame and generated signals that guided a robotic hand. These demonstrations showed that living organisms and machines could work together in ways once thought impossible.

Years later, Maya stood at the edge of the forest watching the sunset glow through the trees. By then, fungal sensors were being tested for wildfire detection, environmental monitoring, and smart building systems. Their greatest strength was not simply their ability to sense heat. They could also grow, adapt, and repair themselves. Traditional electronics are often discarded when damaged, but living fungal networks could regenerate and continue functioning. Scientists began imagining technologies that might one day be partly grown rather than manufactured. Such systems could help monitor crops, protect forests, guide robots, and support more sustainable cities. Looking at the forest around her, Maya realized that the most important lesson of Mycoelectronics was not about technology, it was about learning from nature. Hidden beneath the soil was a network refined by millions of years of evolution. The forest had never needed to learn how to feel. Humans had simply learned how to listen.



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| By Dr. Ipsita Mohanty

THE COCKROACH THAT CARRIED A MILLION-YEAR-OLD SECRET

Once upon a time, in a dark forest filled with fallen logs and damp leaves, there lived a cockroach named Bruno. Like most cockroaches, Bruno spent his days hidden beneath rotting wood, searching for food and avoiding predators. To most animals, he seemed ordinary. But Bruno carried a secret passed down through countless generations. Deep inside his body lived tiny bacteria called Blattabacterium. These bacteria were not enemies but trusted partners that had been living inside cockroaches for more than 150 million years. Long before dinosaurs disappeared, their ancestors had already formed a partnership. The bacteria helped cockroaches survive by providing important nutrients, while the cockroaches offered them a safe place to live. Scientists had known about this relationship for years. What they did not know was that the bacteria had quietly been leaving pieces of their DNA behind inside cockroach genomes for millions of years.

One day, a group of scientists decided to investigate this ancient friendship. They collected genome sequences from many cockroach species and searched for traces of bacterial DNA. At first, they expected to find only a few examples. After all, DNA is usually passed from parents to offspring through a process called vertical inheritance. But sometimes DNA moves between unrelated organisms through horizontal gene transfer. Scientists knew this happened frequently among bacteria but believed it was uncommon in animals. As they analyzed the cockroach genomes, they were astonished. Instead of finding a handful of bacterial DNA fragments, they discovered tens of thousands. Across the species they studied, more than 40,000 bacterial DNA inserts were identified. Some cockroaches carried over 3,000 inserts, while one species contained nearly 5,000. These numbers were far greater than scientists expected. It was as though the bacteria had been quietly adding pages to the cockroach instruction manual for millions of years.

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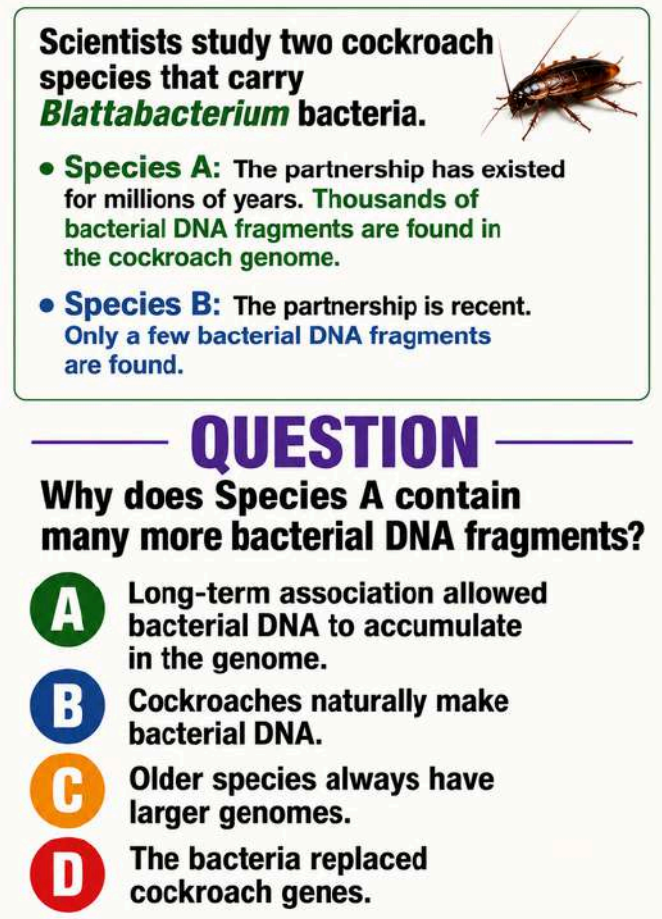
The researchers then wanted to understand how this happened. Because Blattabacterium lives inside specialized cockroach cells and is passed from mother to offspring, its DNA is constantly present near the cockroach's own genetic material. Occasionally, small pieces of bacterial

| By Dr. Ipsita Mohanty

DNA appear to enter the cockroach genome. Most of these fragments are tiny, often only a few hundred DNA letters long. Surprisingly, many are not complete genes but simple DNA fragments. Earlier studies had focused mainly on transferred genes and therefore missed many of these smaller pieces. Thanks to modern genome sequencing technology, researchers could now detect them. They found these inserts scattered throughout the cockroach genome rather than clustered in one location. This pattern suggested that DNA transfer was not a rare accident but something that had occurred repeatedly throughout cockroach evolution. The genome was beginning to look like a museum preserving traces of ancient encounters between insects and microbes.

As the investigation continued, the story became even more fascinating. By comparing related cockroach species, scientists found that some bacterial DNA fragments had survived for at least 28.7 million years. Imagine a tiny piece of DNA lasting through millions of generations while mountains rose, climates changed, and species appeared and disappeared. Such long-term survival raised an important question: could some of these fragments be useful? Most appeared inactive, but a small number were found in RNA molecules, suggesting that cockroach cells were reading or using them. Researchers also discovered unusual "chimeric" inserts, genetic patchworks made from several different bacterial DNA fragments stitched together. In one case, pieces from multiple locations in the bacterial genome had become joined into a single sequence inside the cockroach genome. It was like finding a scrapbook assembled from pages taken from different books. These genetic mosaics showed that horizontal gene transfer can create entirely new DNA combinations that evolution may later act upon. Years later, Bruno's descendants continued carrying this hidden treasure. The scientists had learned an important lesson. Evolution is not simply a story of genes passing from parents to offspring. Sometimes organisms acquire genetic fragments from completely different forms of life. Most borrowed pieces may do nothing, but some could eventually influence how organisms function and evolve. The cockroach study revealed that genomes are not static instruction manuals but living records of ancient relationships and evolutionary experiments. Hidden within every cockroach genome lies evidence of a friendship that began over 150 million years ago. Tiny bacteria and humble insects had shared more than a home, they had shared pieces of their genetic history.

Thanks to modern science, we are only now beginning to uncover the remarkable story written inside their DNA, reminding us that evolution can work in far more creative ways than we once imagined.



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By Dr. Sudha Shankar

NATURE'S EARLY WARNING SYSTEM FOR WILDLIFE

Once upon a time, in a world filled with forests, deserts, mountains, and rivers, there lived a young wildlife scientist named Sofia. She loved animals more than anything else. From colorful birds in tropical forests to tiny frogs hidden among leaves, she believed every creature had a special place in nature. She spent her days exploring the outdoors, watching wildlife, and learning how different species survived in their unique environments. To Sofia, every animal had a story, and every ecosystem was like a giant living family connected by nature.

One summer, Sofia noticed something troubling. News reports from different parts of the world described animals dying during unusual heat waves. Birds fell from the sky, monkeys searched desperately for water, and many creatures seemed unable to escape the extreme temperatures. The strange thing was that these events often surprised everyone. By the time people realized there was a problem, it was already too late to help many of the animals. Sofia wondered, “People receive weather forecasts before storms and floods. Why can't wildlife receive warnings before dangerous heat arrives?” That simple question stayed in her mind for months. The more she thought about it, the more she realized that protecting wildlife often meant acting before a crisis happened, not after.

Determined to find an answer, Sofia joined a team of scientists from many countries. Together, they collected information about thousands of species, where they lived, what temperatures they normally experienced, and how much heat they could tolerate. They also gained access to powerful weather forecasts produced by satellites and climate models. The team imagined each animal carrying an invisible thermometer that recorded the hottest temperatures it had ever experienced. Then they asked a simple question: what if the future weather forecast predicts temperatures hotter than anything that animal has ever faced? If that happened, the species would receive a warning. The scientists built a giant computer system that could check this for more than 30,000 species across

By Dr. Sudha Shankar

the world. It was like creating a weather forecast, not for people, but for nature itself. For the first time, scientists could look months into the future and identify places where wildlife might soon be in danger.

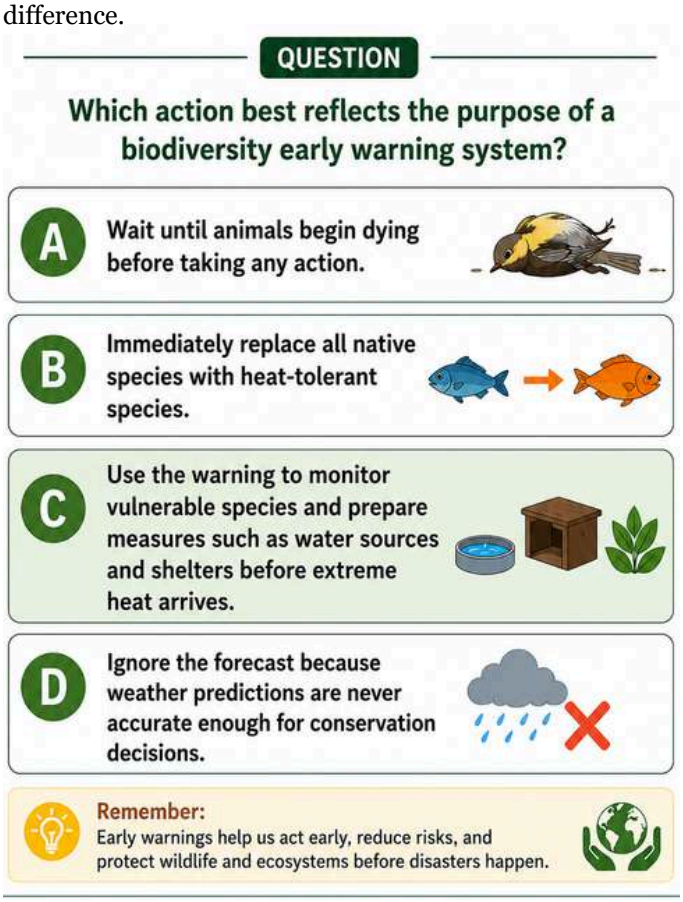
In May 2024, the team tested their new system. The results surprised even them. Thousands of species were predicted to face unusually dangerous heat during the coming months. Bright warning signals appeared on their maps over Mexico, parts of Africa, northern India, Pakistan, and the Himalayan region. Some of these places were home to rare animals already struggling to survive. Sofia looked at the maps and imagined what might happen if no one paid attention. Rivers could shrink, forests could dry, and animals could suffer silently. But she also saw hope. Unlike before, they now had months of advance notice. Conservation groups could prepare water sources, monitor vulnerable species, protect habitats, and be ready to help if conditions became dangerous. Communities, park rangers, and scientists could work together before the heat arrived rather than rushing to respond afterward.

A few months later, reports began arriving from some of the places that had been highlighted by the warning system. In southern Mexico, howler monkeys struggled during intense heat. In other regions, birds and bats were found weakened by unusually high temperatures. The reports saddened Sofia, but they also showed that the forecasts had identified real risks. The system was not perfect, and it could not predict every detail, but it gave people valuable time to prepare. Wildlife managers began discussing how they could use future warnings to act earlier. Instead of waiting for animals to suffer, they could monitor populations, provide emergency support, and protect the most vulnerable species before disaster struck. For the first time, it felt possible to move from reacting to crises to preventing them.

Years later, the early warning system became an important tool for conservation around the world. Every month, scientists updated forecasts and shared information with local communities.

Rangers checked on endangered species, volunteers helped maintain water sources during heat waves, and governments paid closer attention to regions at risk. Sofia often thought about the simple question that had started everything. The answer had not been a machine or a computer model alone. The real answer was preparation.

Nature could not speak for itself, but science could help give it a voice. And that voice was saying something important: the climate is changing, and wildlife needs our help before danger arrives, not after. Thanks to the efforts of many people working together, countless species had a better chance to survive in a warming world. The warning system did not stop heat waves from coming, but it gave nature something it had never had before, a chance to prepare. And sometimes, a little warning can make all the difference.



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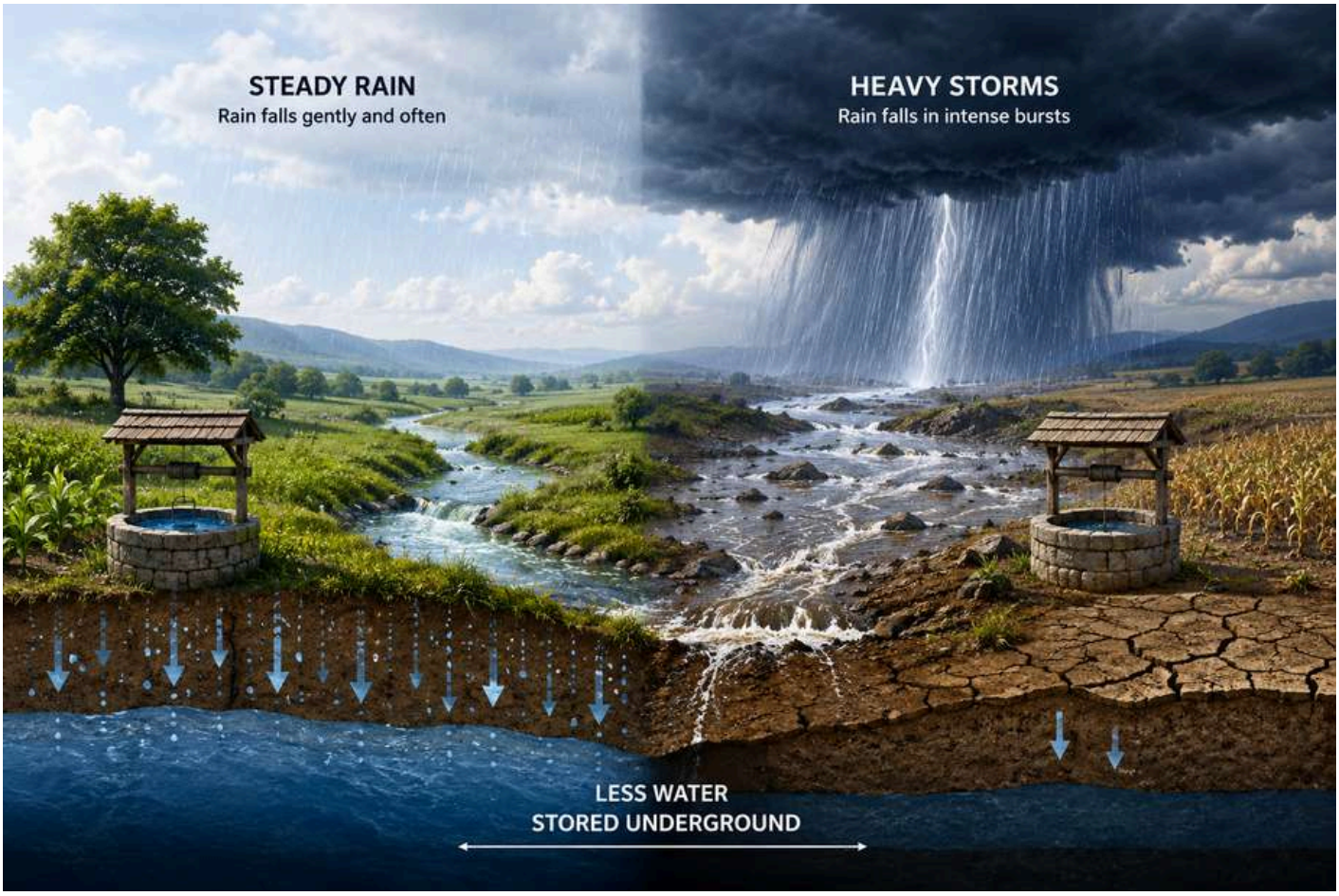
By Dr. Dhanashree Mundhe

THE WATER PARADOX

Once upon a time, in a small farming village called Sundarpur, people believed that more rain always meant more water. The villagers depended on rain for their crops, wells, rivers, and daily life. Every year they eagerly watched the skies, hoping for dark clouds and steady showers. Among them lived a curious young girl named Anika. She loved asking questions about nature. One year, something strange happened. The village received almost the same amount of rain as usual, yet the wells began to dry, the soil cracked, and the crops looked thirsty. Anika could not understand it. “How can we have so much rain and still have so little water?” she asked her grandfather, who had farmed the land for many decades. Her grandfather scratched his beard thoughtfully. “The rain has changed,” he said. “When I was young, rain came gently over many days. Now it comes all at once.” Anika remembered the giant storms that had struck the village that year. Huge clouds arrived, dumped enormous amounts of water in a few hours, and then disappeared.

After each storm, the village experienced long stretches of hot, dry weather. Curious to learn more, Anika visited a nearby university where scientists were studying rainfall and water. There she met Dr. Maya, a climate researcher. Dr. Maya showed her maps from satellites orbiting Earth. The satellites could measure how much water was stored in the land in soils, rivers, lakes, plants, and underground reservoirs. The scientists had discovered that many places around the world were facing the same puzzle as Sundarpur.

Dr. Maya explained that the problem was not the total amount of rain but how the rain arrived. Imagine giving a thirsty plant one cup of water every day for a week. The plant would grow well because it receives water steadily. Now imagine giving the same amount of water all at once on a single day and then nothing for six days. Much of the water would overflow or evaporate before the plant could use it. The same thing happens to the land. During intense storms, the soil cannot absorb all the water quickly enough. Water collects on the surface and forms puddles or flows away. Then, during long dry periods, the sun shines



| By Dr. Dhanashree Mundhe

brightly and much of that water evaporates back into the air. As a result, less water remains underground where it can help plants, rivers, and people. Anika finally understood why the village wells were shrinking even though the rain gauge showed plenty of rainfall.

The scientists had studied this pattern across the entire world. Using satellite observations and computer models, they found that rainfall is becoming more concentrated into fewer but heavier storms. This change is happening because the planet is warming. Warmer air can hold more moisture, which often leads to stronger downpours. At the same time, the periods between storms become longer and drier. The researchers discovered that this pattern reduces the amount of water stored on land almost everywhere. Even forests, grasslands, and humid regions were affected. The effect was surprisingly powerful. In some places, the drying caused by concentrated rainfall was nearly as strong as the benefit gained from receiving more rain. The scientists realized that when thinking about water, people should not only ask "How much rain will fall?" but also "How will that rain fall?"

When Anika returned home, she shared what she had learned with the villagers. At first, many people were surprised. They had always celebrated heavy storms, believing they guaranteed plenty of water. But now they understood that a single giant storm could not replace weeks of gentle rain. The village began discussing ways to capture and store water when storms arrived. They built small ponds, improved rainwater harvesting systems, and planted more vegetation to help the soil absorb water. Over time, the community became more prepared for the changing climate. Anika grew up to become an environmental scientist herself. Whenever she spoke to students, she told them the lesson she learned as a child: nature is not only about quantity but also timing. A bucket of water poured slowly can nourish the earth, while the same bucket dumped all at once may be lost. And as the world grows warmer, understanding this simple truth may help millions of people protect their most precious resource water.

Years later, Sundarpur faced another season of violent storms followed by weeks of intense heat. This time, however, the village was prepared. The ponds collected runoff, rooftop tanks stored rainwater, and newly planted trees slowed the water long enough for it to enter the soil. Farmers used the stored water carefully, and the wells recovered more quickly than before. The villagers understood that adapting to climate change did not mean controlling the rain. It meant redesigning their relationship with water so that sudden abundance could support them during later scarcity. Anika often reminded her students that scientific knowledge becomes truly valuable when communities can translate it into practical action. By observing nature, sharing information, and planning together, even a small village could become more resilient. Sundarpur still could not predict every storm, but it had learned how to protect each precious drop and prepare wisely for an uncertain future ahead.

DO IT NOW!
ONE SITUATION, ONE QUESTION

Think carefully and choose the best answer.

SITUATION:

Two neighboring villages receive exactly the same amount of rain during the year.

- Village A gets small, gentle rains spread throughout the year.
- Village B gets most of its rain during a few very intense storms, followed by long dry periods.

At the end of the year, Village B finds that its wells and soil contain less water than Village A.

QUESTION:

What is the most likely reason for this difference?

A Heavy storms allow more water to soak deep into the ground.

B Intense rainfall creates more surface water that evaporates, while long dry periods increase water loss.

C Plants in Village B use much more water than plants in Village A.

D The total amount of rainfall in Village B was actually lower.

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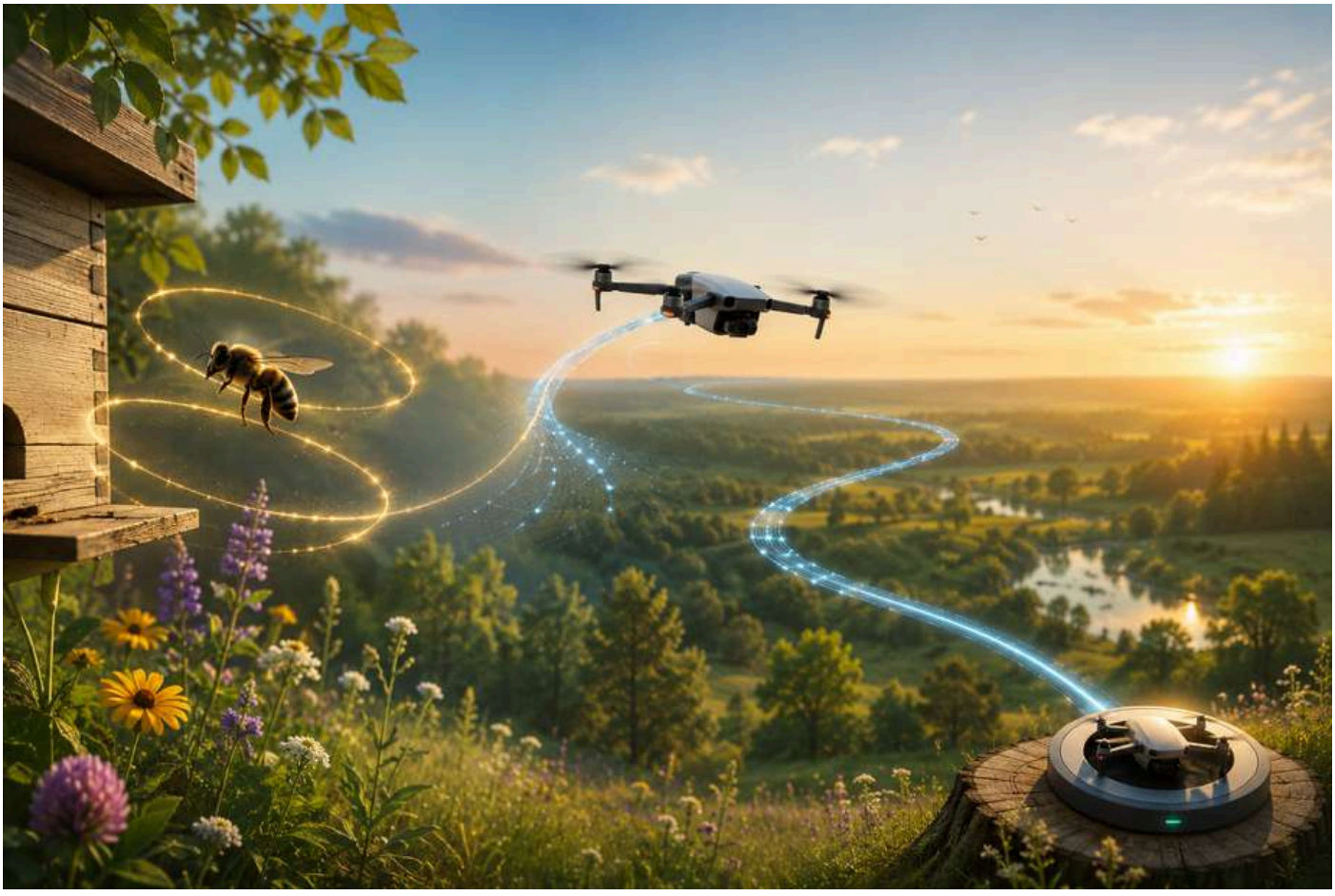
| By Dr. Priyanka

THE LITTLE DRONE THAT LEARNED FROM BEES

Once upon a time, in a small town near a wide green meadow, a young engineer named Emma loved watching honeybees. Every morning, she sat beside a field of colorful flowers and noticed something curious. Before a bee flew away to search for nectar, it would circle around its hive several times. It looked almost as if the bee was taking a careful look at its home before leaving. Emma wondered why. One day, she asked a scientist friend, who explained that the bee was learning the landmarks around its hive so it could always find its way back. The idea fascinated Emma. If a tiny bee with such a small brain could remember its home so well, why did robots need huge computers and complicated maps to do the same thing? That simple question sparked an adventure that would change the future of robotics.

Emma worked with a small flying drone named Buzz. Unlike large drones, Buzz was tiny and light. It could not carry powerful computers or store enormous maps. Whenever Emma sent Buzz on a mission, it often became confused and struggled to find its way home. One afternoon, while watching bees dance among the flowers, Emma had an idea. “What if Buzz learns like a bee?” she thought. The next morning, she programmed Buzz to make small loops around its home base before every journey. As it flew, a special camera captured views in every direction. Buzz stored pictures of trees, bushes, rocks, and nearby buildings. At the same time, it kept track of how far and in which direction it had flown. Slowly, Buzz began building a memory of what home looked like, just as a honeybee does during its first learning flights.

After several days of practice, it was time for a real test. Emma sent Buzz far across the meadow. The little drone flew over grasslands, around ponds, and past rows of trees. At first, everything went well. Buzz carefully counted every turn and every meter it traveled. But after a long journey, tiny mistakes started to add up. A small error in one direction became a larger error later. Soon Buzz was no longer completely sure where home was. Emma watched nervously from her computer screen. Then something



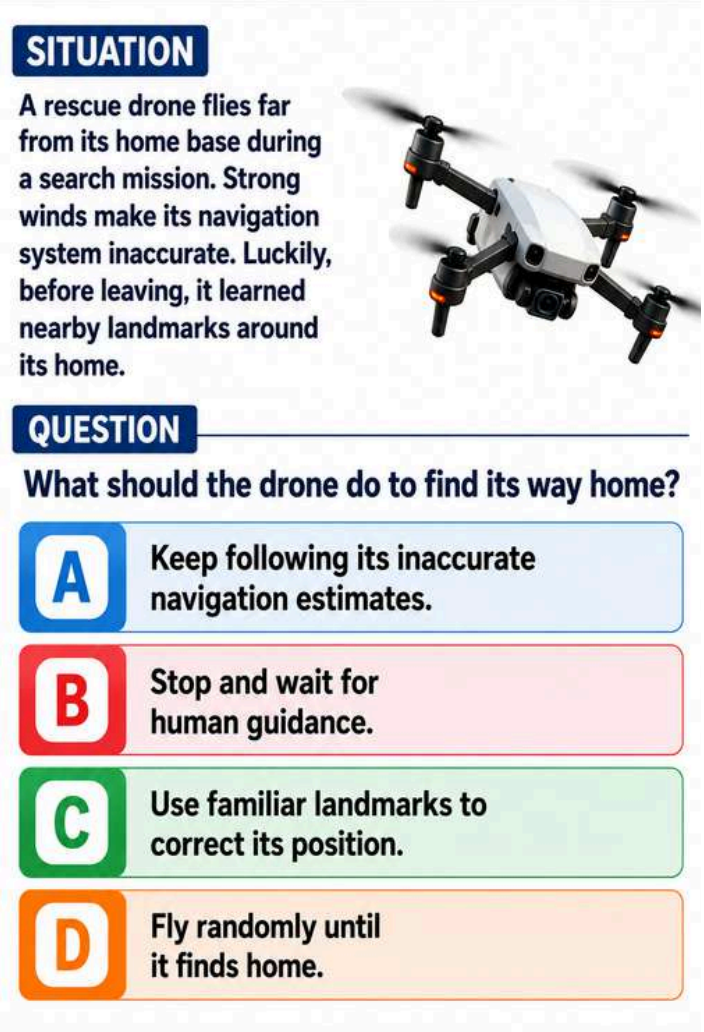
| By Dr. Priyanka

amazing happened. Buzz looked around and recognized familiar landmarks from its earlier learning flights. It spotted the shape of a tree, the position of a shed, and the pattern of a nearby path. Using these clues, it corrected its mistakes and adjusted its course. Instead of wandering aimlessly, the drone confidently headed toward home.

Over the following weeks, Emma and her team tested Buzz again and again. They flew it inside large buildings, across open fields, and even on windy days. Each time, Buzz first performed a short learning flight and then traveled much farther away. The little drone continued to surprise everyone. It could fly hundreds of meters from home and still return successfully. What amazed the scientists most was that Buzz did all this using only a tiny amount of computer memory. Other navigation systems needed large maps and powerful processors, but Buzz carried only a small "brain" inspired by honeybees. The drone did not know everything about the world around it. Instead, it simply remembered what home looked like and how to get back. It was a simple idea, yet it worked remarkably well.

News of Buzz's success spread quickly. Farmers imagined fleets of tiny drones checking crops and returning home to recharge. Warehouse managers pictured small flying helpers carrying information from one place to another. Rescue teams dreamed of drones searching dangerous areas where GPS signals might fail. Yet Emma felt that the most important lesson came from nature itself. For years, people had assumed that advanced technology always required bigger computers and more complex systems. But the humble honeybee had shown another path. Sometimes the smartest solution is not the most complicated one. By learning from a tiny insect, scientists created a robot that could travel great distances and always find its way home. And every time Emma watched bees circling their hive in the evening sunlight, she smiled, knowing that one of nature's smallest creatures had inspired one of robotics' biggest breakthroughs.

Years later, Buzz became the model for a new generation of lightweight autonomous drones. They explored forests, inspected bridges, monitored farms, and entered places where satellite navigation was unreliable. Yet every mission began with the same gentle ritual: a short circling flight to observe the surroundings and remember home. Emma explained that this was more than a technical procedure. It represented a philosophy of engineering that valued efficiency, adaptation, and observation over unnecessary complexity. Students visiting her laboratory studied birds, insects, plants, and other living systems before designing machines. They learned that evolution had already tested countless solutions across millions of years. Buzz therefore became more than a successful drone; it became a reminder that technology and nature need not stand apart. By listening carefully to the living world, engineers can create safer, smarter, and more sustainable inventions for everyone.



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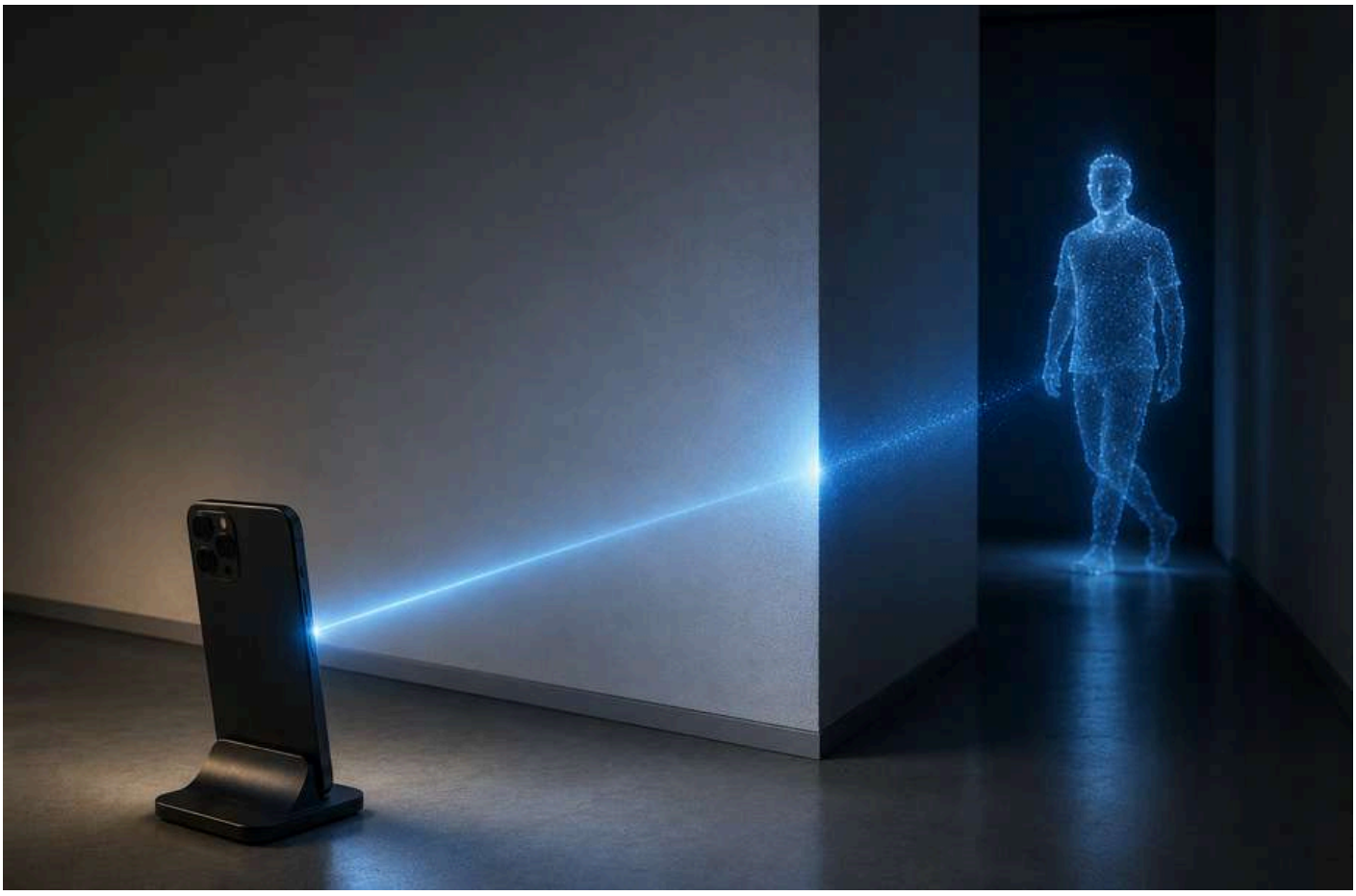
| By Dr. Sourav Kumar

THE SMARTPHONE THAT COULD SEE AROUND CORNERS

Once upon a time, in a busy city filled with smart devices, there lived a young engineer named Arjun. He loved technology and was always curious about what machines could do. One day, while walking through a crowded shopping mall, he wondered about something unusual. “What if my phone could tell me what is hiding around the corner before I get there?” It sounded impossible. After all, cameras can only see what is directly in front of them. If a wall blocks the view, even the smartest camera becomes blind. But a group of scientists had been asking the same question. They believed that maybe a smartphone could do something that seemed almost magical see things that were hidden from view.

One afternoon, Arjun visited a laboratory where researchers were working on a special kind of sensor called LiDAR. This sensor is already found in some smartphones and smart devices. Normally, LiDAR sends out tiny pulses of light and measures how long they take to bounce back. That helps create a 3D map of the surroundings. The scientists showed Arjun a strange experiment. They placed an object behind a wall where no camera could see it. Then they pointed a LiDAR-equipped phone at a nearby wall. Tiny flashes of light bounced off the wall, traveled to the hidden object, bounced back again, and finally returned to the phone. The reflections were extremely weak, almost like whispers in a noisy room. Yet hidden inside those faint signals was information about the object behind the wall. Arjun was amazed. The phone was not looking directly at the object, but it was still gathering clues about it.

At first, the system did not work very well. The hidden signals were weak and blurry. A single measurement was often too noisy to reveal anything useful. The researchers solved this problem in a clever way. Instead of taking one measurement, they collected many measurements while the phone moved slightly in the user’s hand. Each measurement was like a tiny piece of a puzzle. One piece alone revealed very little, but when hundreds of pieces were combined, a clearer picture appeared. It was similar to how our brain understands a story by putting together



| By Dr. Sourav Kumar

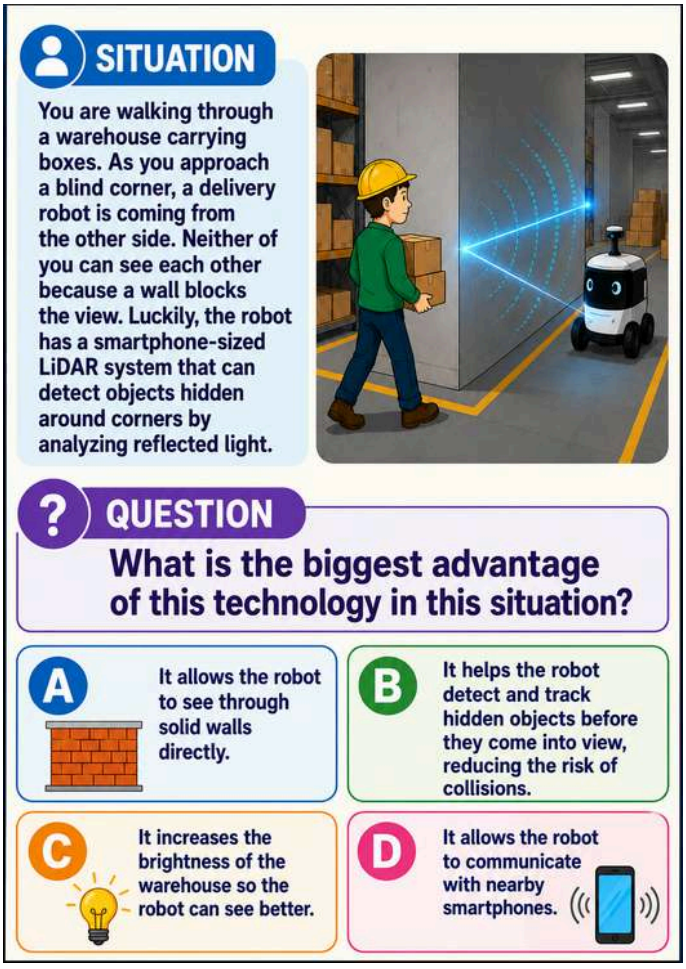
many small clues.

Slowly, the computer learned to combine these signals and create a rough image of the hidden object. Sometimes it could even estimate the object's size and shape. For the first time, a simple consumer device was beginning to "see" beyond its direct line of sight.

The scientists then decided to make the challenge harder. Instead of a stationary object, they asked someone to walk behind a barrier. Could the phone track a moving person it could not directly see? Again, the LiDAR collected tiny flashes of reflected light. The computer made thousands of educated guesses about where the hidden person might be. As new information arrived, it discarded bad guesses and kept the better ones. Little by little, it followed the hidden person's movement. In another experiment, it tracked two hidden objects at the same time. The researchers even used reflective gloves to track the movement of a person's hands around a corner. Watching the demonstration felt almost like magic. The phone was not seeing through walls. Instead, it was using clever mathematics and bouncing light to figure out what was happening in places hidden from view.

As the project grew, the researchers imagined many future uses. A robot in a warehouse could detect a worker approaching from around a corner and avoid an accident. A self-driving machine could move more safely through crowded spaces. Rescue teams could search for people hidden behind obstacles during emergencies. Augmented reality glasses could better understand the world around their users. The most exciting part was that this technology no longer required expensive laboratory equipment costing thousands of dollars. The researchers showed that it could work with low-cost sensors already found in consumer devices. There were still challenges to solve, and the images were far from perfect. Yet Arjun realized he was witnessing the beginning of something remarkable. One day, smartphones might not just show us what is in front of us. They might help us understand what lies just beyond our sight, turning ordinary walls and corners into windows of information and making the world a little less hidden than before.

Years later, Arjun returned to the laboratory and found that the system had become faster, smaller, and more reliable. The phone could not produce perfect photographs of hidden spaces, but it could detect movement, estimate distance, and warn users about approaching objects. Engineers began testing it in hospitals, factories, and emergency training centers, where early awareness could prevent accidents and guide safer decisions. They also developed strict privacy protections so that the technology would assist people without becoming a tool for unwanted surveillance. Arjun understood that every powerful invention required both imagination and responsibility. Seeing around corners was no longer simply a scientific trick; it was a new way for machines to interpret indirect information. By combining ordinary sensors, moving viewpoints, and intelligent computation, researchers had shown that even faint reflections could reveal meaningful patterns in places beyond direct sight.



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Massachusetts Institute of Technology, Cambridge, MA, USA.

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SCIENCE DESK

How Can We Detect Hidden Diseases in Sheep Before They Spread?

Dr. Manoranjan Rout
ICAR-National Institute on Foot and Mouth Disease, Bhubaneswar - 752050, India

Scientific Profile
Organization Link
Factors Press

AREAS OF EXPERTISE
Foot and mouth disease•Epidemiology•Diagnostics, Serosurveillance•Susceptible domestic•wildlife species

Q *What inspired you to focus on foot and mouth disease in sheep, and why is this issue important for farmers and livestock health?*

A As per the 20th Livestock Census-2019 All India Report, the total livestock population is 536.76 million in India, while the total sheep is 74.26 million heads (13.83%). Both sheep and goat play a pivotal role in livelihood security of small and marginal farmers as well as landless, marginal and small farmers in India. It is an important source of income to farmers particularly in disadvantageous regions in the country. Sheep with multi-facet utility play an important role in the socio-economic livelihood of the rural mass of India and its agrarian economy. But, foot and mouth disease (FMD) severely constrains the productivity of the animal and its health. The total economic loss due to FMD in sheep is reportedly due to multifaceted factors e.g., mortality, loss in wool yield, reproductive failure, loss in body weight, complications due to secondary pathogens including cost of treatment etc. The total loss per infected sheep due to FMD was estimated to be Indian rupees (INR) 2023 in Indian scenario. Sheep and goat play an important role in the epidemiology and transmission of FMD more importantly in a mixed farming setup accompanied by unregulated movement of animals. Disease control measures are difficult to plan and implement in isolation targeting only a few susceptible species of animals out of a whole range of epidemiologically significant species. FMD being difficult to diagnose clinically in sheep as they are the maintenance host exhibiting mild inapparent symptoms and lesions of the disease. Hence, the diagnosis of FMD in these species becomes of paramount significance. Further, as sheep is susceptible to FMD and largely they are co-habited with cattle in the mixed farming setup, silently infected sheep can pose a significant challenge in the country and prospects of FMD control programme under government-sponsored Livestock Health and Disease Control Program (LHDCP).

Q *Why is foot and mouth disease often difficult to detect in sheep compared with other livestock animals?*

A Unlike cattle and pig, sheep exhibit less florid and milder clinical signs and lesions of FMD. Very often, lameness will be the first symptom to appreciate. Further, the collection of clinical samples from the mildly developed lesions in the infected animals becomes impossible that constrains the clinical diagnosis. Mere collection of swab samples also very often goes negative in antigen and genome detection systems.

Q *In simple terms, how does the blood test developed in your study work?*

A The developed serological test demonstrates the reliability and feasibility of using 3AB3 NSP indirect ELISA as an affordable tool to identify sheep exposed to FMDV. This immunodiagnostic assay because of its high sensitivity and specificity has the potential to be employed in FMD control and eradication programme with efficient sero-detection of infected/infected sheep. Further, this NSP ELISA has been shown to be a high throughout, simple, low-cost and effective method for detection of FMDV NSP antibodies in sheep population. Considering the unique necessity and economic challenges, this indirect species-specific serological assay with high diagnostic performance attributes can be pretty useful for large-scale application in FMD surveillance in sheep in India.

Q *What were the most important findings of your research?*

A As the disease takes a mild course in sheep, clinical tissue materials from unapparent lesions are often not available. Confirmation through symptomatic diagnosis and laborat-

tory testing of lesion tissue material is therefore hardly possible. Under such situation, serological detection of infection-specific FMD virus (FMDV) antibodies may help detecting the virus-exposed animal, subclinical or persistent infection in retrospect. The overall diagnostic sensitivity of the assay was estimated to be 92.11%, while the diagnostic specificity on naïve and vaccinated animals varied at 97.4% and 94.42%, respectively. This 'in-house' developed indirect ELISA can be applied in large scale serosurveillance of FMD in sheep.

Q *How could this test help veterinarians and farmers identify infections that might otherwise go unnoticed?*

A On serology platform, demonstration of antibodies to FMD virus (FMDV) nonstructural proteins (NSPs) is considered to be the paramount indicator of virus activity irrespective of the serotype and vaccination status. FMD being difficult to diagnose clinically in sheep and unavailability of clinical samples due to lack of frank lesions in most of the cases, serological detection of FMDV NSP antibodies, an indicator of infection remains as the only option amenable to large scale serosurveillance to gather evidence of virus circulation in retrospect. As sheep exhibit less florid clinical signs of FMD and the collection of clinical samples from the mildly developed lesions of infected animals becomes impossible, it constrains the clinical diagnosis. Under such circumstance, application of molecular assays and serotyping ELISA that depends upon the clinical tissue materials, become difficult to provide a confirmatory laboratory diagnosis. Therefore, the clinician is left with no option other than drawing a blood sample as the only sample of choice and convenience that can help detecting the virus activity in retrospect using this developed indirect ELISA.

Q *What impact could this technology have on livestock health, disease control, and food security in countries like India?*

A The test demonstrates the reliability and feasibility of using 3AB3 NSP indirect ELISA as an affordable tool to identify sheep exposed to FMDV. This immunodiagnostic assay because of its high sensitivity and specificity has the potential to be employed in FMD control and eradication programme with efficient sero-detection of infected/infected sheep. Further, this NSP ELISA has been shown to be a high throughout, simple, low-cost and effective method for detection of FMDV NSP antibodies in sheep population. Considering the unique necessity and economic challenges, this indirect species-specific serological assay with high diagnostic performance attributes as well as low production cost seems to be pretty useful for large-scale application in FMD surveillance in sheep in India thereby strengthening the control strategy of FMD in the country. Control of FMD will indirectly ensure the better health status of animals and food security subsequently.

Q *What are the next steps for this research, and how do you hope it will contribute to the future of animal disease surveillance?*

A With such relatively cheaper diagnostic ELISA with good efficacy, huge number of random serosurveillance can be conducted at different sheep dominating belts of the country that will further support the government endorsed FMD control programme in India. Further, the persistence of FMDV in sheep can be studied deciphering its carrier status.

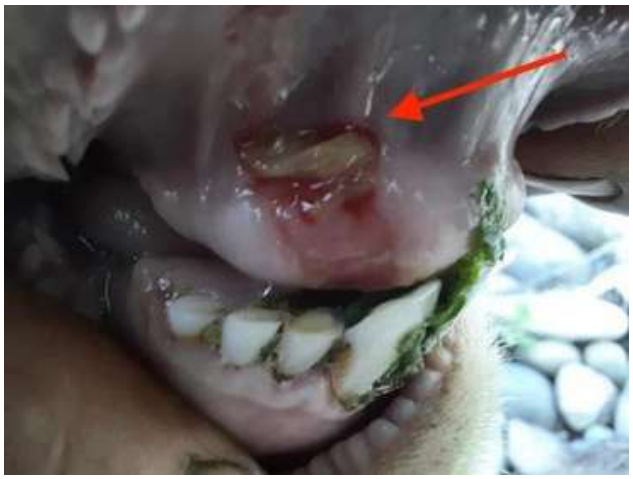

Figure 1: Ruptured blister at the commissure of upper dental pad and mucosa of upper lip of FMD affected sheep (Figure published by Rout et al. (2024) in Indian Journal of Animal Sciences 94 (1): 30–33, January 2024).

Reference

Dr. Rout's expertise in foot-and-mouth disease research is showcased in his recent publication in Virology (2026) (DOI: 10.1016/j.virol.2026.110873), where his team presents an optimized 3AB3 indirect ELISA that improves the detection of foot-and-mouth disease virus antibodies in sheep.

SCIENCE DESK

Squeeze and Expel: How the Fruit Fly Gut Flushes Out Foodborne Infections

Dr. Sandhya Amol Marathe
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Scientific Profile
Organization Link
Factors Press

AREAS OF EXPERTISE
Host–pathogen interactions • Bacterial pathogenesis • Gut immunity • Microbiology

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Scientific Profile
Organization Link
Factors Press

AREAS OF EXPERTISE
Drosophila infection models • Gut immunity • Host-pathogen interactions • Fly husbandry

Q *What inspired you to investigate how fruit flies respond to gut infections, and why is this an important model system?*

A Every year, millions of people suffer from foodborne illnesses caused by bacteria of the Enterobacteriaceae family, and most conventional treatments focus on killing the bacteria with antibiotics. We kept coming back to a different question: what if the host itself has smarter, built-in mechanisms to clear an infection? Drosophila melanogaster turned out to be the ideal model to study this. Despite being a simple organism, the fruit fly shares striking evolutionary conservation with humans (particularly in its innate immune cascades, signal transduction pathways and transcriptional regulators), so what we learn in the fly often translates to higher animals. It also has a relatively low-complexity microbiome and relies solely on innate immunity, which lets us study a coordinated, whole-organism response without the confounding layer of adaptive immunity. Much of this began as coffee-table discussions between Dr Marathe and Dr Tare, in the lab about how any gut, be it yours, mine, or a fly's, actually fights a bacterial infection, and the project took shape when Shreya Verma joined with a background in fly husbandry and a keen interest in host–pathogen interactions.

Q *For readers unfamiliar with the topic, how do fruit flies defend themselves against harmful bacteria that enter through food?*

A To combat bacteria, the fly relies entirely on its innate immune system. This provides fly a rapid non-specific defense against invading pathogens. Upon bacterial invasion, two immune pathways - IMD and Toll are activated which leads to the production of antimicrobial peptides. Additionally, flies also have immune cells like hemocytes which phagocytose the invading bacteria.

Q *Your study found that fruit flies can actively expel pathogens from their gut. How does this process work in simple terms?*

A In simple terms, the fly physically pushes the bacteria out. When bacteria are ingested, a sensor channel called TRPA1, found in the enteroendocrine cells of the gut, becomes activated. Once switched on, TRPA1 triggers signals that make the intestinal muscles contract. Those rhythmic contractions are peristalsis, the same wave-like squeezing that normally moves food along the gut, and here they serve to flush the live bacteria out of the body. We could see signs of this as we recovered live bacteria being shed by the infected flies. So rather than only trying to kill the invaders chemically, the fly uses gut movement to expel them.

Q *What role do reactive oxygen species (ROS) and the TRPA1 pathway play in controlling gut infections?*

Within just 4 hours of ingesting the bacteria, the fly gut activated its initial line of defence and rapidly produced reactive oxygen species (ROS). These molecules are reactive and powerful enough to damage any macromolecule, including bacterial membranes. However, ROS, when left unchecked, begins destroying the fly's own cells. The ROS levels dropped by 24 hours post-ingestion, suggesting a preventive mechanism in place. Then, at 48 hours post-ingestion, ROS levels surged again. The team traced the ROS production primarily to an enzyme called Duox (Dual Oxidase), which acted as the gut's main ROS factory. Remarkably, all of this was happening solely in the gut, leaving the rest of the body at peace.

Q *One interesting finding was that different bacterial species triggered different responses. What were the most surprising differences you observed?*

A The most striking thing was within just 48 hours of bacterial ingestion, the flies cleared nearly all bacterial species, although *E. cloacae* persisted briefly (at least 72 hours post ingestion) before being gradually pushed out of the body.

Additionally, *S. Typhimurium* and *E. cloacae* induced TRPA1, accompanied by their shedding. However, *K. pneumoniae* was the real mystery: ROS was high but TRPA1 was not induced, yet the flies still excreted it, pointing to a TRPA1-independent route as well. Despite all these differences, by 15 days post infection no bacteria could be recovered from any group, and very few flies died.

Q *How could insights from fruit fly gut immunity help scientists better understand infection control and gut health in other animals, including humans?*

A Since *TRPA1* and *Duox* have counterparts in the human gut, it's possible that a similar mechanism operates in humans as well.

This raises Important concerns: what would happen to bacterial expulsion when gut contractions are reduced by antispasmodic drugs in certain diarrheal conditions? While these medications may alleviate discomfort, are we also hindering the host's ability to effectively defend against the infection? Validating this mechanism in a mammalian model system could help address these questions.

Clinically, gut-motility disorders such as irritable bowel syndrome and bacterial gastroenteritis are linked to Intestinal contractions. Our work emphasis on the message that not all discomfort is a sign of weakness; sometimes those contractions mean the body is fighting back.

Q *What are the next key questions your team hopes to explore about host–pathogen interactions and gut defence mechanisms?*

A Our future work aims to better understand these responses mechanistically and to map out the differential way fly activates and regulates these pathways against different pathogens. Beyond that, we are interested in whether these natural host defences can be repurposed to improve the way gastrointestinal infections are treated.

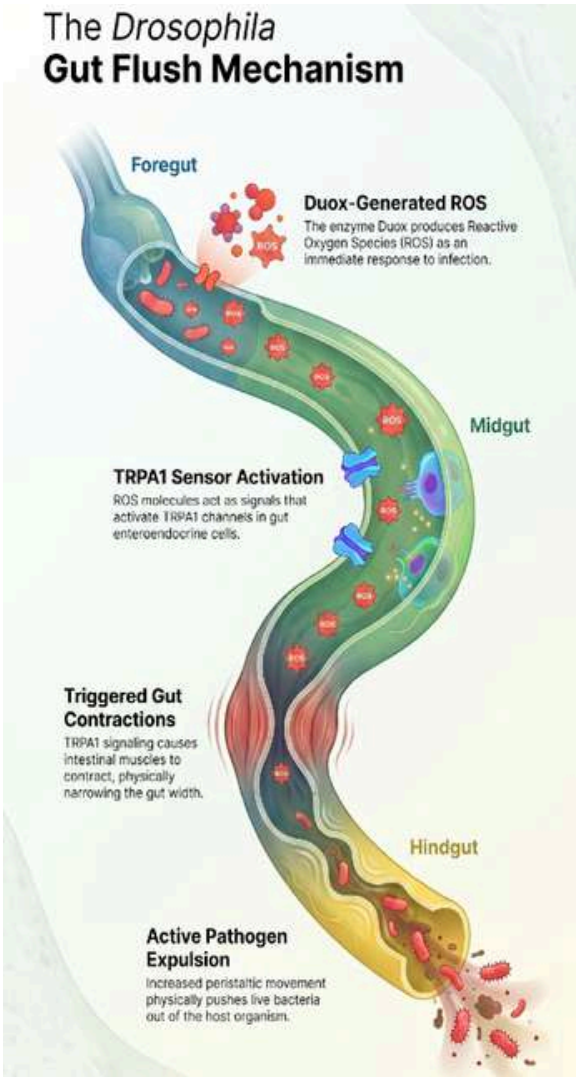

Figure 1: Duox-generated ROS activate TRPA1 in enteroendocrine cells, inducing peristalsis movement that expels bacteria via intestinal muscular contractions.

SCIENCE DESK

From Coal to Quantum Technology: How Nigerian Lignite Could Help Power the Next Generation of Nanotechnology

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AREAS OF EXPERTISE
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Q *What inspired you to explore low-grade lignite coal as a starting material for carbon quantum dots?*

A The inspiration arose from two important realities. First, Nigeria possesses significant lignite coal reserves, particularly in Enugu State, that have remained largely untapped since the country's transition from coal to petroleum-based energy. Second, there is a growing global demand for sustainable, affordable, and environmentally friendly nanomaterials.

Rather than viewing lignite coal solely as a fuel or an environmental burden, we saw an opportunity to transform it into a high-value technological resource. Our goal was to demonstrate that a locally available and underutilized material could be converted into advanced nanomaterials with significant industrial and scientific value. This approach aligns with modern principles of resource recovery, sustainability, and the circular economy.

Q *In simple terms, what are carbon quantum dots, and why are they attracting so much attention?*

A Carbon quantum dots are extremely small carbon-based nanoparticles, typically less than 10 nanometres in size. To put this into perspective, thousands of these particles could fit across the width of a human hair.

What makes them special is that matter behaves differently at such small dimensions. When particles become sufficiently small, they exhibit quantum confinement effects, which alter how electrons move within the material. As a result, carbon quantum dots can absorb and emit light, conduct electrical charge, and interact with chemicals in unique ways.

These properties have attracted worldwide attention because CQDs can potentially be used in medical imaging, drug delivery, environmental monitoring, water purification, photocatalysis, solar energy harvesting, light-emitting devices, sensors, and advanced electronic technologies. Unlike some conventional quantum dots that contain toxic heavy metals, carbon quantum dots are generally considered more environmentally friendly and biocompatible.

Q *What makes lignite coal a particularly suitable and sustainable precursor?*

A Lignite coal offers several advantages that make it uniquely suited for CQD production.

First, it contains a high concentration of carbon, whi-

ch forms the backbone of carbon quantum dots. More importantly, lignite naturally contains elements such as nitrogen, sulfur, silicon, aluminium, calcium, iron, magnesium, and oxygen. During synthesis, many of these elements become incorporated into the quantum dots as dopants, enhancing their functionality without requiring expensive additional chemicals.

The relatively low carbonization level of lignite also makes it highly reactive. Its abundance of oxygen-containing functional groups and volatile matter facilitates the breakdown of the coal structure into nanoscale carbon domains during synthesis.

From a sustainability perspective, lignite is abundant, inexpensive, and readily available. Using it as a nanomaterial precursor transforms a low-value resource into a high-value technological product while reducing dependence on costly synthetic feedstocks.

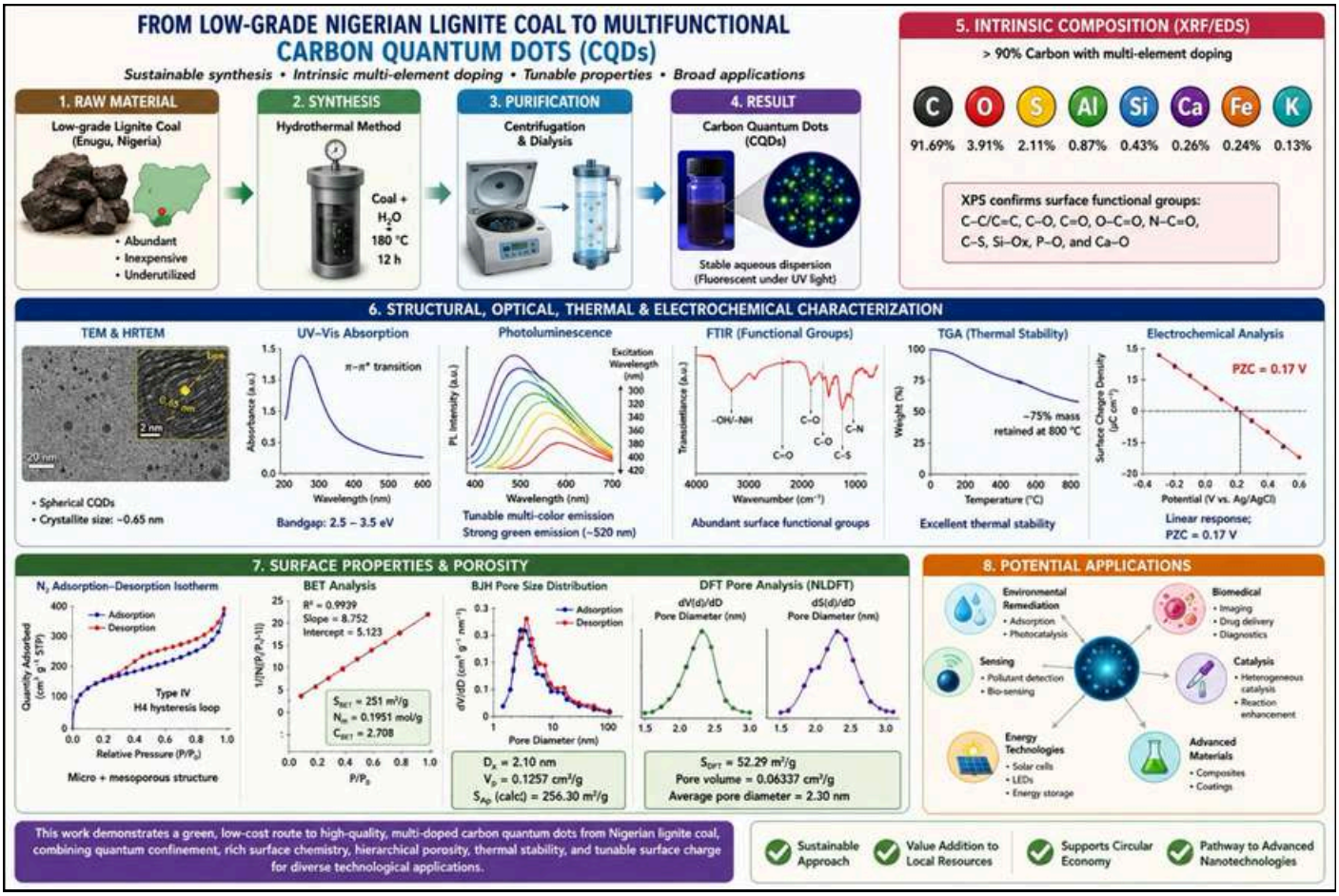
Q *What was the most surprising or exciting finding from your study?*

A Several discoveries were particularly exciting. First, the synthesized CQDs contained over 90% carbon while simultaneously incorporating naturally occurring dopants such as nitrogen, sulfur, silicon, and aluminium. This intrinsic multi-element doping significantly enhanced their functionality.

Second, we observed strong quantum confinement effects. The CQDs possessed an extremely small crystallite size of approximately 0.65 nanometres, resulting in tunable optical properties and bandgap energies between approximately 2.5 and 3.5 electron volts. These values are highly desirable for optoelectronic applications.

Another exciting result was their fluorescence behaviour. The CQDs emitted different colours depending on the excitation wavelength, producing stable and tunable photoluminescence with strong green emission. Such behaviour is highly valuable for imaging and sensing technologies.

We also discovered a hierarchical pore structure cons-



isting of both micropores and mesopores, combined with a moderate surface area and abundant surface functional groups. These characteristics make the material attractive for adsorption, catalysis, and environmental remediation.

Finally, the CQDs exhibited remarkable thermal stability, retaining approximately 75% of their mass at temperatures as high to 800°C. This suggests potential suitability for applications requiring robust performance under demanding conditions.

Q *How could these coal-derived carbon quantum dots be used in real-world applications?*

A The potential applications are extensive.
In environmental remediation, the CQDs can adsorb contaminants and enhance photocatalytic degradation of pollutants such as dyes, heavy metals, and organic compounds. Their porous structure, surface functional groups, and dopant-rich composition make them particularly effective for water treatment technologies.

In sensing applications, their fluorescence changes can be used to detect pollutants, metal ions, food contaminants, and biological molecules with high sensitivity.

In biomedical fields, the CQDs show promise as fluorescent imaging probes because they emit bright, tunable light. Their surface charge characteristics and biocompatibility may also support future applications in targeted drug delivery and diagnostics.

For energy technologies, the CQDs possess optical bandgaps suitable for solar energy conversion, light-emitting devices, photocatalysis, and other optoelectronic applications. Their ability to absorb and transfer energy efficiently makes them attractive candidates for next-generation renewable energy systems.

The combination of quantum confinement, intrinsic doping, hierarchical porosity, and tunable surface charge creates a multifunctional platform capable of serving numerous technological sectors.

Q *What are the next major challenges and opportunities in this field?*

A One of the major challenges is scaling up production while maintaining precise control over particle size, surface chemistry, and optical properties. Laboratory synthesis is relatively straightforward, but industrial-scale manufacturing requires consistency and quality assurance.

Another challenge involves optimizing the materials for specific applications. Different uses require different combinations of fluorescence, conductivity, porosity, and surface functionality.

Further studies are also needed to evaluate long-term environmental safety, biological interactions, and commercial viability.

The opportunities, however, are enormous. Growing global interest in sustainable nanotechnology creates a pathway for transforming underutilized natural resources into advanced materials. For countries such as Nigeria, this research demonstrates how local resources can contribute to high-value manufacturing, environmental technologies, renewable energy systems, and scientific innovation.

Our findings show that low-grade lignite coal is far more than a fossil fuel resource. It can serve as a naturally pre-engineered nanomaterial precursor that simultaneously provides carbon, dopants, surface functional groups, hierarchical porosity, and electronic tuning. By converting an underutilized resource into multifunctional carbon quantum dots, we have demonstrated a pathway toward sustainable nanotechnology that benefits both science and society.

Reference

Prof. Eddy and Dr. Garg's contributions to sustainable nanomaterials research are highlighted in their recent publication in BMC Chemistry (2026), https://doi.org/10.1186/s13065-026-01798-x which demonstrates an innovative approach to transforming an underutilized natural resource into high-value nanomaterials while supporting sustainable resource utilization and environmental management.

SCIENCE DESK

How Cancer Cells Survive Low Oxygen Stress

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Scientific Profile
Organization Link
Factors Press

AREAS OF EXPERTISE
Cancer biology • Cancer Drug Resistance • Non-coding RNA in Cancer

Q *What first led you to explore the connection between hypoxia, ER stress, and DNA repair in solid tumors?*

A Our interest began with a simple question: How do cancer cells survive under extreme stress? Earlier studies showed that proteins involved in DNA repair and cell recycling (autophagy) move to different parts of the cell when it is under stress, suggesting that these systems communicate with each other. In our previous research, we discovered that Beclin1, a protein best known for its role in autophagy, also helps repair damaged DNA by working with a DNA repair protein called MDC1. We found that Beclin1 supports DNA repair after damage caused by chemotherapy or radiotherapy. This revealed that the DNA repair system and autophagy work together to help cells decide whether to survive or die under stressful conditions. Solid tumors experience constant stress because they often lack oxygen and nutrients and contain high levels of harmful molecules. Cancer cells rely heavily on these stress-response systems such as DNA repair, autophagy, and the endoplasmic reticulum (ER) stress response to survive. Understanding how these systems interact may help us identify new ways to target cancer cells.

Q *Can you explain in simple terms what happens to cancer cells when they face low-oxygen conditions inside tumors?*

A Low oxygen, or hypoxia, makes cancer cells more aggressive and harder to treat. Under these conditions, a protein called HIF-1α becomes active and switches on many genes that help cancer cells survive including, DNA repair, autophagy, and the ER stress response genes. HIF-1α also activates the changes that allow tumors to grow new blood vessels, spread to other parts of the body, and change the way they produce energy. Instead of relying on oxygen dependent sugar breakdown they switch to oxygen independent mechanism of energy generation, a process known as the Warburg effect. This produces lactic acid, making the area around the tumor more acidic. The acidic environment weakens the body's immune response and makes it more difficult for medicines to enter the tumor. The chemotherapy drugs are pumped out of the cell before the drugs have a chance to work, making treatment less effective.

Q *Your review discusses both ER stress and DNA repair pathways, why is their interaction so important in cancer biology?*

A ER stress and DNA repair are closely connected and decide cellular fate. Low oxygen causes proteins to fold incorrectly inside the endoplasmic reticulum, triggering the ER stress response. ER stress is accompanied by generation of reactive oxygen species which induce oxidative DNA damage including double stranded DNA breaks leading to activation of DNA repair response. Additionally, ER stress can directly suppress or activate DNA repair pathways. The DDR proteins can modulate the ER stress response and when the DDR is overwhelmed, it can sensitize a cell to ER stress-induced cell death. In this way, the two systems constantly communicate with each other. Cancer cells often experience continuous DNA damage and problems during DNA replication. By working together, the ER stress response and DNA repair pathways allow cancer cells to keep growing despite these challenges, making tumors more resistant to treatment.

Q *What surprised you the most about how these stress pathways help tumors survive and become more aggressive?*

A One surprising finding is that the same stress-response systems that normally protect healthy cells can also help cancer cells survive. When these pathw-

ays remain active for long periods, they allow cancer cells to accumulate mutations, become genetically unstable, and develop into more aggressive forms. The ER stress response helps protect proteins from damage, while DNA repair systems fix damaged DNA and pause cell division until repairs are completed. Together, these pathways help cancer cells survive difficult conditions such as low oxygen, chemotherapy, and radiation. Unfortunately, this also makes tumors more diverse, more likely to spread, and more resistant to treatment.

Q *Do you think understanding this cellular "survival system" could help improve cancer treatment in the future?*

A Yes. Although these stress-response systems help cancer cells survive, they may also provide an opportunity for new treatments. If therapies are developed that block both the ER stress response and DNA repair at the same time, cancer cells may no longer be able to cope with the damage caused by treatment. Without these protective systems, cancer cells would become much more likely to die. This suggests that combining drugs that target both pathways could improve treatment effectiveness and help overcome resistance to chemotherapy and radiotherapy.

Q *What are the next steps, and what still needs to be discovered before this knowledge can be translated into better therapies?*

A Several challenges remain before these discoveries can be turned into effective treatments. First, these stress-response systems are also essential for healthy cells, so any new therapy must avoid causing excessive damage to normal tissues. Second, tumors constantly evolve and can become resistant by activating alternative survival pathways. In addition, different parts of the same tumor may respond differently to treatment because tumors contain a mixture of sensitive and resistant cells. Researchers also need to determine the best order and timing for combination treatments. Finding reliable biomarkers that identify patients whose tumors depend most on these stress pathways will help doctors choose the right patients for these therapies. Finally, new drug delivery technologies, such as nanoparticles and antibody-guided treatments, may help deliver these medicines more precisely to tumors while reducing side effects.

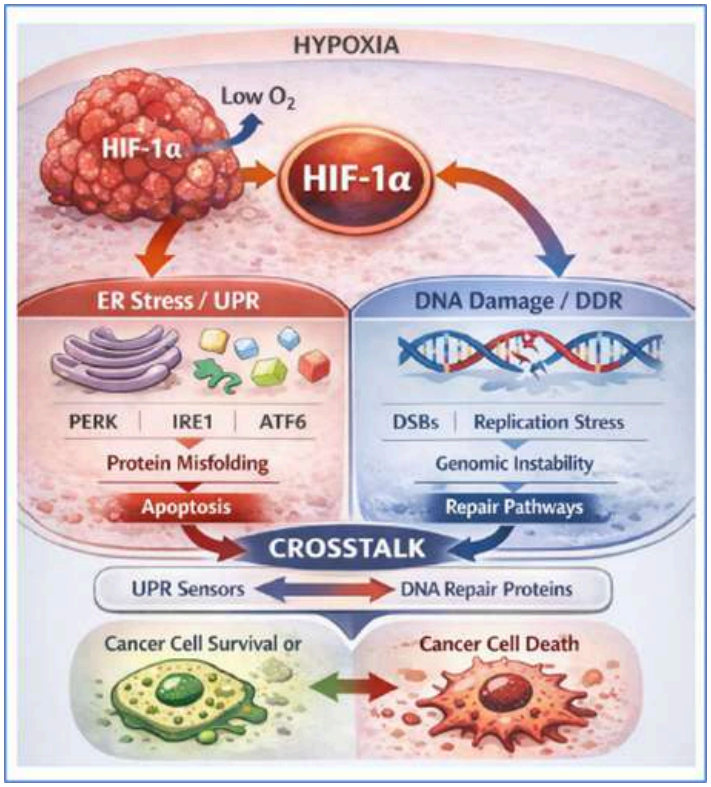
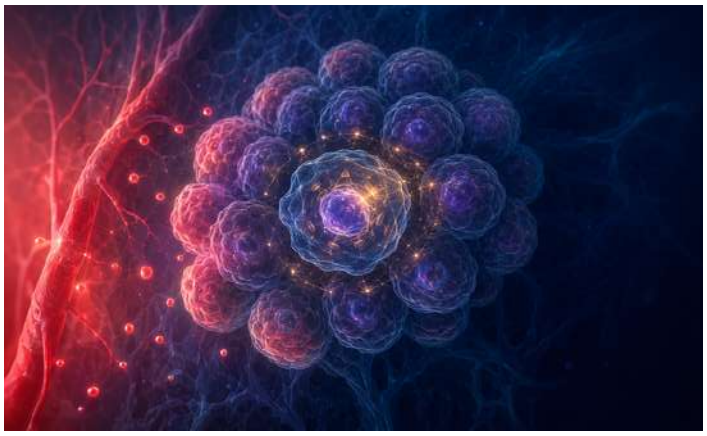


Figure shows activation of HIF1α during hypoxia in tumor microenvironment. The transcriptional activity of HIF1α regulates DDR and UPR/ESR and the two pathways interact to decide cellular fate promoting either survival or cell death.

These advances could make future therapies both safer and more effective.

Reference

Dr. Singh's contributions to cancer research are highlighted by the recent publication in the International Journal of Cancer (2025), https://pubmed.ncbi.nlm.nih.gov/41804218/. The review explains how low oxygen, ER stress, and DNA repair work together to help cancer cells survive and resist treatment. It also highlights new opportunities to develop more effective cancer therapies.



SCIENCE DESK

The drama of genetic susceptibility for oral cancer: an interplay between genes and risk factors

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

AREAS OF EXPERTISE
Oral Cancer Biology • Oral Pathology • Molecular Biomarkers • Salivary Diagnostics

Q *Many people use tobacco for decades without developing oral cancer, while others develop it much sooner. What inspired you to investigate the role of genetics in this striking difference?*

A This question arises from a common observation in society. While tobacco is the major cause of oral cancer, not everyone who uses tobacco develops the disease. Some individuals consume tobacco for decades without developing any high-risk oral lesions, whereas others develop oral cancer after a relatively short period of exposure. This suggests that factors beyond tobacco itself influence cancer risk. Our study focused on one of these key factors, genetic susceptibility, which determines how effectively an individual's body repairs damage caused by carcinogens.

Q In simple terms, what is genetic susceptibility, and why can two people with similar tobacco and/or alcohol habits have very different risks of developing oral cancer?

A Every individual's body has a natural ability to repair damage caused by harmful substances such as tobacco and alcohol. When this repair system works efficiently, damaged cells can be repaired or eliminated. However, if this protective capacity is reduced because of inherited genetic differences, DNA damage accumulates over time, increasing the risk of oral cancer. Genetic susceptibility is inversely proportional to an individual's inherent capacity to repair DNA damage caused by various carcinogens. It means that if repair capacity is reduced or not functioning properly, the genetic susceptibility to developing cancer increases. Processes such as DNA repair, programmed cell death (apoptosis), immune surveillance, detoxification, and elimination of carcinogens all contribute to protecting the body, but their efficiency varies from person to person.

Q *Your study identified several genes, including TP53, CASP8, HIF, DEC1, MTNR1B, and CYP1A1. What roles do these genes play, and why are they important in oral cancer?*

A Our analysis showed that variations (polymorphisms) in several genes are significantly associated with oral squamous cell carcinoma in people exposed to tobacco and alcohol. TP53, often called the "guardian of the genome," prevents damaged cells from multiplying. CASP8 helps remove abnormal cells through programmed cell death. HIF regulates how cells respond to low oxygen conditions, while DEC1 participates in immune regulation. MTNR1B plays a role in physiological processes such as circadian rhythm regulation. Among these, CYP1A1 showed particularly strong associations in the Indian population because it activates tobacco-related chemicals into highly reactive compounds that can damage DNA and promote cancer development.

Q *Your analysis found particularly strong associations in Asian populations, especially India, China, and Taiwan. Why might these populations be at higher risk?*

A Our study found higher odds of oral cancer-associated genetic polymorphisms in Asian populations than in many other populations. This increased susceptibility is likely due to a combination of inherited genetic factors and environmental exposures. In addition, tobacco products are widely cultivated and readily available in many Asian countries, increasing exposure from an early age. Therefore, both genetic

susceptibility and environmental factors together contribute to the higher burden of oral cancer in these populations.

Q *What is the most important message from your study for the public, particularly regarding tobacco use and individual cancer risk?*

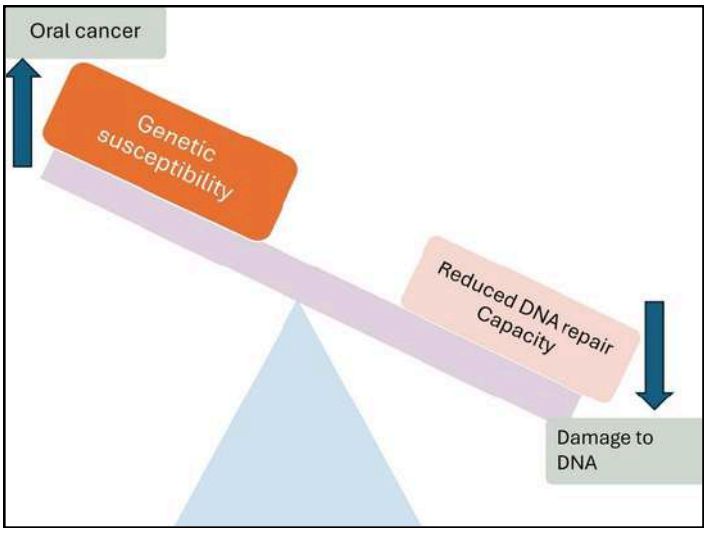
A The most important message is that no one knows their own genetic susceptibility. Every individual has a different ability to repair DNA damage caused by carcinogens. Therefore, it is a mistake to assume that tobacco is safe simply because someone else has used it for many years without developing cancer. Genetics differs from person to person, and tobacco remains a proven carcinogen. The safest approach is to avoid tobacco altogether rather than relying on comparisons with others.

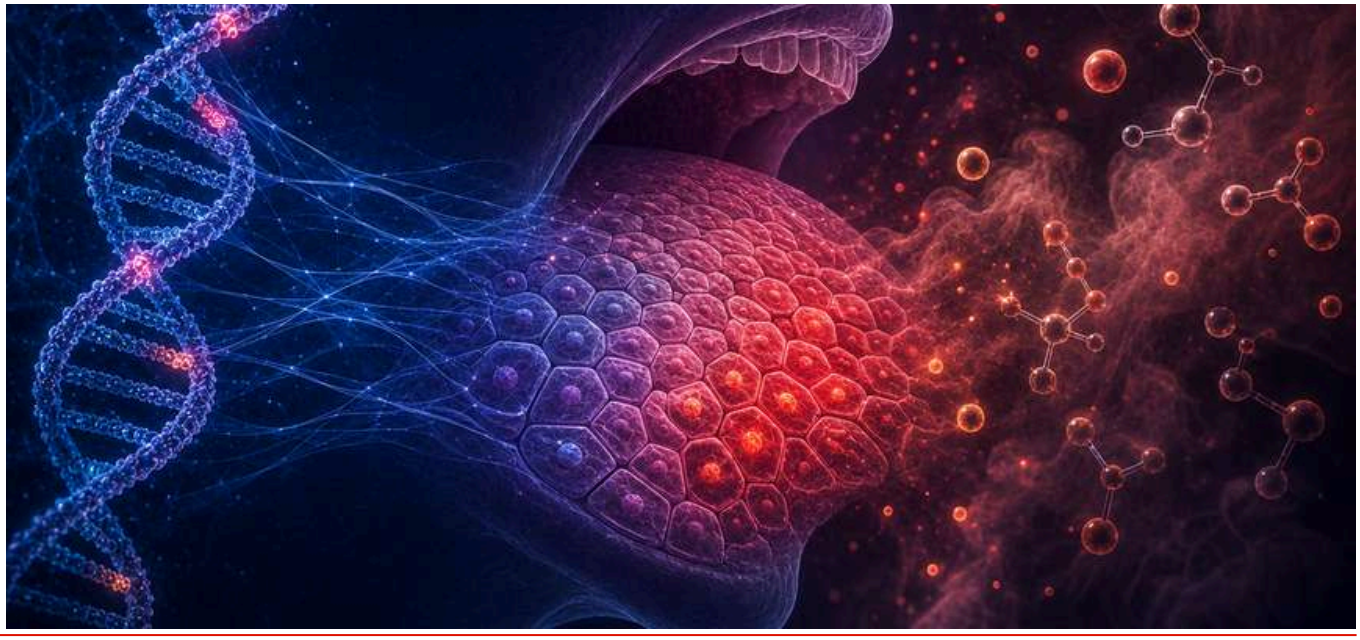
Q *What should future research focus on in the area of genetic susceptibility to oral cancer?*

A Several important questions remain unanswered. More studies are needed to understand the hereditary contribution to oral cancer, particularly through large familial studies. Future research should also investigate how genetic susceptibility varies across different geographical regions and ethnic groups, helping identify high-risk genes in specific populations. Such studies will improve our understanding of why oral cancer prevalence differs worldwide and may eventually support more personalized approaches to prevention and risk assessment.

Reference

Prof. Jadhav's contributions to oral cancer research are highlighted by the recent publication of in Communications Medicine (2026), https://doi.org/10.1038/s43856-026-01398-9. The study advances our understanding of how inherited genetic variation interacts with environmental risk factors such as tobacco and alcohol use, supporting improved risk assessment, prevention strategies, and the future development of personalized approaches to oral cancer management.





SCIENCE DESK

A New Natural Weapon Against Fungal Infections

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Scientific Profile
Organization Link
Factors Press

AREAS OF EXPENTISE
Antimicrobials • AMR • Food-grade Probiotics • Plant-Microbe Interaction

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AREAS OF EXPERTISE
Seed endophytes • Plant microbe interaction • Plant growth promotion • Biocontrol

Q *What inspired you to explore rice seed-associated microbes as a source of new antifungal compounds?*

A Our laboratory has long been fascinated by the remarkable partnership between plants and their beneficial endophytic microbes. Rice seeds, in particular, carry inherited bacterial communities that have co-evolved with the plant over millions of years, making them a special and mostly unexplored microbial reservoir. We reasoned that such long-term evolutionary interactions might have equipped seed-associated endophytes with unique chemical weapons that have remained largely unexplored. We sought to find naturally existing microbial resources with strong antifungal qualities in light of the growing global concern over antifungal resistance and the effects of artificial fungicides on the environment. The notion that beneficial bacteria living in rice seeds could offer long-term, environmentally acceptable solutions for managing diseases while also deepening our knowledge of microbial biodiversity and plant-microbe interactions served as the impetus for our investigation.

Q *Your team discovered a novel molecule called SM06. Can you take us through the journey from its discovery to identifying its antifungal properties?*

A The discovery of SM06 was initiated from our extreme interest on an exceptional bacterial strain associated with rice seeds that had several advantageous characteristics started the process of finding SM06. This bacterium may be used as a probiotic to treat hypercholesterolemia, as demonstrated by us in previous research using mice models. Simultaneously, the strain demonstrated potent plant growth-promoting capabilities that improved plant health and stress tolerance which indicates its use both as promising plant probiotic and a human probiotic strain.

We first screened the strain against bacterial and fungal phytopathogens and found significant inhibitory effects against multiple tested fungal strains. The next challenge was identifying the active molecule responsible for this activity. Using chromatographic purification coupled with high-resolution mass spectrometry and advanced spectroscopic analyses, we isolated the metabolite SM06. Structural characterization revealed that it represented a new natural chemical (indole dimer) entity. We then rigorously validated its biological activity through laboratory assays against multiple economically and medically important fungal pathogens. Microscopic analyses, biochemical investigations, and molecular studies consistently demonstrated that SM06 possesses broad-spectrum antifungal activity. Additional research revealed that the chemical disrupts cellular integrity and fungal development. Importantly, we also showed that the bacterium naturally synthesizes SM06 inside rice plants, indicating that this metabolite is not merely produc-

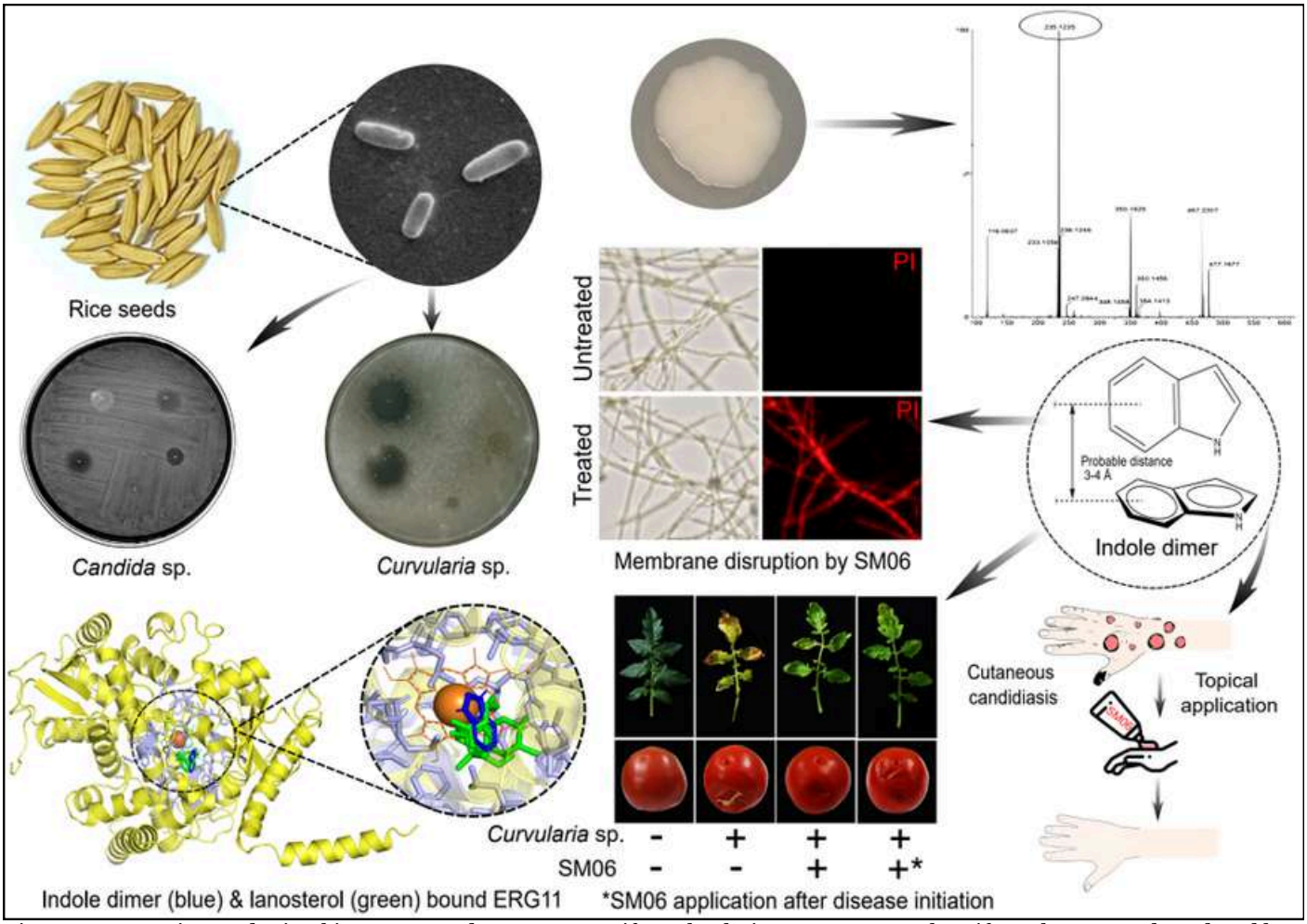

Figure 1. From Rice Seed Microbiome to Broad-Spectrum Antifungal Solution. SM06, a novel antifungal compound produced by a rice seed-associated bacterium, offers a sustainable and innovative solution to combat fungal disease in crops and humans.

ed under laboratory conditions but is likely involved in the natural defense system of the plant.

Q *How does SM06 attack fungal pathogens, and what makes its mode of action different from many existing antifungal treatments?*

A Our mechanistic investigations revealed that SM06 targets one of the most critical components of fungal biology- ergosterol biosynthesis. Ergosterol functions as the principal sterol of fungal cell membranes and is essential for maintaining membrane integrity, nutrient transport, and cellular survival. By disrupting ergosterol production, SM06 destabilizes fungal membranes, leading to severe cellular damage and inhibition of fungal growth. Microscopic and biochemical analyses demonstrated that exposure to SM06 causes significant damage to the fungal spore as well as vegetative cells. In addition, SM06 induced excessive accumulation of reactive oxygen species (ROS) within fungal cells, resulting in oxidative stress that further compromises essential cellular functions.

What makes SM06 particularly interesting is that it is structurally distinct from currently available antifungal drugs. Although several clinical antifungals also interfere with ergosterol pathways, SM06 represents a completely new natural scaffold discovered from a beneficial plant-associated bacterium. Novel chemical scaffolds are especially valuable because they may overcome existing resistance mechanisms and provide new opportunities for developing next-generation antifungal therapeutics. Additionally, SM06 is derived from a naturally occurring bacterium associated with rice seeds, demonstrating the potential of plant microbiomes as sources of novel and ecologically sustainable antifungal treatments. SM06 is a good candidate for future uses in agriculture and perhaps other fields where fungal infections exert serious concerns for the civilization.

Q *Fungal diseases and antifungal resistance are growing concerns worldwide. How could discoveries like SM06 contribute to more sustainable disease management in agriculture and beyond?*

A The increasing emergence of antifungal resistance poses serious challenges in agriculture, medicine, and food preservation. Modern agriculture often depends heavily on repeated fungicide applications, which increase production costs, create environmental concerns, and accelerate resistance development. Similarly, clinicians have relatively few therapeutic options when treating invasive fungal infections.

Natural microbial metabolites such as SM06 offer a promising alternative. As they originate from beneficial microorganisms that naturally coexist with plants, they provide an opportunity to develop environmentally sustainable disease-management strategies. Such compounds could potentially reduce reliance on synthetic fungicides while simultaneously extending the diversity of antifungal molecules available for medical research. It may spur the creation of next-generation antifungal therapies to treat resistant fungal infections in clinical settings. Although substantial work remains pending before clinical applications become feasible, discoveries like SM06 expand the pipeline of natural antifungal leads that may eventually contribute to safer crop protection, improved food security, and future therapeutic development.

Q *One of the fascinating findings was that the beneficial bacterium can produce SM06 inside plants. Why is this discovery particularly important for future crop protection strategies?*

A Perhaps one of the most significant findings of our study was demonstrating that the rice seed endophyte produces SM06 within the living plant itself. This observation suggests that the bacterium functions as an internal biological factory, continuously generating protective molecules exactly where pathogens attempt to establish infection. Unlike conventional fungicides, which require repeated external applications, beneficial endophytes have the potential to establish long-term residence within plant tissues. If they consistently produce protective metabolites during colonization, they could provide continuous biological protection throughout plant development. This concept opens exciting possibilities for developing next-generation biological crop protection systems in which naturally occurring beneficial microbes strengthen plant immunity from within. Such approaches align well with sustainable agriculture by reducing chemical inputs while improving disease resilience.

Q *Your study showed that SM06 is effective against both plant and human fungal pathogens while remaining biocompatible. What does this suggest about its broader potential applications?*

A The dual activity of SM06 against both agricultural and clinically relevant fungal pathogens is particularly encouraging. Many fungal species affecting crops share fundamental biological processes with fungi responsible for human disease. Therefore, compounds capable of targeting conserved fungal pathways may possess broad-spectrum applications. Also, preliminary biocompatibility studies indicated that SM06 exhibited minimal toxicity toward mammalian cells under the experimental conditions examined. While considerably more preclinical evaluation is necessary, these findings provide an encouraging foundation for future development. Dual agricultural-medical relevance of SM06 exemplifies the growing "One Health" concept, recognizing that the health of plants, animals, humans, and ecosystems is interconnected. Natural products capable of serving multiple sectors may become increasingly valuable as society seeks integrated solutions to combat antimicrobial resistance.

Q *Looking ahead, what are the next steps in developing SM06, and how close are we to seeing such natural antifungal solutions used in real-world agriculture or healthcare?*

A Our published study establishes SM06 as a promising natural antifungal lead, but it also marks the beginning rather than the end of the scientific journey. We are now examining whether production can be enhanced through metabolic engineering. Additional studies will evaluate efficacy against larger collections of fungal pathogens, investigate resistance development, and assess safety towards normal flora upon application. We are also interested in understanding how endophytic bacteria establish stable colonization within plants and whether similar metabolites exist in other crop-associated microbiomes. Although commercialization requires

substantial additional research, we believe discoveries like SM06 illustrate how exploring beneficial plant microbiomes can simultaneously advance sustainable agriculture, food security, and human health. By uncovering these hidden microbial partnerships, we may discover entirely new generations of environmentally friendly antifungal agents capable of addressing one of the most pressing global challenges of the twenty-first century.

Reference

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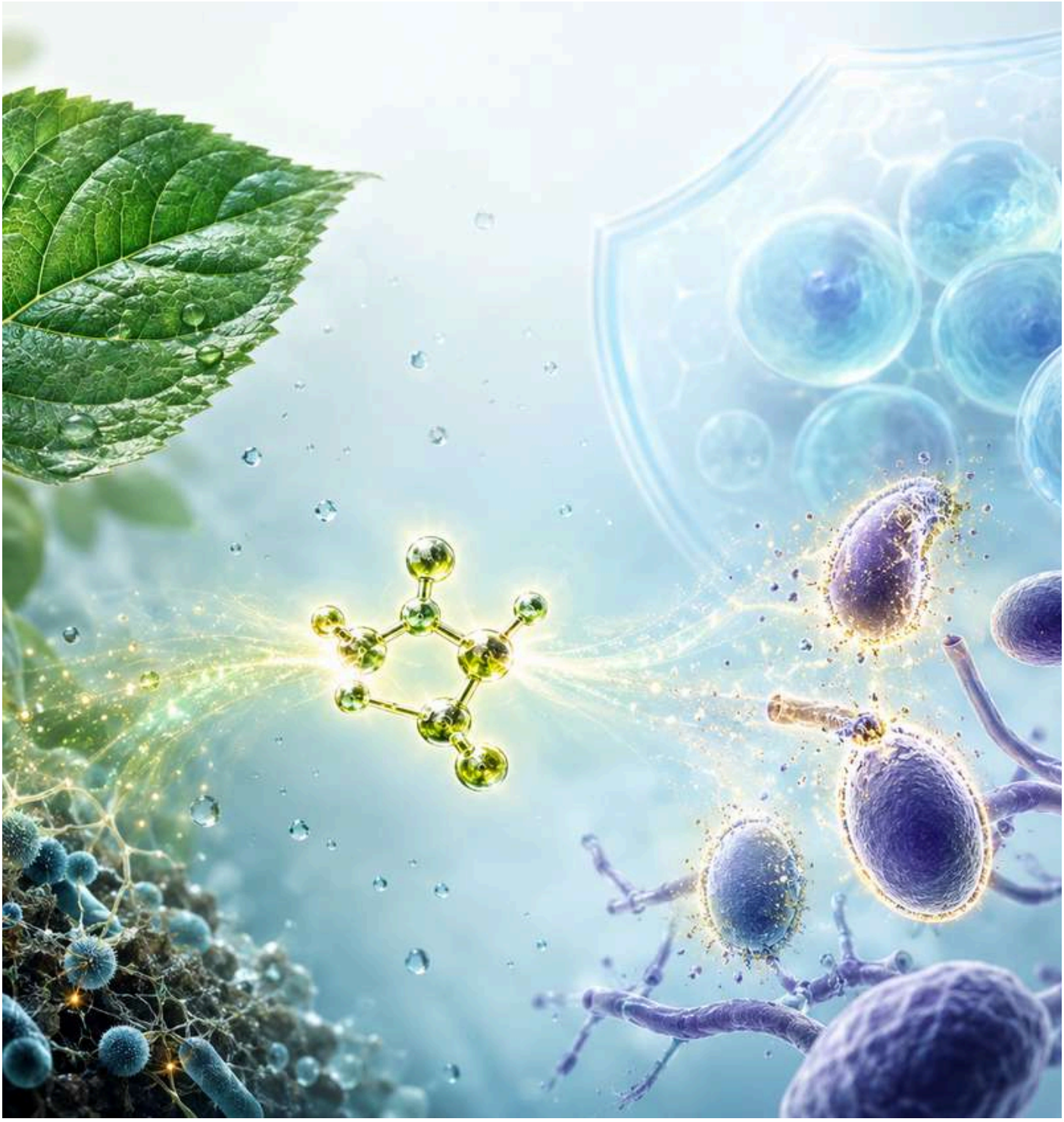

SCIENCE DESK

Water clusters in interstellar space: Why do they matter?

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Scientific Profile
Organization Link
Factors Press

AREAS OF EXPERTISE
Quantum Topology • Aromaticity • Excited states

Q *What inspired you to investigate how water interacts with small molecules found in interstellar space?*

A If asked about the importance of water, almost anyone can write a thesis, as water is the very foundation of life. If the responder has a background in chemistry, the importance of water as a solvent would also be highlighted. We know water can dissolve many polar molecules and even several non-polar molecules under suitable conditions.

The mechanism of dissolution is fascinating. A polar solute is surrounded by water molecules that form a primary hydration shell, where the water molecules orient themselves according to the charges of the solute. This shell is stabilized by hydrogen bonds between the water molecules themselves. Beyond this lies a secondary hydration shell, which is more flexible because its water molecules interact mainly with each other rather than directly with the solute.
When the solute is very small, fewer water molecules are needed to build these hydration shells. This naturally leads us to ask how such tiny hydrated systems behave, particularly under the extreme conditions of interstellar space.

Q *Why are these molecules important for understanding the chemistry of the universe and the origins of life?*

A Instead of bulk solvation, we study the solvation of individual molecules, a process known as micro-solvation. Here, a finite number of water molecules surround a single solute to form molecular clusters.
These clusters become especially important in interstellar space, where temperatures are around 10 K and water cannot exist as a liquid. Instead, water molecules accumulate around small molecules frozen onto dust grains, creating hydrated clusters.

Scientists recreate these conditions in the laboratory by depositing molecules such as ammonia and carbon monoxide onto cold dust grains inside ultra-high vacuum chambers. Surprisingly, these experiments have shown that complex molecules—including sugars and peptides, the building blocks of proteins—can form under such conditions. This raises exciting possibilities that some of the ingredients necessary for life may have existed long before planets formed and may have been delivered to young planets by comets and meteorites.

Q *In simple terms, what are non-covalent interactions, and how do they help molecules stick together in space?*

A The chemical forces responsible for forming these clusters are called non-covalent interactions, with hydrogen bonding being one of the most important examples. These are relatively weak attractive forces that hold molecules together without forming permanent chemical bonds.

Although individual non-covalent interactions are weak, collectively they stabilize molecular clusters. In the cold environment of space, when reactive molecules collide, they lack sufficient thermal energy to separate again. Instead, they remain attached through these interactions, allowing chemical reactions to proceed.

Q *What were the most surprising discoveries about the hydrogen bonds formed in these hydrated molecular clusters?*

A When we studied the formation of these clusters, we found that the processes are both exothermic and spontaneous. Even more surprisingly, they are driven by a positive change in entropy, which is contrary to the usual expectation that association processes decr-

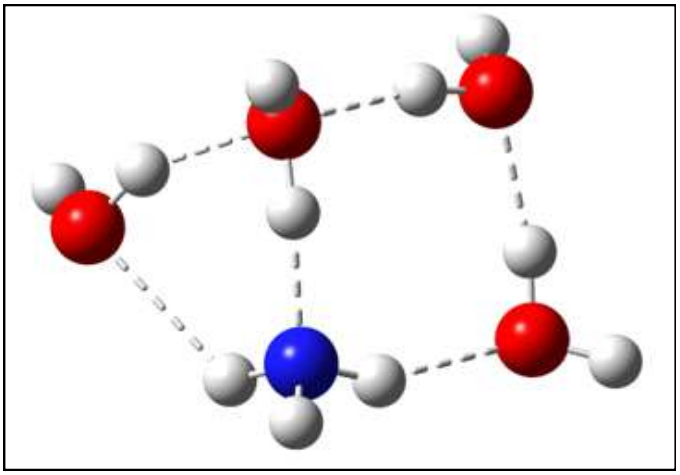

Figure 1. Simulated structure of the $NH_3(H_2O)_4$ cluster. The dotted lines represent the hydrogen bonds.

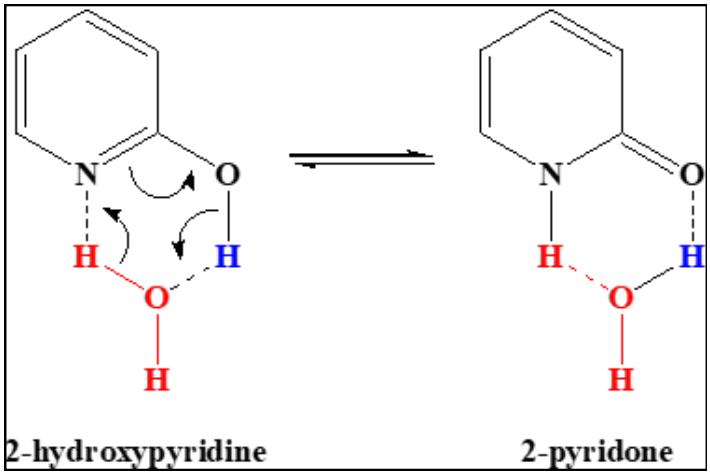

Figure 2. Water-mediated proton transfer. These two tautomers interconvert with the help of the attached water molecule.

ease entropy.

This occurs because two opposing effects determine the entropy change. While clustering reduces molecular flexibility, it also greatly increases the number of possible energy arrangements, known as microstates. In these systems, the increase in microstates outweighs the loss of flexibility.

Q *Your study found that some hydrogen bonds have partial covalent character. Why is this finding important?*

A Hydrogen bonding does more than simply hold molecules together. It can also promote chemical reactions through proton transfer.

Normally, isolated molecules require energy to switch between different tautomeric forms. However, when surrounded by water molecules, proton transfer can occur with an extremely small energy barrier. As a result, stable molecules can be converted into highly reactive forms even at temperatures close to absolute zero. This provides a mechanism by which complex chemistry can occur in deep space despite the lack of thermal energy.

Q *How does water influence the stability and behavior of molecules in the interstellar medium?*

A Water stabilizes molecular clusters through hydrogen bonding and other non-covalent interactions. These interactions make cluster formation energetically favorable and help molecules remain associated long enough for chemical reactions to occur.

In this way, water acts not only as a passive environment but also as an active participant that influences molecular stability, promotes proton transfer, and enables reactions that would otherwise be impossible under interstellar conditions.

Q *What are the next major questions you hope to answer about molecular interactions and chemistry in deep space?*

A One of the most exciting implications of this work is the possibility that the building blocks of life formed in dark molecular clouds before stars and planets existed. If meteorites and comets transported these molecules to young planets such as the early Earth, they may have contributed to the origin of life.

Future research aims to understand these molecular interactions in even greater detail, identify additional reaction pathways, and determine how widespread such chemistry may be throughout the universe. If these mechanisms are common, the probability of life emerging on habitable planets beyond Earth could be much higher than previously thought.

Reference

Dr. Ganguli's contributions to this field can be found in his recent publications in the journals ChemistrySelect (2026), https://doi.org/10.1002/slct.202504412 (DOI) and ChemPhysChem, which explore the role of non-covalent interactions and micro-solvation in determining the structure, stability, and properties of molecular clusters, including those relevant to interstellar chemistry(2026), https://doi.org/10.1002/cphc.70413.

SCIENCE DESK

Can Nose Surgery Look More Natural? The Science Behind a New Surgical Technique

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Scientific Profile
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AREAS OF EXPERTISE
Rhinoplasty • Blepharoplasty • Midface lift • Liplift

Q *What inspired you to develop this new approach to nose reshaping surgery?*

A Despite being called plastic surgery, the ultimate goal of aesthetic rhinoplasty is not to create a different face, but to refine existing features while preserving individuality. The best rhinoplasty is often the one that goes unnoticed, where patients simply look like the best version of themselves.

Traditional augmentation rhinoplasty has long relied on techniques that alter the native dorsal anatomy and place grafts directly beneath the skin. While effective, these methods can be associated with prolonged healing, postoperative irregularities, and outcomes that may evolve unpredictably over time. Preservation Push-Up Rhinoplasty was developed to address these limitations while maintaining the natural contour of the nasal dorsum.

Q *For readers unfamiliar with rhinoplasty, what problem does this new technique aim to solve?*

A Several augmentation techniques are currently available, among which diced cartilage and fascia (DC-F) remains widely practiced. However, the postoperative course with DC-F is highly dependent on patient compliance and is often associated with a prolonged healing phase. Patients frequently need to manipulate or mould the graft during the healing period, creating uncertainty regarding the final outcome. These challenges highlighted the need for a more stable and predictable method of dorsal augmentation.

Q *How is this method different from the traditional techniques surgeons commonly use today?*

A As its name suggests, Preservation Push-Up Rhinoplasty preserves the dorsal framework. Instead of positioning the graft between the skin and the dorsum, the graft is placed beneath the preserved dorsum. This allows the patient's natural dorsal contour to remain in direct contact with the skin. The graft itself is meticulously sculpted and customized to the exact dimensions required for augmentation and has therefore been termed the Dorsal Preservation Graft (DPG).

By retaining the native dorsal architecture, the natural dorsal aesthetic lines remain intact, allowing the skin to drape over the patient's own anatomy rather than over a graft. This creates a softer transition, a more authentic appearance, and results that are better integrated with the rest of the face.

Q *Why is it important to preserve the natural structure of the nose during surgery?*

A Preserving the natural structures helps maintain structural integrity while enhancing aesthetics. By respecting native anatomy and minimizing unnecessary dissection, the technique promotes predictable healing, preserves nasal function, minimizes postoperative irregularities, and maintains the natural dorsal aesthetic lines. Patients benefit from a nose that not only looks natural immediately after recovery but continues to age naturally over time.

The increasing demand for natural-looking outcomes has changed the way rhinoplasty is perceived today. Patients no longer seek a surgically altered appearance; rather, they seek refinement that complements their existing facial features. Preservation Push-Up Rhinoplasty aligns well with th-

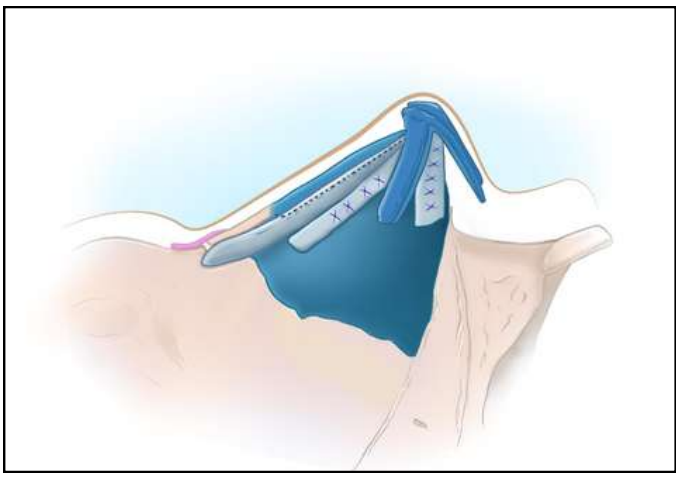

Figure 1. Push-up rhinoplasty with DPG. DPG extending 3-4mm into the ethmoid and positioned beneath nasal bone.

this philosophy by utilizing and respecting the native dorsal anatomy instead of replacing it.

Q *What benefits can patients expect from this approach compared with conventional procedures?*

A From a patient's perspective, the advantages are significant. Healing appears quicker and more predictable. Unlike traditional DC-F augmentation, patients are not required to mould the graft during recovery. Eyewear can generally be resumed one month after surgery, a considerable improvement over conventional approaches. Most importantly, patients often report that the outcome feels like their own nose, only better proportioned and more refined. The psychological comfort of recognizing oneself after surgery should not be underestimated.

The predictability of healing, reduced postoperative manipulation, and improved patient comfort further contribute to the appeal of this technique.

Q *Were there any surprising findings or lessons you learned while developing and refining this technique?*

A As with any innovation, the development of this technique was not without challenges. The procedure demands a high level of surgical expertise and specialized training, making reproducibility a key concern during its development. Efforts were therefore made to simplify critical surgical steps, modify the DPG design to improve accessibility, and refine the harvesting approach so that it could be readily adopted by surgeons familiar with rhinoplasty principles. Additional refinements, including a dedicated method of stabilization of the cephalic end of the graft, were introduced to improve reliability and reduce complications.

The successful publication of this technique validated years of refinement and clinical experience. More importantly, it introduced a concept that aligns with the broader evolution of modern rhinoplasty, moving away from resection and replacement toward preservation and restoration.

Q *How might this work influence the future of cosmetic and reconstructive nose surgery?*

A Preservation Push-Up Rhinoplasty represents more than a new augmentation method; it reflects a paradigm shift in aesthetic nasal surgery. Owing to its broad range of indications, this technique can be applied in the majority of patients with an intact nasal cartilaginous framework. By combining aesthetic enhancement with preservation of structural integrity and function, this approach may help establish new standards for aesthetic nasal surgery.

Its emphasis on natural results, long-term stability, and reduced morbidity could encourage wider adoption of preservation principles and inspire the development of more refined, anatomy-respecting surgical techniques in the future.

In the end, the success of rhinoplasty is not measured by how much a nose has changed, but by how naturally it belongs to the face. Preservation Push-Up Rhinoplasty was developed with exactly this goal in mind. By preserving the native dorsum while providing the desired augmentation, the technique allows surgeons to achieve results that are aesthetically pleasing, structurally sound, and functionally stable. It represents not just a new method of augmentation, but a shift toward a more anatomy-respecting and patient-centred approach to rhinoplasty.

Reference

Dr. Jain's contributions to the field of facial plastic surgery are reflected in his research on preservation rhinoplasty and innovative techniques for nasal augmentation. The findings build upon advances in dorsal preservation techniques and have been published in Aesthetic Plastic Surgery (2026; DOI: 10.1007/s00266-026-05926-9).

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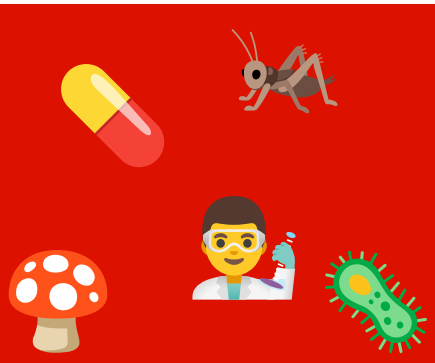


Q1

You clean your room regularly so that waste does not pile up. Which part of a cell performs a surprisingly similar job?

A. Nucleus
B. Lysosome
C. Ribosome
D. Chromosome

Q2

A natural oil works well against bacteria in the lab but loses its power before reaching where it is needed. What should scientists improve first?

A. Its colour
B. Its delivery and stability
C. Its natural smell
D. The name of the plant

Q3

A tiny water droplet can sometimes trigger chemical changes much faster than a large pool of water. What does this remind us about science?

A. Size and environment can change how molecules behave
B. Small things have no chemical activity
C. Water always behaves the same way
D. Faster reactions are always dangerous

Q4

Imagine sending a fragile message through a crowded city. You would protect it and give it a safe vehicle. In an mRNA vaccine, what plays a similar protective role?

A. Lipid nanoparticles
B. Red blood cells
C. Calcium crystals
D. Antibiotics

Q5

The same virus can live quietly in a mosquito but cause illness in a human. What is the most important lesson from this difference?

A. The host can shape how an infection behaves
B. Viruses only attack humans
C. Mosquitoes have no biology
D. All infections behave identically

Q6

Your phone slows down when too many unwanted files accumulate. If a cell's cleanup system becomes sluggish, what might you expect?

A. Cellular balance may be disturbed
B. The cell becomes larger and stronger
C. DNA immediately disappears
D. The cell produces sunlight

Q7

When your cupboard is full, you organize extra items into proper storage instead of leaving them everywhere. How do cells safely manage excess fat?

A. Store it in lipid droplets
B. Put it inside chromosomes
C. Convert it into light
D. Send it to ribosomes

Q8

A hospital has excellent doctors and treatment, but public health officials do not know about many diagnosed TB cases. What important link is missing?

A. Timely communication and case reporting
B. More microscopes
C. Bigger hospital rooms
D. New uniforms

DISCOVERY HIGHLIGHTS

CLIMATE & ENVIRONMENT

INDIA'S WATER CHALLENGE GOES BEYOND RAINFALL

India receives enough rainfall in many regions, yet floods and water shortages continue to occur side by side. A new study examined nearly four decades of climate and land-use changes across six major physiographic regions of India to understand why. Using advanced climate–human interaction models, researchers found that although the proportion of rainfall converted into usable water has remained relatively stable since 1985, rising temperatures have caused a sharp increase in potential evapotranspiration, the amount of water lost back to the atmosphere through evaporation and plant transpiration. At the same time, forests, barren lands, and glacier-covered areas have declined, while agriculture, urban areas, wetlands, and water bodies have expanded. The findings suggest that recent water-related disasters are driven less by changes in rainfall and more by the combined effects of climate change and human activities. The researchers conclude that improving urban planning, protecting natural landscapes, and adopting sustainable water management strategies will be essential to strengthen India's long-term water security.

Pathak S. et al., Environmental Research, 2026.

CLIMATE CHANGE COULD HELP AN INVASIVE PLANT SPREAD ACROSS THE HIMALAYAS

Invasive plants are becoming an increasing threat to native biodiversity, and climate change may allow them to spread even faster. A new study has predicted the future distribution of Solanum viarum, an aggressive invasive plant, across Jammu and Kashmir using advanced species distribution modelling. The researchers found that temperature is the single most important factor controlling the plant's spread. Under current conditions, only a small part of the region is highly suitable for the species. However, future climate projections show a dramatic expansion of suitable habitats, with its potential range increasing by up to 161% under one climate scenario by 2070. Alarmingly, many protected areas are also expected to become more vulnerable, with highly suitable habitats expanding by nearly 169%. The findings highlight the urgent need for early detection, regular monitoring, and rapid management strategies to prevent the invasive plant from spreading further and threatening the unique ecosystems and biodiversity of the Northwestern Himalayas.

Jan S. et al., Scientific Reports, 2026.

ASTRONOMY

HIDDEN MICROBES DISCOVERED IN NASA'S MARS CLEANROOMS

NASA cleanrooms are built to keep spacecraft as free from microbes as possible before missions to other planets. However, a new study has revealed an unexpected hidden world of resilient bacteria living in these ultra-clean environments. During a six-month investigation of the Mars 2020 mission assembly cleanrooms, researchers isolated 182 bacterial strains and discovered 14 previously unknown species, including eight capable of forming highly resistant spores. Many of these microbes escaped detection by conventional metagenomic sequencing because they were extremely rare and difficult to extract. Genome analysis showed that the newly identified bacteria possess genes linked to radiation resistance, survival in nutrient-poor conditions, nitrogen cycling, and carbohydrate metabolism. The study also uncovered gene clusters capable of producing valuable compounds

DISCOVERY HIGHLIGHTS

with potential biotechnological applications. These findings will help improve planetary protection strategies, prevent accidental contamination of future space missions, and provide new insights into life in extreme environmentsKaur S. et al., Journal of Medicinal Chemistry (2026).
Sivabalan S.K.M. et al., Microbiology Spectrum, 2026.

LASER COMMUNICATION BREAKTHROUGH COULD SPEED UP SPACE DATA TRANSFER

Future satellites will need to exchange enormous amounts of data quickly and reliably, especially for Earth observation, global communications, and deep-space exploration. Researchers have now designed a high-speed laser communication system capable of transmitting data at 160 gigabits per second between satellites. By combining advanced technologies such as Orthogonal Frequency Division Multiplexing (OFDM), Polarization Division Multiplexing (PDM), 32-QAM modulation, and sophisticated signal processing, the team achieved stable communication over distances of up to 7,000 kilometres. The system maintained a low error rate and high signal quality despite challenges such as pointing errors, signal loss, and long transmission distances. These improvements could significantly increase the speed and efficiency of inter-satellite communications while reducing data loss. The technology has the potential to support next-generation satellite networks, real-time Earth monitoring, global internet services, and future deep-space missions where fast, reliable communication is essential.
Armghan A. et al., Scientific Reports, 2026.

BIOTECHNOLOGY & GENETICS

A NEW WAY TO STOP MALARIA BY TARGETING MOSQUITOES

Most malaria control strategies focus on killing mosquitoes or attacking the malaria parasite directly. A new study has taken a different approach by disrupting how mosquitoes manage iron, a nutrient essential for both mosquito reproduction and parasite development. Researchers discovered that ferritin, the mosquito's main iron-storage protein, plays a critical role in egg production and survival of the malaria parasite (Plasmodium) inside the mosquito. When the ferritin gene was suppressed, female mosquitoes showed severe defects in reproductive tissue development, greatly reducing their fertility. The team also identified an iron-binding compound, β-thujaplicin, that significantly blocked the development of malaria parasites within mosquitoes. By targeting iron homeostasis, the strategy simultaneously reduces mosquito reproduction and limits parasite transmission. This dual-action approach could pave the way for innovative malaria control methods that complement existing insecticides and antimalarial drugs, helping reduce the spread of one of the world's deadliest infectious diseases.
Tupe C. et al., ACS Infectious Diseases, 2026.

BANANA GENE BOOSTS PLANT GROWTH AND REGENERATION

Scientists have discovered that a single gene from banana could make it easier to regenerate plants and improve crop productivity. The study focused on WUS2, a developmental regulator that controls how new plant tissues form. When the banana-derived GN-WUS2 gene was introduced into tobacco and banana plants, it stimulated shoot regeneration even without the plant hormones normally required for tissue culture. To avoid unwanted side effects from continuous gene activity, the researchers also developed an inducible version that could be switched on only when needed, producing healthy plants. Beyond improving regeneration, the gene rewired plant metabolism by increasing the production of beneficial phytosterols and other compounds associated with cell growth. The modified tobacco plants produced greater biomass, larger pods, and higher seed yields. This discovery provides a powerful new tool for plant biotechnology and could accelerate crop improvement, genetic transformation, and the development of high-yielding, climate-resilient crops. Ultimately, this approach could overcome plant regeneration barriers, simplify genetic transformation, and accelerate sustainable improvement of difficult-to-transform crops worldwide.
Chaudhary R. et al., Plant Biotechnology Journal, 2026.

DISCOVERY HIGHLIGHTS

MEDICINE & HEALTH

NATIONWIDE STUDY REVEALS HOW DENGUE IS EVOLVING IN INDIA

A nationwide study has provided the most comprehensive picture yet of dengue virus circulation across India, offering valuable insights for disease control and vaccination strategies. Researchers analysed 6,889 dengue-positive samples collected between 2023 and 2025 from 45 Virus Research and Diagnostic Laboratories across 25 states and Union Territories. The study found that DENV-2 was the dominant dengue serotype nationwide, although all four dengue serotypes were circulating simultaneously in many regions. Alarmingly, about 7% of patients were infected with more than one dengue serotype, and these co-infections were associated with a greater risk of thrombocytopenia, joint pain, and haemorrhagic complications. The findings highlight the dynamic nature of dengue transmission in India and emphasize the importance of continuous molecular surveillance. Such nationwide monitoring can improve outbreak prediction, guide region-specific public health responses, and support the introduction of effective dengue vaccination programmes.

Deshpande G.R.N. et al., International Journal of Infectious Diseases, 2026.

CLIMATE CHANGE MAY INCREASE ANTHRAX RISK IN INDIA

Climate change is not only affecting weather patterns but also reshaping the spread of infectious diseases. A new study has mapped the future risk of anthrax across India's agro-climatic zones using machine learning. By analysing climate, environmental, and livestock data, the researchers identified rainfall, temperature, soil moisture, soil pH, land surface temperature, humidity, and livestock density as the most important factors influencing anthrax outbreaks. The findings suggest that rising temperatures and more frequent heatwaves, droughts, and floods could create conditions that favour the disease in new regions. The study also highlights the importance of conserving biodiversity, particularly large wild herbivores, and improving livestock health management to reduce future outbreaks. By identifying areas at greatest risk, the research provides a valuable tool for disease surveillance, early warning systems, and targeted interventions. These findings will help strengthen India's preparedness against climate-sensitive zoonotic diseases that threaten both animal and human health.

Naveesh Y.B. et al., Acta Tropica, 2026.

ARTIFICIAL INTELLIGENCE

AI-DESIGNED CRISPR TOOL EXPANDS PRECISION CROP EDITING

Artificial intelligence is helping reshape the future of crop improvement. Researchers have successfully adapted OpenCRISPR-1, an AI-designed genome-editing enzyme originally developed for human cells, to work efficiently in rice plants. The new platform, called Plant OpenCRISPR-1 (POC1), performed highly effective gene knockout, base editing, and prime editing, offering a versatile toolkit for precise plant genome engineering. Unlike conventional CRISPR systems that rely on naturally occurring bacterial enzymes, OpenCRISPR-1 was designed using AI and differs substantially from the widely used Cas9 protein. The study demonstrates that this AI-generated nuclease functions reliably in plants, opening new possibilities for developing improved crop varieties with greater precision. Because OpenCRISPR-1 is open-source, it

DISCOVERY HIGHLIGHTS

could also make advanced genome-editing technologies more widely accessible to researchers worldwide. The breakthrough represents an important step toward faster development of climate-resilient, high-yielding, and disease-resistant crops using next-generation AI-powered biotechnology.

Das P. et al., New Phytologist, 2026.

AI HELPS DETECT EYE DISEASES BEFORE VISION IS LOST

Many retinal diseases develop silently and can lead to permanent vision loss if they are not detected early. Researchers have developed a new artificial intelligence (AI) system that can identify retinal diseases with high accuracy using Optical Coherence Tomography (OCT) images. The approach combines advanced image processing, feature selection, and a deep learning model called the Opto-Structural Graphical Memory Network (OSGMN) to analyse subtle changes in retinal structure that may be difficult for the human eye to detect. When tested against existing AI methods, the new system achieved higher accuracy, precision, recall, and overall diagnostic performance. By providing rapid and reliable detection, the technology could support ophthalmologists in diagnosing retinal disorders at an earlier stage, when treatment is most effective. Such AI-assisted screening tools have the potential to improve eye care, reduce preventable blindness, and expand access to retinal disease diagnosis, particularly in regions with limited specialist healthcare.

Prasath A.R. et al., SN Computer Science, 2026.

AI SYSTEM IMPROVES BRAIN TUMOUR DETECTION FROM MRI SCANS

Early and accurate detection of brain tumours is critical for effective treatment, but analysing MRI scans can be challenging because of image noise and the complex shape of tumours. Researchers have developed a new artificial intelligence (AI) system that combines advanced image processing with deep learning to improve tumour detection. The method integrates an Adaptive Cuckoo Optimization Algorithm, Weighted Singular Value Decomposition (WSVD), and an enhanced U-Net model to produce more precise tumour segmentation. Tested on the widely used BRATS dataset, the system achieved an impressive 98% accuracy, with a Dice score of 0.94, outperforming existing approaches. The AI model also proved robust across different datasets, demonstrating its reliability in varied clinical settings. By helping doctors identify tumour boundaries more accurately, this technology could support earlier diagnosis, improve treatment planning, and reduce the time required to analyse medical images, ultimately enhancing patient care.

Yadav A.S. et al., SN Computer Science, 2026.

ENERGY & SUSTAINABILITY

NEW CONVERTER MAKES RENEWABLE EV CHARGING MORE EFFICIENT

As electric vehicles become more common, integrating renewable energy into charging stations is essential for cleaner transportation. Researchers have developed a novel hybrid power converter that improves the efficiency and reliability of EV charging systems powered by solar and wind energy. The new SEPIC–Landsman Bidirectional Converter combines the advantages of two existing converter designs to deliver stable voltage, efficient power transfer, and smooth energy flow. To further enhance performance, the system uses an artificial intelligence-based control algorithm that automatically adapts to changing energy conditions. Tests showed that the converter achieved high energy efficiency, reduced electrical distortion, and effectively managed the variable power generated by renewable sources. By enabling more reliable integration of solar panels, wind turbines, the electricity grid, and battery storage, the technology could help build smarter, cleaner, and more efficient EV charging infrastructure, supporting the global transition to sustainable transportation.

Hema S. et al., Scientific Reports, 2026.

SMART SOLAR CONTROL SYSTEM BOOSTS POWER GRID STABILITY

As more solar energy is added to electricity grids, maintaining a stable power supply has become increasingly challenging due to changing sunlight and fluctuating demand. Researchers

DISCOVERY HIGHLIGHTS

have developed a Dynamic Reserve Power Point Tracking (DRPPT) system that helps solar power plants respond more effectively to real-time grid conditions. Unlike conventional controllers that focus only on maximizing solar power output, the new system intelligently reserves part of the available power, allowing it to quickly support the grid when sudden changes occur. By combining Maximum Power Point Tracking (MPPT) and Flexible Power Point Tracking (FPPT) with real-time monitoring, the controller automatically adjusts power generation to maintain grid stability. Hardware and simulation tests showed that the new approach significantly reduced electrical distortion and outperformed existing control methods. This technology could improve the reliability of renewable energy integration, making future electricity grids more stable, efficient, and resilient as the world transitions toward cleaner energy sources.

Kumar S. et al., PLOS ONE, 2026.

AGRICULTURE AND FOOD SECURITY

PLANTS MAY REMEMBER STRESS TO SURVIVE CLIMATE CHANGE

As climate change brings more frequent droughts, heatwaves, and soil salinity, scientists are exploring new ways to help crops survive multiple environmental stresses. A new study highlights how plants can develop a form of "stress memory" through changes in their epigenome —the chemical marks that regulate gene activity without altering DNA. The researchers also found that beneficial soil bacteria, known as plant growth-promoting rhizobacteria (PGPR), can influence these epigenetic changes, helping plants respond more effectively to future stress. Together, the plant's epigenome and microbiome create a natural defence system that enhances resilience under harsh conditions. The study further discusses emerging technologies such as epigenome editing, CRISPR-based gene regulation, and microbiome engineering, which could be used to develop crops that are naturally "primed" to withstand climate extremes. These integrated approaches may play a key role in strengthening global food security as environmental conditions become increasingly unpredictable.

Sayyed R. et al., Journal of Applied Microbiology, 2026.

WILD RICE TRAITS COULD HELP CROPS THRIVE IN SALTY SOILS

Rising sea levels and increasing soil salinity threaten rice production in coastal regions worldwide. In a major breeding breakthrough, researchers successfully transferred valuable traits from the salt-loving wild rice species Oryza coarctata into cultivated rice. After more than 36,000 interspecific crosses and advanced embryo-rescue techniques, the team developed new rice lines with exceptional salt tolerance and C4-like leaf characteristics, traits rarely found in cultivated rice. The hybrid plants survived salt levels of 240 mM sodium chloride, twice the tolerance of well-known salt-tolerant rice varieties. They achieved this through improved sodium–potassium balance, specialized salt secretion, and efficient internal ion regulation. The new lines also developed leaf structures associated with improved photosynthesis and reduced energy loss under stressful conditions. This pioneering work provides an important genetic resource for breeding climate-resilient rice capable of producing stable yields in saline coastal environments, helping strengthen future food security in the face of climate change.

Prusty M.R. et al., Scientific Reports, 2026.

INFECTIOUS DISEASES

DISCOVERY HIGHLIGHTS

PROGRESS AGAINST DIARRHOEAL DISEASES CONTINUES, BUT MILLIONS REMAIN AT RISK

Deaths from diarrhoeal and other enteric infectious diseases have fallen dramatically over the past three decades, yet they continue to claim 1.27 million lives every year, according to the latest Global Burden of Disease Study. Researchers analysed data from 204 countries and territories between 1990 and 2023 and found that global mortality has declined by more than 65%, reflecting improvements in sanitation, healthcare, and vaccination. However, South Asia and sub-Saharan Africa remain the hardest-hit regions, with young children carrying the greatest burden. Rotavirus remains the leading cause of diarrhoeal deaths, particularly among children under five years of age. Although 141 countries have achieved the global target for reducing childhood diarrhoeal mortality, many nations continue to fall behind. The findings highlight the urgent need to strengthen vaccination, improve access to clean water and sanitation, and expand public health interventions to protect vulnerable populations from preventable enteric diseases.

GBD 2023 Diarrhoeal Disease and Enteric Infectious Diseases Collaborators, The Lancet Infectious Diseases, 2026.

OBESITY IS RISING AMONG TRIBAL COMMUNITIES IN EASTERN INDIA

A new study has revealed that overweight and obesity are becoming important health concerns among tribal communities in Odisha, signalling a shift from traditional undernutrition to lifestyle-related diseases. Researchers analysed health data from 17,976 tribal adults across 13 tribal-dominated districts and found that one in five adults (20.2%) was overweight or obese. In nearly 10% of households, all adult members were overweight or obese, indicating that family and household environments strongly influence health. The study also found that overweight and obesity were more common among wealthier households, married individuals, men, and people living in urbanised areas. Changes in diet, lifestyle, and living conditions were identified as key contributors to this growing trend. The findings highlight the need for targeted public health strategies that promote healthy nutrition and physical activity while preserving traditional lifestyles, helping reduce the future burden of diabetes, heart disease, and other non-communicable diseases among India's tribal populations.

Singh L. et al., Scientific Reports, 2026.

NEUROSCIENCE

CELLS USE TINY MEMBRANE STRUCTURES TO SENSE PHYSICAL FORCE

Our cells constantly experience physical forces such as stretching, pressure, and movement, but how they convert these forces into biological signals has remained a mystery. A new study reveals that tiny membrane structures called caveolae act as cellular force sensors. When cells are mechanically stressed, caveolae rapidly disassemble, releasing caveolin-1 protein scaffolds that spread across the cell membrane. These mobile scaffolds interact with key signalling proteins, including JAK1, eNOS, PTEN, and PTP1B, temporarily switching their activity on or off. The researchers combined advanced single-molecule imaging, super-resolution microscopy, and theoretical modelling to show that this process allows cells to rapidly coordinate responses to mechanical stress. The findings uncover a previously unknown mechanism by which cells translate physical forces into biochemical signals. This discovery could improve our understanding of diseases linked to abnormal mechanosignalling, including cancer, cardiovascular disorders, and fibrosis, and may open new avenues for targeted therapies.

Mani S.K. et al., Nature Cell Biology, 2026.

PNEUMOCOCCAL VACCINE SHOWS EARLY SUCCESS IN REDUCING MENINGITIS IN INDIA

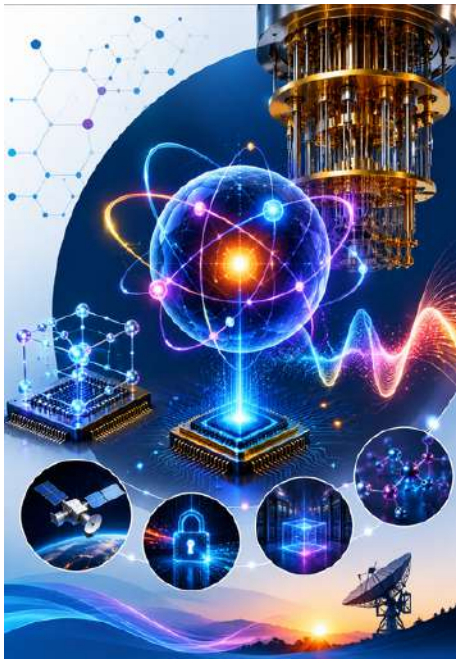
India's pneumococcal vaccination programme is already showing encouraging signs of protecting young children against one of the deadliest forms of bacterial meningitis. Researchers analysed data from 12,971 children admitted with suspected meningitis at 32 hospitals across 19 states between 2019 and 2022. The proportion of children diagnosed with pneumococcal meningitis fell from 3.5% before vaccine introduction to 1.8% after the rollout of pneumococcal conjugate vaccines. The study also foun-

DISCOVERY HIGHLIGHTS

d a decline in disease caused by vaccine-covered pneumococcal serotypes, demonstrating the early impact of the national immunisation programme. Most affected children were younger than one year, highlighting the importance of infant vaccination. Although some disease-causing strains not covered by the vaccine remain in circulation, the findings provide strong evidence that pneumococcal vaccination is reducing severe childhood meningitis in India. Continued nationwide surveillance will be essential to monitor changing bacterial strains and guide future vaccine strategies.

Purushothaman G.K.C. et al., The Lancet Regional Health – Southeast Asia, 2026.

QUANTUM TECHNOLOGIES



SMARTPHONE SENSOR OFFERS QUICK TEST FOR THE SLEEP HORMONE MELATONIN

Melatonin, often called the sleep hormone, plays a vital role in regulating the body's internal clock and has been linked to brain health, antioxidant defence, and cancer prevention. Researchers have developed a highly sensitive nanosensor that can detect melatonin in blood using nitrogen-doped carbon quantum dots. The sensor works through a fluorescence mechanism known as Förster Resonance Energy Transfer (FRET), allowing it to identify extremely small amounts of melatonin with high accuracy. To make the technology more practical, the team integrated the sensor with a smartphone-based detection platform, enabling rapid and portable analysis outside traditional laboratories. Tests on human blood samples achieved recovery rates of 96–104%, demonstrating excellent reliability. This low-cost, user-friendly approach could support point-of-care diagnostics, sleep disorder monitoring, and biomedical research, bringing fast hormone testing closer to clinics and even home-based healthcare.

Priyanka K.M. et al., Journal of Fluorescence, 2026.

NEW QUANTUM MODEL COULD ACCELERATE NANOMATERIAL DISCOVERY

Designing new materials at the atomic scale often requires complex quantum calculations that demand enormous computing power. A new study presents a faster and more accurate approach that could significantly improve simulations of molecules and nanomaterials. The researchers developed a new orbital-free kinetic energy functional based on the jellium-with-gap model, allowing quantum calculations to be performed without explicitly tracking every electron. Benchmark tests showed that the new method predicts the properties of finite systems, including molecular clusters, more accurately than existing orbital-free approaches. It also produced reliable optical property calculations that closely matched reference quantum-mechanical results. By reducing computational cost while maintaining high accuracy, the new framework extends the capabilities of orbital-free density functional theory to systems that were previously difficult to model. This advance could speed up the design of next-generation nanomaterials, catalysts, quantum devices, and energy-storage materials, while helping scientists better understand the behaviour of matter at the nanoscale.

Bhattacharjee A. et al., Journal of Chemical Theory and Computation, 2026.

ENGINEERING & MATERIALS SCIENCE

DISCOVERY HIGHLIGHTS

GOLD NANOPARTICLES DELIVER THERAPEUTIC PROTEINS DIRECTLY TO THE CELL NUCLEUS

Many protein-based medicines lose their effectiveness because they become trapped and degraded inside cellular compartments before reaching their target. Researchers have developed an innovative gold nanoparticle carrier that delivers therapeutic proteins directly into the cell nucleus, bypassing the cell's normal recycling pathway. The tiny 2-nanometre, histidine-coated gold nanoparticles temporarily create small pores in the cell membrane, allowing proteins to enter without being trapped in endosomes or lysosomes. The study found that protein–nanoparticle complexes smaller than 50 nanometres were most effective for nuclear delivery. Importantly, proteins delivered directly to the nucleus showed about twice the therapeutic effectiveness compared with conventional methods that release proteins only into the cell's cytoplasm. This breakthrough could improve the delivery of protein-based medicines for cancer, genetic disorders, and other diseases, opening new possibilities for more precise and effective intracellular therapies.

Mukherjee N. et al., ACS Nano, 2026.

NEW MOLECULE DESTROYS DRUG-RESISTANT MRSA AND HELPS WOUNDS HEAL

Methicillin-resistant Staphylococcus aureus (MRSA) is one of the world's most dangerous antibiotic-resistant bacteria, making new treatments urgently needed. Researchers have designed a small synthetic molecule, TPL(II)-07, that attacks MRSA in multiple ways. The molecule specifically binds to lipid II, a key building block of the bacterial cell wall, while simultaneously disrupting the bacterial membrane, breaking down protective biofilms, generating harmful reactive oxygen species, and reducing important virulence factors. It proved highly effective against both drug-resistant and drug-sensitive S. aureus strains while showing excellent safety toward human cells and minimal damage to red blood cells. The researchers also incorporated TPL(II)-07 into a guar gum hydrogel, which successfully controlled MRSA infections and accelerated wound healing in mice. This multifunctional strategy offers a promising new platform for developing next-generation antibiotics capable of overcoming antimicrobial resistance while promoting faster recovery from infected wounds.

Jana A. et al., Angewandte Chemie International Edition, 2026.

ALOE-INSPIRED DESIGN HELPS HARVEST MORE ELECTRICITY FROM WATER DROPLETS

Water droplets can generate electricity when they strike specially designed surfaces, offering a promising way to harvest natural energy. However, conventional droplet electricity generators collect energy efficiently only within a small area close to their electrodes. Researchers have developed an innovative generator inspired by the water-guiding structure of Aloe vera leaves. Aloe leaves use a central ridge and water-repellent surface to guide droplets over long distances. Mimicking this design, researchers created a curved, midrib-like surface that directs droplets in one direction and a hydrophobic artificial cuticle that allows water to slide smoothly. This expanded the effective energy collection area and produced approximately 236% more electrical charge than conventional droplet generators. The nature-inspired design could support large-area energy harvesting and help develop adaptable technologies that generate electricity from rain and other widely available water sources.

Lee G. et al., Advanced Materials, 2026.

TINY PEPTIDES CREATE PROGRAMMABLE CELL-LIKE COMPARTMENTS

Living cells organize complex chemical processes within specialised compartments, but recreating such adaptable structures artificially remains challenging. Researchers have now developed a minimal peptide-based system that can spontaneously form programmable, cell-like compartments called condensates. Using a simple “sticker-and-spacer” design, short peptides separate into distinct phases as water evaporates, creating structures ranging from uniform droplets to complex core–shell compartments. By changing specific peptide components, researchers could control the internal architecture and chemical behaviour of these tiny structures. The condensates efficiently trapped and protected small molecules and also functioned as microscopic reaction chambers. Remarkably, their natural redox activity enabled selective mineral formation and the production of uniform metal–peptide nanohybrids.

Kumar R. et al., Advanced Materials, 2026.

SCIENCE IN FOCUS

INDIA'S WATER MISSION

ANRF Launches ₹200-Crore MAHA Water Mission to Drive Water Innovation

India has launched the ₹200-crore ANRF–Ministry of Jal Shakti MAHA Water Mission, a national initiative designed to accelerate innovation in the water sector by supporting startups, MSMEs, universities, research institutions, and industry partners. With a projected outlay of ₹200 crore over five years, the mission aims to bridge the gap between laboratory research and real-world deployment of technologies that address critical water challenges. Selected multidisciplinary consortia will be eligible for funding of up to ₹20 crore for technology development, field validation, and implementation. The programme focuses on five priority areas: water resource assessment and sustainable management, drinking water, water quality and ecological health, water-use efficiency and circular economy, and climate resilience and adaptation. The mission seeks to create a collaborative ecosystem connecting academia, industry, startups, government agencies, and local stakeholders to develop scalable and sustainable solutions for India's growing water needs. An open call for proposals, including opportunities for startups and MSMEs to develop products and prototypes, has also been announced. By promoting innovation-driven solutions and encouraging broader participation in research and development, the MAHA Water Mission aims to strengthen India's long-term water security and support sustainable development.

INDIA AND SOUTH AFRICA

India and South Africa Strengthen Partnership in Emerging Technologies

India and South Africa have agreed to strengthen cooperation in emerging technologies, with a focus on artificial intelligence, digital infrastructure, advanced manufacturing, biotechnology, quantum technologies, and hydrogen energy. The discussions, held in New Delhi, highlighted the need to transform traditional research partnerships into innovation-driven collaborations that generate economic and societal benefits. Both countries identified opportunities for joint work in startup ecosystems, industry-linked research, technology commercialization, and skills development. Priority areas include advanced materials, geospatial technologies, health sciences, vaccine development, renewable energy, and digital technologies. The meeting also reviewed ongoing scientific cooperation between the two nations, which includes nearly 150 co-funded research projects spanning diverse fields. Collaboration in astronomy, particularly through the Square Kilometre Array (SKA) project, was recognized as a successful example of international scientific partnership. Both sides reaffirmed their commitment to strengthening engagement through platforms such as BRICS, IBSA, G20, and IORA. The discussions concluded with a shared vision of building a future-ready innovation partnership that supports sustainable development, technological advancement, and inclusive growth across the Global South.

SCIENCE IN FOCUS

INDIA AND NEPAL

India and Nepal Join Hands to Advance Multilingual AI and Digital Access

India's Digital India BHASHINI Division (DIBD) and Kathmandu University have signed a Memorandum of Understanding (MoU) to strengthen cooperation in artificial intelligence, language technology, and digital public infrastructure. The partnership aims to develop a “voice-first” language translation platform for Nepal and promote inclusive digital services across the region. Under the agreement, both institutions will collaborate on creating Nepali language datasets, speech corpora, machine translation systems, speech-to-text and text-to-speech technologies, and multilingual conversational AI tools. The initiative will also support the preservation and digitization of low-resource and underrepresented languages, helping communities access digital services in their native languages. The collaboration seeks to reduce language, literacy, and digital barriers while expanding access to education, skill development, e-commerce, and government services. Joint research projects, training programmes, capacity-building initiatives, and pilot deployments are also planned. By combining BHASHINI’s open language technology ecosystem with Kathmandu University’s expertise, the partnership is expected to strengthen regional digital cooperation and accelerate the development of multilingual AI solutions for South Asia.

INDIA AND VIETNAM

India’s Space Economy Set to Reach USD 45 Billion, Powered by Startups and Innovation

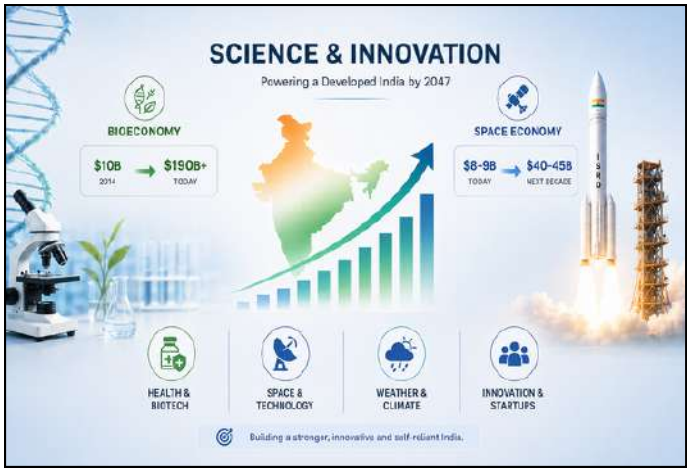
India’s space economy is projected to grow from the current USD 8–9 billion to nearly USD 40–45 billion over the next decade, driven by policy reforms, private-sector participation, and a rapidly expanding innovation ecosystem. More than 400 space startups are now contributing to the country’s growing space sector, reflecting the impact of recent reforms and increasing entrepreneurial activity. India’s achievements in missions such as Chandrayaan-3 and the upcoming Gaganyaan programme have strengthened its position among the world’s leading space-faring nations. At the same time, space technology is playing an increasingly important role in governance and infrastructure development. Initiatives such as PM Gati Shakti, urban development programmes, and drone-based monitoring systems are using satellite data to improve planning, implementation, and project monitoring. The country is also witnessing a stronger connection between science and society, with growing public interest in scientific achievements and technology-driven development. Experts believe that continued collaboration among startups, industry, research institutions, and policymakers will help drive innovation, technological self-reliance, and economic growth, supporting India’s vision of becoming a developed nation by 2047.

SCIENCE IN FOCUS

INDIA FRANCE

India–France ATL Bridge to Connect Young Innovators Across Borders

India and France have launched the India–France ATL Bridge, a new initiative aimed at strengthening bilateral innovation cooperation by connecting young innovators through school-based innovation labs. The programme, established by Atal Innovation Mission (AIM), NITI Aayog, and La Fondation Dassault Systèmes, marks the creation of the first School Innovation Lab in France inspired by India's successful Atal Tinkering Lab (ATL) model. The initiative will provide a platform for students, educators, and innovation ecosystems in both countries to collaborate on real-world challenges through innovation, entrepreneurship, and technology-driven learning. It will support cross-border innovation programmes, knowledge exchange, capacity building, and joint projects designed to foster creativity and problem-solving skills among young learners. Launched during the India–France Year of Innovation 2026, the ATL Bridge reflects the growing partnership between the two nations in science, technology, and education. Since 2016, India's ATL network has expanded to more than 10,000 labs, engaging over 11 million students in robotics, artificial intelligence, design thinking, and other emerging technologies. The initiative aims to inspire the next generation of global innovators. By connecting young minds across borders, the programme could build lasting innovation networks, encourage cultural and scientific exchange, and empower students to jointly develop practical solutions for shared global challenges, while preparing a new generation of creative, collaborative, and globally connected innovators.



INNOVATION IN INDIA

India's Bioeconomy Surges to $190 Billion as Science and Innovation Drive Growth

India's science and technology sector has witnessed remarkable growth over the past decade, with the country's bioeconomy expanding from nearly $10 billion in 2014 to over $190 billion today. The sector is projected to reach $300 billion by 2030, driven by advances in biotechnology, healthcare, genomics, diagnostics, and biopharmaceuticals. India's space sector has also experienced rapid expansion, with the number of space startups growing from single digits to more than 400 startups. The country's space economy, currently valued at around $8–9 billion, is expected to reach $40–45 billion in the coming decade. Major achievements such as Chandrayaan-3, indigenous vaccine development, and advancements in deep-tech innovation have strengthened India's position as a global science and technology leader. Weather forecasting capabilities have also improved significantly, with operational weather radars increasing from 17 to nearly 50, and another 50 planned under Mission Mausam. Experts say continued investment in research, startups, and emerging technologies will play a crucial role in supporting India's vision of becoming a developed nation by 2047. Strengthening collaboration between universities, research institutions, industry, and young entrepreneurs will be equally important for translating scientific discoveries into practical solutions. With sustained funding, skilled talent, and supportive innovation policies, India could further expand its technological capabilities and contribute significantly to addressing major national and global challenges.

SCIENCE IN FOCUS

QUANTUM SENSING

CSIR Transfers Seven Technologies to Industry, Strengthens Quantum and Standards Ecosystem

The Council of Scientific and Industrial Research (CSIR) has transferred seven homegrown technologies to industry partners, released ten Bharatiya Nirdeshak Dravyas (BNDs), and handed over critical quantum sensing components to the Defence Research and Development Organisation (DRDO), highlighting India's growing strength in innovation and technology commercialization. The technologies transferred include broadband electric field sensing systems, PM2.5 air monitoring devices, pharmaceutical waste recycling processes, drone-based bridge inspection systems, air-cleaning road sealants, pothole repair machines, and glare mitigation devices. These technologies are expected to support sectors such as infrastructure, transportation, environmental monitoring, and sustainability. A key achievement was the release of ten Bharatiya Nirdeshak Dravyas, including phytochemical, precious metal, and propane gas reference materials. These standards will help laboratories, industries, and regulatory agencies improve measurement accuracy, traceability, and quality assurance. CSIR-National Physical Laboratory also delivered five vapor cells to DRDO's Solid-State Physics Laboratory for use in quantum sensing applications, marking progress in India's quantum technology capabilities. The event showcased CSIR's commitment to translating scientific research into impactful technologies that support industry, national priorities, and self-reliance.

CLIMATE CHANGE

IITM and ARIES Partner to Establish Long-Term Climate Monitoring Station in the Himalayas

The Indian Institute of Tropical Meteorology (IITM), Pune, and the Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital, have signed a long-term Memorandum of Understanding (MoU) to establish a climate observation station in the Himalayan region under the Bharat Climate Observation Network (BCON). The agreement, signed for a period of more than 50 years, aims to strengthen climate and atmospheric research in India. The new station will be located at ARIES, Devasthal, a high-altitude site that provides ideal conditions for monitoring atmospheric and climate processes over the Himalayas. Researchers will collect long-term data on meteorological parameters, greenhouse gases, short-lived climate pollutants, atmospheric chemistry, and soil moisture. BCON, a national initiative led by IITM under the Ministry of Earth Sciences, seeks to create a high-quality climate database to improve understanding of climate change and support evidence-based policymaking. The data will also help validate Earth System Models, including India's first indigenous Earth System Model developed by IITM. Scientists believe the collaboration will significantly strengthen climate monitoring, climate research, and future climate projections for India. The long-term observations could also improve early climate risk assessments and provide valuable scientific insights for protecting vulnerable Himalayan ecosystems and communities from future environmental changes.

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

A SMART TATTOO THAT COULD MONITOR YOUR HEALTH AROUND THE CLOCK

Imagine a tattoo that does much more than express your personality, it quietly watches over your health. No needles, no bulky gadgets, and no frequent hospital visits. Simply place a thin, flexible patch on your skin, and it continuously monitors important biomarkers in your sweat, helping detect early signs of disease before symptoms appear. This futuristic idea is becoming a reality through a newly granted Indian patent developed at the Indian Institute of Technology Hyderabad.

Unlike decorative tattoos, this innovative "smart tattoo" is a wearable biosensor made from a special calcium-based bio-metal–organic framework (Bio-MOF) embedded within a soft hydrogel. The material gently adheres to the skin without the need for harsh adhesives, making it comfortable enough to wear for long periods. Even more remarkably, if the sensor is scratched or slightly damaged, it can repair itself thanks to its self-healing hydrogel network, extending its lifespan and ensuring reliable performance.

The sensor works by analyzing tiny amounts of sweat or interstitial fluid naturally present on the skin. As molecules such as glucose, lactate, electrolytes, amino acids, creatinine, and other health-related biomarkers pass into the hydrogel, the Bio-MOF detects them through electrochemical interactions and converts these signals into measurable electrical responses. Because the material contains a highly porous calcium-based framework, it provides abundant active sites for rapid and sensitive detection.

One of the greatest challenges with wearable health monitors is maintaining stable contact with the constantly moving human body. Traditional sensors often peel away, become uncomfortable, or lose accuracy after repeated stretching or sweating. This new smart tattoo overcomes these problems by combining flexibility, self-adhesion, ionic conductivity, and self-healing into a single material. It conforms naturally to the skin, remains functional during everyday activities, and continues monitoring without causing irritation.

The technology could transform healthcare in many ways. People living with diabetes, kidney disease, cardiovascular disorders, or metabolic conditions may one day monitor their health continuously without repeated blood tests. Athletes could track hydration and fatigue in real time, while soldiers, industrial workers, and elderly patients could benefit from continuous physiological monitoring during demanding conditions. The sensor is also designed to integrate with smartphones and wearable devices, allowing health information to be transmitted instantly for personalized medical care.

As wearable electronics continue to evolve, innovations like this smart tattoo point toward a future where healthcare becomes continuous, personalized, and non-invasive. Instead of waiting for illness to appear, tiny intelligent sensors may one day help detect health problems early, empowering people to take action before disease progresses. This invention represents an exciting step toward a future where a simple patch on the skin could become one of our most powerful tools for protecting human health.

INNOVATION

Ravipati M, Badhulika S. Calcium Bio-MOF Hydrogel Tattoo Sensor for Long-Term Epidermal Monitoring. Indian Patent No. 591568

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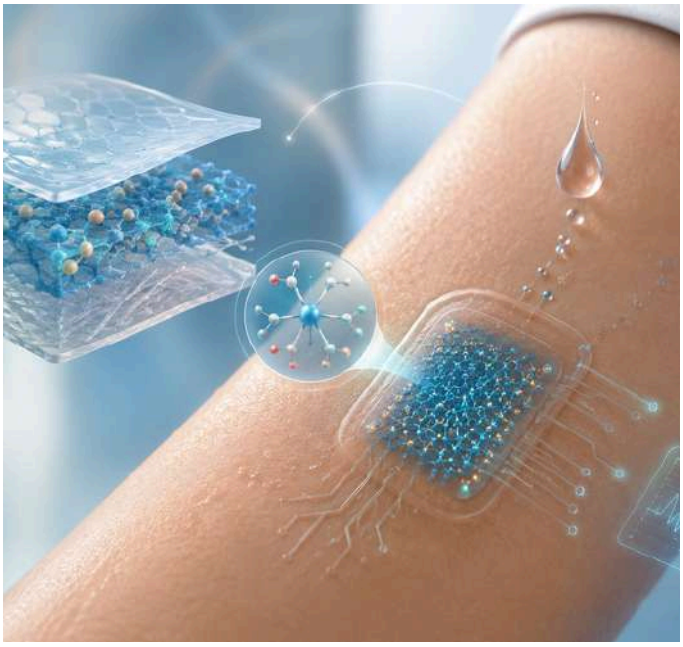
Indian Institute of Technology Hyderabad



| By Dr. Priyanka

CAN SOLAR PANELS SURVIVE UNDERWATER? A SMARTER WAY TO PREDICT FAILURE BEFORE IT HAPPENS

As the world searches for cleaner sources of energy, solar power has become one of the fastest-growing renewable technologies. But with land becoming increasingly scarce and floating solar farms expanding across lakes and reservoirs, scientists are beginning to explore an even more ambitious frontier, underwater solar panels. These submerged systems could generate clean electricity while avoiding competition for valuable land and benefiting from the natural cooling effect of water, which can improve solar panel efficiency. Yet operating beneath the water's surface comes with an entirely new set of challenges.

Unlike conventional solar panels exposed only to sunlight and weather, underwater panels must endure constant hydrostatic pressure, salt-induced corrosion, water leakage, biofouling from algae and marine organisms, insulation breakdown, and reduced light transmission. Even a minor seal failure can allow water to enter the system, triggering corrosion that gradually damages electrical components. Detecting these hidden problems before they become catastrophic has remained one of the greatest obstacles to underwater solar technology.

A newly granted Indian patent introduces an intelligent solution that acts like a health monitoring system for underwater solar panels. Instead of relying on routine inspections or waiting until equipment fails, the invention continuously monitors the condition of the solar panel assembly using a network of specialized sensors. These sensors measure critical parameters such as water leakage, corrosion, connector temperature, surrounding water conductivity, and turbidity caused by biofouling. Together, they provide a real-time picture of the panel's health beneath the water.

What truly makes the system unique is its use of Bayesian reasoning, a form of artificial intelligence that constantly updates the probability of equipment failure as new information arrives. Rather than treating each problem independently, the model understands how one fault can trigger another. For example, if a sensor detects water leakage, the system immediately calculates how much the risk of corrosion, junction-box failure, or connector damage has increased. As fresh sensor data continues to flow, the reliability of every component is automatically recalculated, allowing the system to predict failures long before they occur.

When the calculated reliability of a component falls below a safe threshold, the system instantly generates an early warning and recommends preventive maintenance. This allows engineers to repair only the affected components before expensive failures occur, reducing maintenance costs, extending the lifespan of underwater solar installations, and minimizing energy losses. The framework can also learn from historical operational data, making its predictions increasingly accurate over time.

As renewable energy expands into oceans, reservoirs, and coastal environments, intelligent monitoring systems like this may become just as important as the solar panels themselves. By combining real-time sensing with artificial intelligence, this innovation transforms underwater solar panels from passive energy generators into self-monitoring, predictive systems capable of detecting hidden problems before they surface. It represents an important step toward making underwater solar energy safer, more reliable, and ready for the future.

INNOVATION

Das A, Roychowdhury S, Kumar V, Dutta S, Singh BK, De D. System and Method for Reliability Analysis of Underwater Solar Panel Assembly. Indian Patent No. 593333

📄 By Department of Computer Science and Engineering, National Institute of Technology Jamshedpur

System and Method for Portable Capacitive Liquid Level Monitoring with LoRA Transmission

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

Areas of Expertise: Green Manufacturing | Sustainable Water Management | Ecofriendly Technologies | Micro-Manufacturing | Systems Engineering | New Product Development

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Areas of Expertise: Rural Technology Development | Engineering Education & Innovation | Technology Design | Prototyping

Managing water levels in storage tanks can be a constant challenge, especially in rural villages, isolated facilities, or large agricultural farms where checking tanks manually is difficult and time-consuming. Traditional monitoring systems often rely on bulky equipment, require continuous electricity, need regular maintenance, or depend entirely on a stable internet connection. To solve these issues, an innovative, portable, and energy-efficient liquid level monitoring system has been developed.

At the heart of this invention is a smart application of physics called capacitive sensing. The system uses lightweight, flexible insulated wires that are dropped directly into a water tank or reservoir. Because water and air alter electrical properties differently, any change in the water level causes a distinct, measurable shift in electrical capacitance. By using a precise charging and discharging measurement technique, the device can accurately calculate the exact height of the liquid in real time while using a minimal amount of battery power.

What truly sets this system apart is how it transmits this data. Instead of relying on Wi-Fi or cellular networks, which are frequently unavailable or highly unreliable in remote regions, the device integrates LoRa (Long Range) wireless technology. LoRa allows the system to send data across distances of several kilometers while consuming very little energy. Because the setup is entirely battery-operated, compact, and standalone, it can function continuously for extended periods without needing a wired infrastructure or connection to an electrical grid.

The applications for this technology are incredibly broad. For municipal corporations and water distribution agencies, it offers an affordable way to track reservoirs spread across vast geographical areas from a single centralized location, helping prevent costly leakages and overflows. In agriculture, it can monitor irrigation tanks and farm reservoirs to promote smarter water utilization. Its portable design even makes it perfect for temporary setups, such as disaster relief camps, construction zones, or emergency operations.

Ultimately, this invention combines flexible sensor technology with long-range wireless communication to deliver a cost-effective, low-maintenance, and highly scalable solution. By removing the barriers of high costs and complex infrastructure, it provides resource-constrained communities and modern industries alike with a practical tool to better conserve, manage, and protect our most vital natural resource.

Patent Reference:

System and Method for Portable Capacitive Liquid Level Monitoring with LoRa Transmission" (Patent No. 586408).

Smart and Sustainable Roads: Zinc-Coordinated Porphyrin-Integrated Geocomposite Systems for Future Pavement Engineering

Dr. Vivek
DEPARTMENT OF CIVIL ENGINEERING, NATIONAL INSTITUTE OF TECHNOLOGY, SRINAGAR, JAMMU AND KASHMIR, INDIA
Scientific Profile | Organization Link | Research Lab Page | Factors Press
Areas of Expertise: Sustainable Pavement Engineering | Geosynthetics | self-healing roads | Carbon-capturing pavements | climate-resilient transportation infrastructure

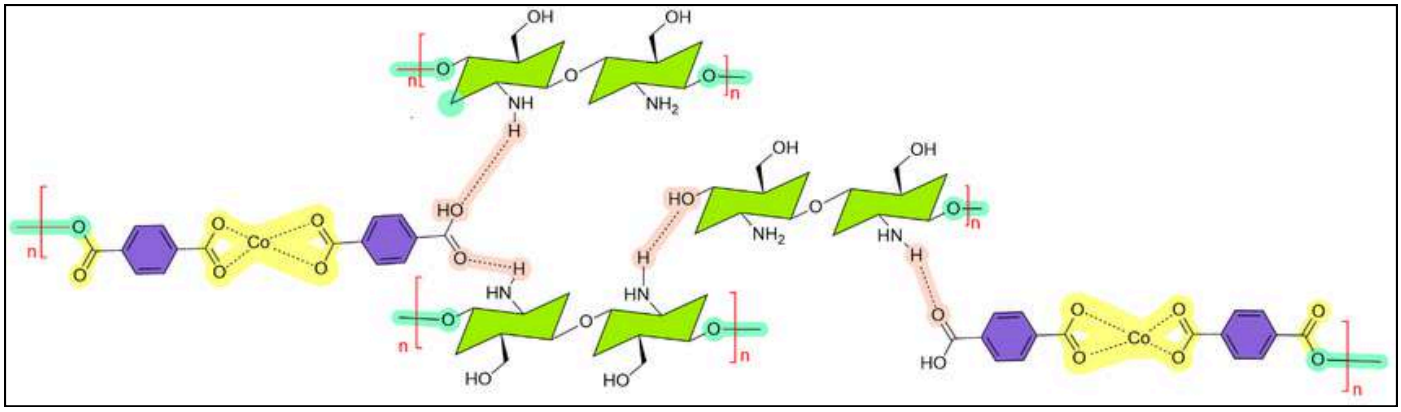
The rapid growth of transportation networks has increased the demand for road infrastructure that is durable, cost-effective, and environmentally sustainable. Conventional pavement systems often experience deterioration due to traffic loading, temperature variations, moisture intrusion, and environmental pollution. These challenges lead to frequent maintenance activities, increased costs, and significant environmental impacts. To overcome these limitations, an innovative technology known as Zinc-Coordinated Porphyrin-Integrated Geocomposite Systems has been developed for sustainable pavement engineering.

This advanced technology combines geosynthetic materials with zinc-coordinated porphyrin structures to create multifunctional pavement systems. Geosynthetics such as geotextiles, geogrids, geomembranes, and geocells are already widely used in road construction to improve soil stability, reinforce weak subgrades, and enhance pavement performance. However, their functionality is primarily structural. The integration of zinc-coordinated porphyrins introduces additional smart features that significantly improve the overall performance and sustainability of road infrastructure.

Porphyrins are naturally occurring organic compounds known for their unique light-absorbing and catalytic properties. When combined with zinc ions, they form stable complexes with enhanced chemical and photophysical characteristics. These zinc-porphyrin structures can be uniformly distributed within geocomposite materials, transforming traditional pavement reinforcement systems into intelligent and environmentally responsive infrastructure components.

One of the most remarkable features of this technology is its self-healing capability. Small cracks and minor damages that develop within pavement layers can be repaired automatically through catalytic reactions triggered by environmental conditions such as sunlight and moisture. This self-healing mechanism reduces the progression of pavement distress, extends service life, and minimizes maintenance requirements.

Another important benefit is pollutant degradation. The zinc-coordinated porphyrin system acts as a catalyst that can break down harmful organic pollutants deposited on road surfaces. Through photocatalytic reactions activated by sunlight, these materials help reduce environmental contamination and contribute to cleaner surroundings.



Patent Reference:

Zinc-Coordinated Porphyrin-Integrated Geocomposite Systems for Sustainable Pavement Engineering" (Patent No. 586895).

The technology also enables solar energy harvesting. Zinc-porphyrins possess excellent light absorption properties, allowing them to capture solar energy and convert it into usable electrical energy. This harvested energy can power embedded sensors, lighting systems, or monitoring devices within the pavement structure, reducing dependence on external power sources and promoting energy-efficient infrastructure.

In addition, the system offers environmental sensing capabilities. The integrated porphyrin structures can detect changes in temperature, moisture, and pollutant concentrations, providing real-time information about pavement conditions and surrounding environmental factors. This capability supports proactive maintenance strategies and facilitates the development of smart transportation networks.

Beyond these advanced functionalities, the geocomposite system continues to provide traditional engineering benefits such as improved load distribution, enhanced soil stabilization, and increased structural durability. By combining mechanical reinforcement with environmental responsiveness, energy generation, and self-healing properties, the technology represents a significant advancement in pavement engineering.

In conclusion, Zinc-Coordinated Porphyrin-Integrated Geocomposite Systems offer a revolutionary approach to sustainable road construction. By creating roads that can sense, heal, clean, and even generate energy, this innovation supports the development of resilient, eco-friendly, and intelligent transportation infrastructure for future generations.

Patent Reference:

Zinc-Coordinated Porphyrin-Integrated Geocomposite Systems for Sustainable Pavement Engineering" (Patent No. 586895).

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?*

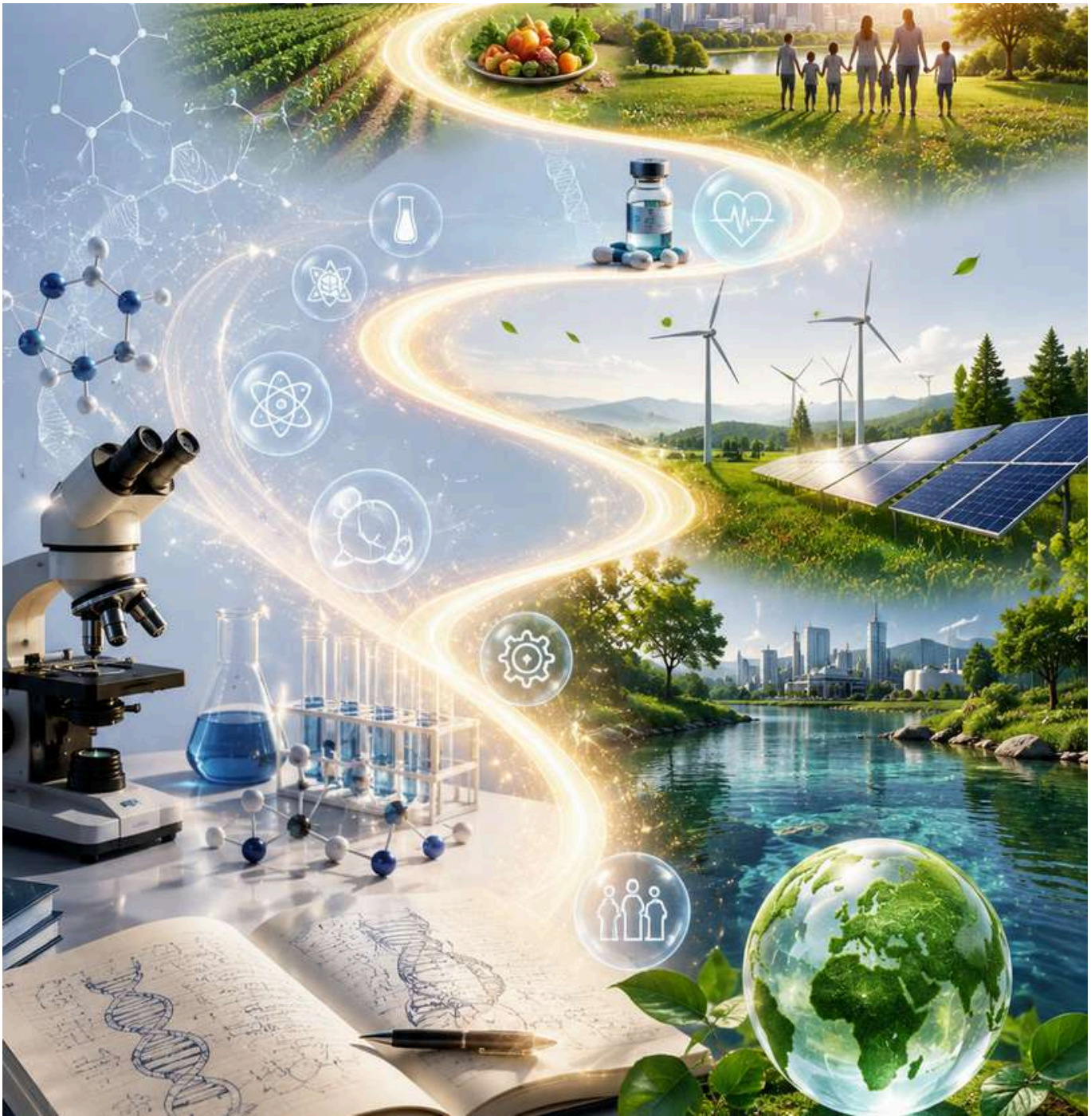
A A few years ago, at the height of the pandemic, coding was the most sought-after skill in every sector. Today, AI can produce functional code from a plain-language description. The half-life of specific technical skills is shrinking, and pretending otherwise is not useful advice for anyone trying to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



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

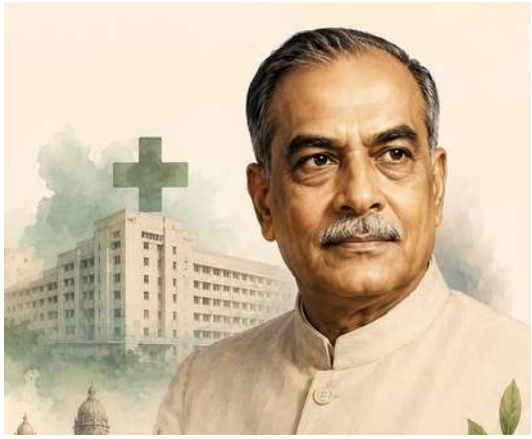
SCIENCE NEWS & OPPORTUNITIES

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

Dr. Bidhan Chandra Roy: The Physician Who Shaped Modern Indian Healthcare

01

1 July is celebrated as National Doctor's Day in India in honor of Dr. Bidhan Chandra Roy, an eminent physician, educator, and statesman. His contributions to medical education, healthcare infrastructure, and public service transformed healthcare in independent India. His legacy continues to inspire generations of doctors to combine scientific excellence with compassionate patient care.



How the Higgs Boson Changed Our Understanding of the Universe

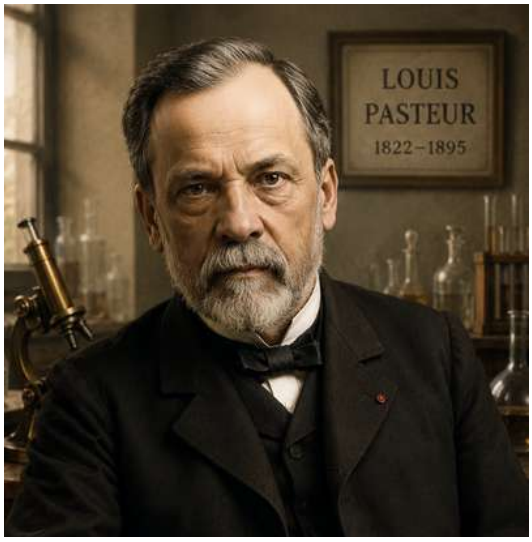
02

On 4 July 2012, the European Organization for Nuclear Research (CERN) announced the discovery of the Higgs boson, confirming a key prediction of the Standard Model of particle physics. Often called the "God Particle," it explains how fundamental particles acquire mass. This landmark achievement transformed our understanding of the universe and showcased the power of international scientific collaboration.

World Zoonoses Day: Preventing the Next Pandemic

03

6 July is observed as World Zoonoses Day, commemorating Louis Pasteur's first successful rabies vaccination in 1885. The day highlights diseases that spread from animals to humans, including rabies, avian influenza, and COVID-19. It emphasizes surveillance, vaccination, responsible animal care, and global collaboration to prevent future outbreaks and protect public health.



A Milestone in India's Space Programme

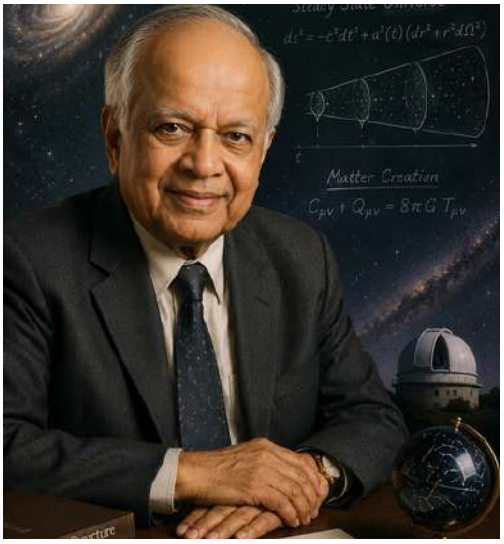
04

18 July 1980 marked a defining moment in India's space journey when the Indian Space Research Organisation (ISRO) successfully launched the Satellite Launch Vehicle-3 (SLV-3) from the Satish Dhawan Space Centre (SHAR), Sriharikota. The mission placed the Rohini RS-1 satellite into orbit, making India the sixth nation capable of launching its own satellites and showcasing the country's growing technological self-reliance under the leadership of scientists including Dr. A. P. J. Abdul Kalam.

Jayant Narlikar and India's Contributions to Modern Cosmology

05

19 July 1938 marks the birth of Prof. Jayant V. Narlikar, one of India's most respected astrophysicists. His pioneering work in cosmology, particularly the Hoyle–Narlikar theory, broadened scientific understanding of the universe. Beyond his research, he inspired generations through science communication, making astronomy accessible and encouraging young minds to explore the cosmos.



International Moon Day: From Apollo 11 to Artemis

06

20 July marks International Moon Day, commemorating humanity's first successful lunar landing by the Apollo 11 mission in 1969. The day celebrates scientific curiosity, engineering excellence, and international cooperation in space exploration. Today, missions such as NASA's Artemis program and India's Chandrayaan achievements are paving the way for sustainable lunar exploration and future human missions.

Chandrayaan-2 Advances India's Lunar Exploration

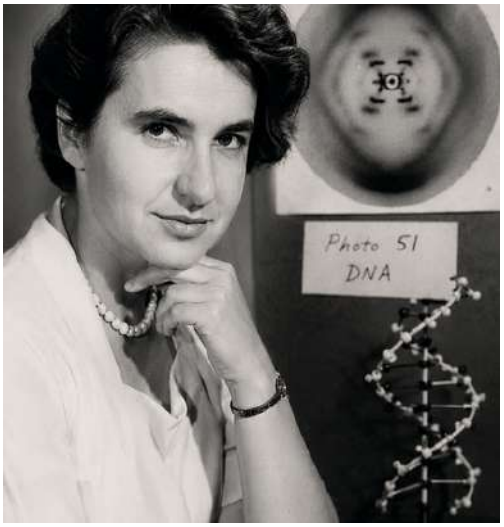
04

22 July 2019 marked another landmark in India's space journey when the Indian Space Research Organisation (ISRO) launched Chandrayaan-2 from the Satish Dhawan Space Centre, Sriharikota. The mission comprised an orbiter, the Vikram lander, and the Pragyan rover to explore the Moon's south polar region. Although the lander's soft landing was unsuccessful, the orbiter continues to deliver valuable scientific data, demonstrating India's technological capability and paving the way for the successful Chandrayaan-3 mission in 2023.

Rosalind Franklin's Birth Changed the Course of Molecular Biology

05

25 July 1920 marks the birth of Rosalind Elsie Franklin, a pioneering British chemist and X-ray crystallographer whose groundbreaking research transformed our understanding of DNA. Her famous Photo 51 provided crucial evidence for the discovery of DNA's double-helix structure. Franklin's work also advanced the study of viruses, coal, and graphite, leaving a lasting legacy in molecular biology and structural science.



Remembering Dr. A. P. J. Abdul Kalam

06

Dr. A. P. J. Abdul Kalam, remembered on 27 July, transformed India's aerospace and missile programs while inspiring millions through education and public service. Known as the "People's President," he believed that dreams, knowledge, and perseverance could shape a better nation. His life continues to motivate students, scientists, innovators, and future leaders across India and beyond.

Prof. Venkatesan Sundaresan: Advancing the Future of Crop Improvement

Wolf Prize in Agriculture (2024)

Prof. Venkatesan Sundaresan, an Indian-American plant biologist, received the 2024 Wolf Prize in Agriculture for his pioneering discoveries in plant developmental biology. His groundbreaking research on plant reproduction, seed development, and synthetic apomixis has opened new avenues for developing high-yielding, resilient crops, making a lasting impact on global food security and sustainable agriculture.

Prof. Jainendra K. Jain: Pioneering the Quantum Revolution

Wolf Prize in Physics (2025)

Prof. Jainendra K. Jain, an Indian-American physicist born in Rajasthan, received the 2025 Wolf Prize in Physics for developing the groundbreaking composite fermion theory, which transformed our understanding of the fractional quantum Hall effect. A professor at Pennsylvania State University, his pioneering work has become a cornerstone of modern quantum physics, making him the first physicist of Indian origin to receive the Wolf Prize in Physics.

Shri Kallipatti Ramasamy Palaniswamy: A Lifetime of Service to Medicine

Padma Bhushan (2026) – Medicine

Shri Kallipatti Ramasamy Palaniswamy was awarded the Padma Bhushan 2026 in recognition of his lifelong contributions to medicine and healthcare. Through decades of dedicated clinical service, he has improved healthcare access and patient outcomes, particularly in underserved communities. His commitment to compassionate care, medical excellence, and public service has earned him one of India's highest civilian honours.

Dr. Nori Dattatreyudu: Transforming Cancer Care Worldwide

Padma Bhushan (2026) – Medicine

Dr. Nori Dattatreyudu was awarded the Padma Bhushan 2026 for his outstanding contributions to oncology and cancer treatment. An internationally renowned radiation oncologist based in the United States, he pioneered advanced radiation therapies and expanded access to quality cancer care. His decades of clinical excellence, research, and patient-centered innovations have improved the lives of thousands of cancer patients worldwide.

Shri A. E. Muthunayagam: Architect of India's Liquid Rocket Propulsion

Padma Shri (2026) – Science and Engineering

Shri A. E. Muthunayagam received the Padma Shri 2026 for his pioneering contributions to India's space programme. Widely regarded as the architect of India's liquid rocket propulsion technology, he laid the foundation for propulsion systems that power the PSLV and GSLV launch vehicles. As the founding Director of ISRO's Liquid Propulsion Systems Centre (LPSC), his work played a vital role in establishing India's self-reliance in space technology.

Ms. Armida Fernandez: Champion of Newborn Care

Padma Shri (2026) – Medicine

Ms. Armida Fernandez was awarded the Padma Shri 2026 for her remarkable contributions to neonatal medicine and child healthcare. A pioneering pediatrician from Maharashtra, she has worked to improve survival and care for newborn babies, especially premature and critically ill infants. Her service has strengthened maternal and child health and inspired compassionate medical care in India.

Shri Gopal Ji Trivedi: Advancing Science Through Innovation

Padma Shri (2026) – Science and Engineering

Shri Gopal Ji Trivedi was awarded the Padma Shri 2026 for his distinguished contributions to science and engineering. Recognized for his dedication to scientific innovation and technological development, he has played an important role in advancing research and promoting practical applications of science. His work reflects a lifelong commitment to strengthening India's scientific and technological capabilities.

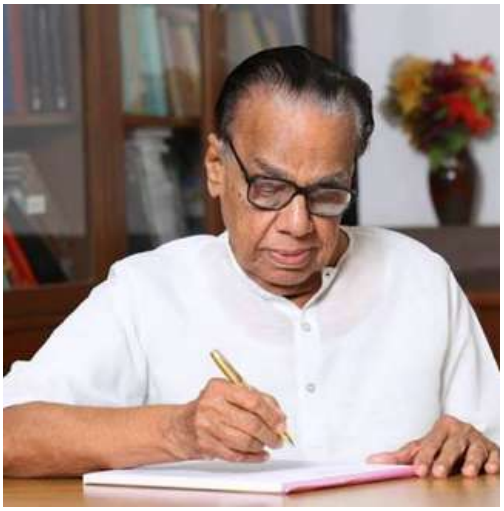
Shri Guduru Venkat Rao: Dedicated to Advancing Surgical Care

Padma Shri (2026) – Medicine

Shri Guduru Venkat Rao was awarded the Padma Shri 2026 for his outstanding contributions to medicine and surgery. A renowned gastrointestinal surgeon from Telangana, he has dedicated decades to advancing minimally invasive surgical techniques, improving patient care, and mentoring future surgeons. His clinical excellence and commitment to healthcare have significantly strengthened surgical practice in India.

Shri H. V. Hande: A Lifetime of Service to Medicine and Public Health

Padma Shri (2026) – Medicine



Shri H. V. Hande was awarded the Padma Shri 2026 for his exceptional contributions to medicine and public health. A distinguished physician from Tamil Nadu, he has devoted his career to improving healthcare delivery, medical education, and public welfare. His lifelong commitment to compassionate patient care and community service has left a lasting impact on India's healthcare system.

Shri Juzer Vasi: Shaping India's Electrical Engineering Excellence

Padma Shri (2026) – Science and Engineering

Shri Juzer Vasi was awarded the Padma Shri 2026 for his outstanding contributions to electrical engineering and engineering education. A distinguished academic from Maharashtra, he is internationally recognized for his pioneering research in semiconductor devices, power electronics, and microelectronics. His work has advanced scientific innovation while mentoring generations of engineers and researchers in India.

Shri K. Ramasamy: Advancing Agricultural Science for Food Security

Padma Shri (2026) – Science and Engineering

Shri K. Ramasamy was awarded the Padma Shri 2026 for his outstanding contributions to agricultural science and crop improvement. An eminent agricultural scientist from Tamil Nadu, he has played a key role in developing improved crop varieties and promoting sustainable farming practices. His research has strengthened agricultural productivity and contributed to India's food and nutritional security.

Shri Kewal Krishan Thakral: Dedicated Service to Community Healthcare

Padma Shri (2026) – Medicine

Shri Kewal Krishan Thakral was awarded the Padma Shri 2026 for his distinguished contributions to medicine and public healthcare. A respected physician from Uttar Pradesh, he has devoted decades to delivering quality medical care and improving community health. His commitment to compassionate treatment, patient welfare, and accessible healthcare has earned him national recognition.

Shri Krishnamurty Balasubramanian: Advancing Theoretical Chemistry

Padma Shri (2026) – Science and Engineering

Shri Krishnamurty Balasubramanian was awarded the Padma Shri 2026 for his outstanding contributions to theoretical and computational chemistry. An internationally acclaimed scientist from Telangana, his research has advanced the understanding of molecular structure, chemical reactions, and materials science. His pioneering work has influenced modern chemical research and inspired scientists across the world.

Shri Kumarasamy Thangaraj: Unlocking India's Genetic Heritage

Padma Shri (2026) – Science and Engineering

Shri Kumarasamy Thangaraj was awarded the Padma Shri 2026 for his exceptional contributions to human genetics and genomics. An eminent scientist from Telangana, his pioneering research has advanced the understanding of India's population history, genetic diversity, and inherited diseases. His work has significantly contributed to medical genetics, precision medicine, and human evolutionary studies.

Dr. Padma Gurmet: Advancing Healthcare in the Himalayas

Padma Shri (2026) – Medicine

Dr. Padma Gurmet was awarded the Padma Shri 2026 for her outstanding contributions to medicine and public healthcare. A pioneering physician from Ladakh, she has dedicated her career to improving maternal and child health, expanding access to quality healthcare in remote Himalayan communities, and promoting preventive medicine. Her lifelong service has transformed healthcare delivery in one of India's most challenging regions.

Shri Palkonda Vijay Anand Reddy: Advancing Cancer Care in India

Padma Shri (2026) – Medicine

Shri Palkonda Vijay Anand Reddy was awarded the Padma Shri 2026 for his outstanding contributions to oncology and cancer care. A leading radiation oncologist from Telangana, he has played a pivotal role in advancing cancer treatment, promoting early diagnosis, and improving patient outcomes. His dedication to clinical excellence, research, and compassionate care has benefited thousands of patients across India.

Shri Prem Lal Gautam: Advancing Grassroots Innovation in Agriculture

Padma Shri (2026) – Science and Engineering

Shri Prem Lal Gautam was awarded the Padma Shri 2026 for his outstanding contributions to agricultural innovation and rural technology. Hailing from Himachal Pradesh, he is recognized for developing practical, low-cost farming solutions that improve productivity and support sustainable agriculture. His work demonstrates how grassroots innovation can empower farmers and strengthen India's agricultural sector.

Dr. Punniamurthy Natesan: Advancing Cardiac Care

Padma Shri (2026) – Medicine

Dr. Punniamurthy Natesan was awarded the Padma Shri 2026 for his outstanding contributions to cardiology and cardiovascular healthcare. A distinguished cardiologist from Tamil Nadu, he has dedicated decades to advancing heart disease diagnosis, treatment, and medical education. His commitment to clinical excellence, research, and compassionate patient care has significantly strengthened cardiac healthcare in India.

Shri Rajendra Prasad: Dedicated to Advancing Respiratory Medicine

Padma Shri (2026) – Medicine

Shri Rajendra Prasad was awarded the Padma Shri 2026 for his outstanding contributions to respiratory medicine. A distinguished pulmonologist from Uttar Pradesh, he has devoted his career to improving the diagnosis and treatment of lung diseases, advancing medical education, and promoting public awareness of respiratory health. His work has significantly enhanced patient care and strengthened pulmonary medicine in India.

Shri Ramchandra Godbole and Ms. Suneeta Godbole: A Lifetime of Service to Community Healthcare

Padma Shri (2026) – Medicine

Shri Ramchandra Godbole and Ms. Suneeta Godbole were jointly awarded the Padma Shri 2026 for their exceptional contributions to medicine and community healthcare. The husband-and-wife team from Chhattisgarh has dedicated decades to providing affordable, compassionate medical care, particularly in underserved communities. Their lifelong commitment to patient welfare and public health has positively impacted countless lives.

Shri Saroj Mandal: Dedicated Service to Rural Healthcare

Padma Shri (2026) – Medicine

Shri Saroj Mandal was awarded the Padma Shri 2026 for his outstanding contributions to medicine and community healthcare. A respected physician from West Bengal, he has devoted decades to providing accessible and compassionate medical care, particularly in underserved rural communities. His lifelong commitment to patient welfare, preventive healthcare, and public service has earned him national recognition.

Ms. Shubha Venkatesha Iyengar: Driving Innovation from Defence to Civil Aviation

Padma Shri (2026) – Science and Engineering

Ms. Shubha Venkatesha Iyengar was awarded the Padma Shri 2026 for her outstanding contributions to science and engineering. A distinguished scientist from Karnataka, she played a key role in India's missile and defence programmes at DRDO and later developed the indigenous "Drishti" runway visibility assessment system, now deployed at airports across India, enhancing aviation safety and technological self-reliance.

Shri Shyam Sundar: Advancing Healthcare Through Clinical Excellence

Padma Shri (2026) – Medicine

Shri Shyam Sundar was awarded the Padma Shri 2026 for his outstanding contributions to medicine and public healthcare. A distinguished physician from Uttar Pradesh, he has dedicated decades to improving patient care, advancing medical practice, and serving communities with compassion. His lifelong commitment to clinical excellence, medical education, and public service has earned him one of India's highest civilian honours.

Dr. Suresh Hanagavadi: Advancing Dental and Oral Healthcare

Padma Shri (2026) – Medicine

Dr. Suresh Hanagavadi was awarded the Padma Shri 2026 for his outstanding contributions to dentistry and oral healthcare. A distinguished dental surgeon from Karnataka, he has dedicated his career to advancing dental treatment, promoting oral health awareness, and mentoring future professionals. His commitment to clinical excellence and patient care has made a lasting impact on healthcare in India.

Shri Veezhinathan Kamakoti: Advancing Computing and Artificial Intelligence

Padma Shri (2026) – Science and Engineering

Shri Veezhinathan Kamakoti was awarded the Padma Shri 2026 for his outstanding contributions to computer science and engineering. A distinguished academic from Tamil Nadu, he is recognized for his pioneering work in artificial intelligence, cybersecurity, and computer architecture. His research, leadership, and commitment to technology education have significantly strengthened India's digital innovation and scientific ecosystem.

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

How Chemistry Controls Motion in Active Matter

Long before life emerged, Earth was likely filled with water and a variety of chemicals, what Darwin called the ”chemical soup.” This primordial soup contained various chemicals that reacted, forming countless new combinations. All it takes is a tiny droplet of this aqueous solution trapped in an oily medium, or an oily droplet within water, combined with the right chemistry inside and outside, to create a system capable of movement that can sense its environment, detect chemicals (aka food), and respond to heat, cold, or electric and magnetic fields. Still, they are not alive because they do not self-replicate. Their chemistry is much simpler than that of the simplest single-celled organisms, yet these droplets share an uncanny resemblance to them.

This type of non-living matter that can move autonomously is called active matter. A simple active matter can be created by placing camphor balls in water, as they will move on their own. Self-propelling droplets represent an intriguing class of active matter that can be engineered to perform a variety of fascinating tasks. The composition of such droplets can be tuned to produce a wide range of individual and collective behaviours. For example, the droplet could move randomly, as if agitated, or along a straight path. They can run and suddenly turn around, as in the run and tumble movement of a bacterium. When we place a large number of such droplets in a confined area, their collective dynamics could take several different forms. They could form swarms, like a school of fish. Two such droplets come together for a time being and move together, or one could go around the other. They could form moving or rotating clusters. Because of these possibilities, there has been a surge of interest in the autonomous movement and collective behaviour of active droplets.

The propulsion of these liquid droplets is powered by the Marangoni effect. In this process, localized chemical gradients induce variations in surface tension across the droplet’s interface, ultimately driving it forward.

A popular active droplet is made from a liquid that contains or can generate bromine and is placed in an oily medium (squalane) saturated with a surfactant (monolinolein). The bromine (Br) can react with the monoolein (MO) and form bromomonooein (BrMO) near the surface of the droplet. This reaction changes the physical properties of the surfactant molecule and can create a localised dip in surface tension at the interface between two liquids. The surface tension asymmetry creates fluid flow near the surface. To conserve momentum, the entire droplet must move in the opposite direction. When we use simple bromine water inside the droplet, it can move steadily, with speeds varying from 1 to 100 μ m/s. We can

Dr. T. K. Shajahan
National Institute of Technology Karnataka, India

| Scientific Profile |
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AREAS OF EXPERTISE

Nonlinear dynamics • Pattern formation in excitable media • Cardiac arrhythmias • Biophysics

Dr. Vivek Bharat Meshram
National Institute of Technology Karnataka, India

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| Organization Link |
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AREAS OF EXPERTISE

Nonlinear Dynamics • Biophysics

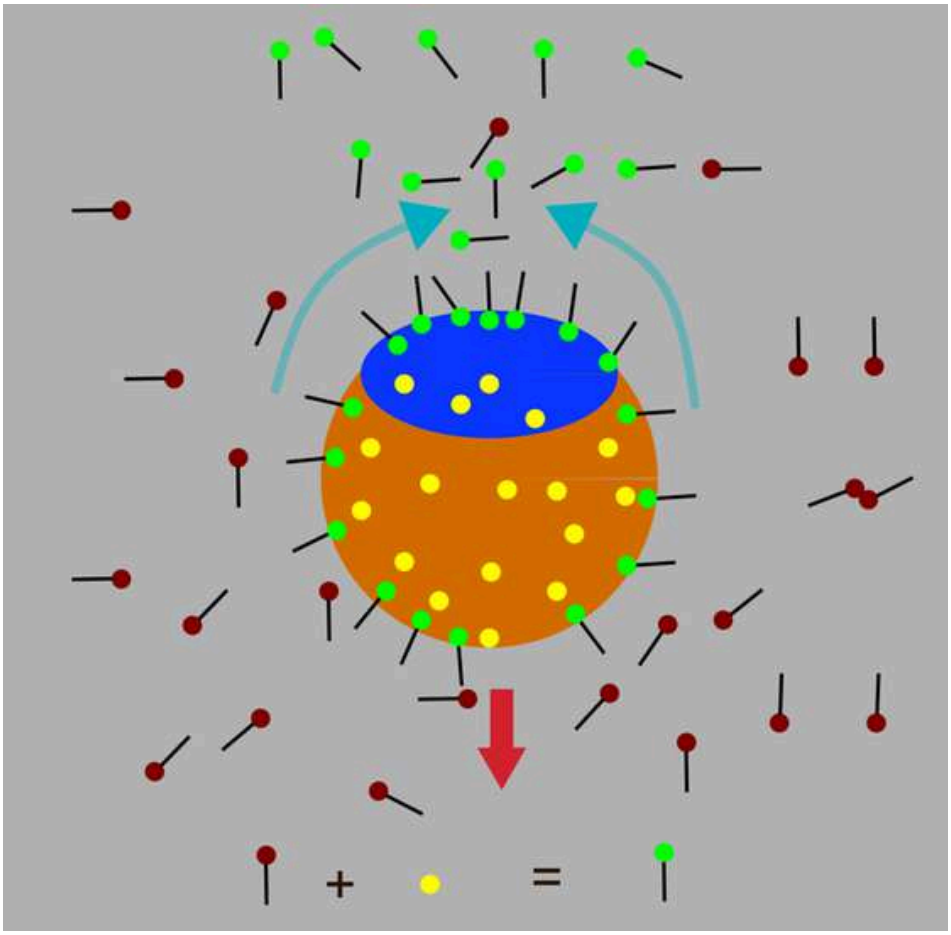


Figure 1: Schematic of self - propulsion of BZ droplet : Chemical waves (blue) travelling through the droplet periodically produce reaction intermediates, bromine (yellow circle), which migrate to the droplet's outer boundary. This bromine molecule reacts with the monoolein surfactant (red-headed line) in the oil medium, forming bromomonoolein (green-headed line). It generates the asymmetrical distribution of interfacial tension that propels the droplet.

speed up the bromination reaction by adding sulphuric acid to the droplet. At a higher reaction rate, the droplet not only moves faster but its motion can also become random.

We can make active droplets more interesting by incorporating the BelousovZhabotinsky (BZ) reaction. The BZ reaction is a nonlinear chemical reaction characterized by cyclic chemical oscillations. It consists of chemicals such as sodium bromate, sulphuric acid, malonic acid, and a metal catalyst, Ferroin, as an indicator. One of the intermediate products of the reaction is bromine (Br2). The cyclic reaction can change the colour of the solution from blue (indicating the oxidised state of Ferroin) to red (indicating the reduced state). This colour change can propagate as a chemical wave, with bromine produced just ahead of it. This chemical wave generated within the droplet can further enhance the asymmetric distribution of bromine, which, in turn, can create a larger gradient in surface tension. As a result, when the chemical wave reaches the interface, the droplet's speed can increase by as much as 10 times.

Another interesting mechanism of generating a surface tension gradient is micellar solubilization. A surfactant molecule, such as monoolein, has a polar end (which can interact with water and hence is hydrophilic or water-loving) and a non-polar end (which does not interact with water and hence is hydrophobic or water-hating). When the surfactant concentration in the oily medium exceeds a critical threshold, surfactants form spherical structures called micelles. In the oily medium, all the hydrophilic parts will come together and form the centre of the sphere, away from the surrounding oil. The hydrophobic part will point outwards and face the oil. These micelles can trap water at their centres, forming swollen micelles. As the droplets move, the micelles carry water out of the droplets, further enhancing the surface tension gradient. Moreover, the droplet leaves behind a trail of such filled micelles, and as they are no longer able to remove water from the droplets, the droplets tend to move away from them. The filled micelles leave the medium with the memory of the droplet's previous trails. These chemical trails are another way droplets can communicate with each other.

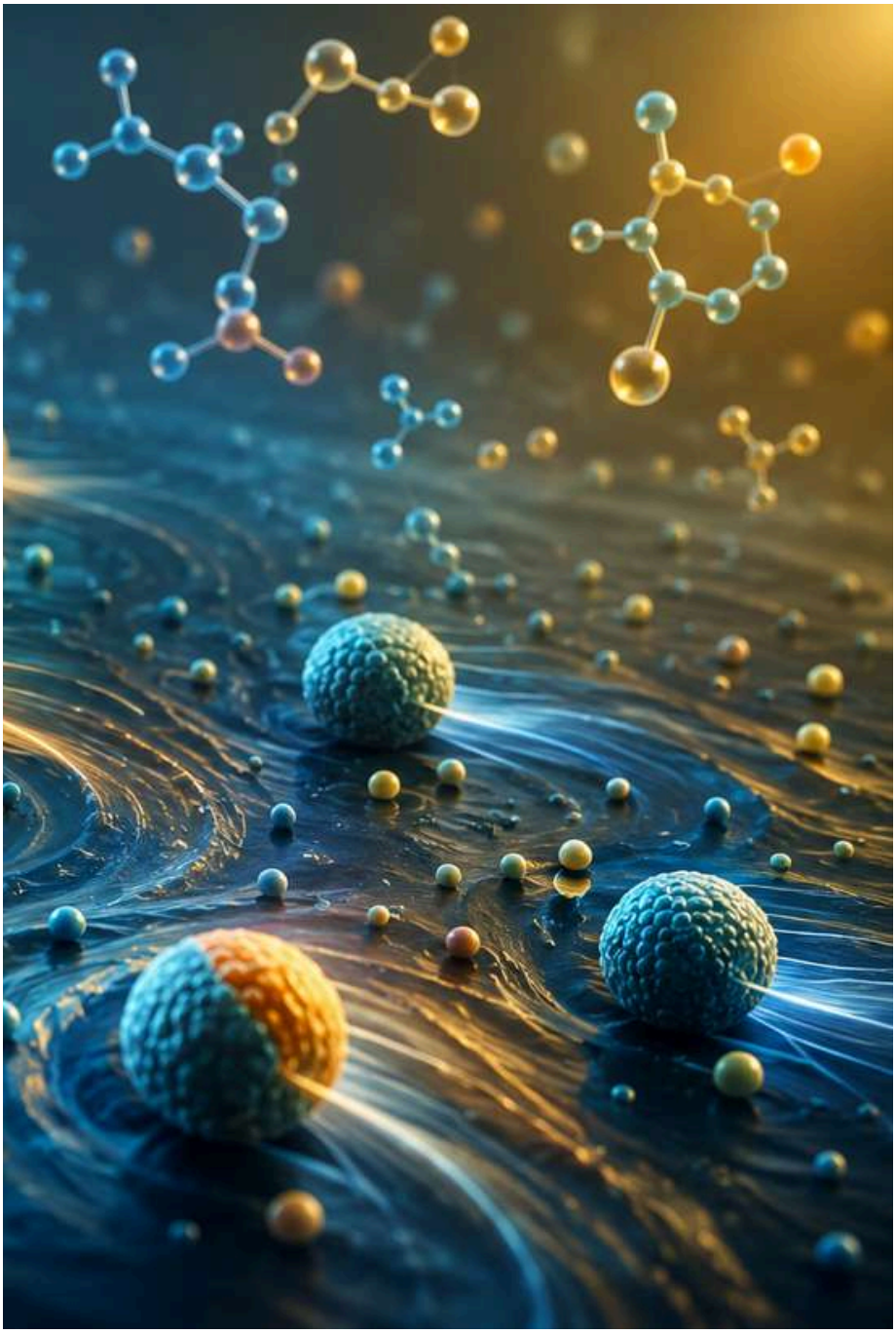
We have observed a variety of interactions between droplets. When several BZ droplets are placed in a Petri dish, some of them come closer to other droplets and move around or move parallel for some time, and then move away. Circular motion of one droplet around its pair is observed when the inter-droplet distance is at a minimum. The droplets can come very close to each other; however, they do not merge. The bromo-monoolein layer that forms around each droplet in the squalene–monoolein medium can p-

prevent droplet merging. We characterized this pairwise interaction by measuring the total time the two droplets remained in proximity. The interaction time of the two BZ droplets decreases as a function of sodium bromate concentration inside the droplet.

We observe similar dynamics when the droplets of different volumes interact. When a big droplet and a small droplet approach from opposite directions or move parallel to each other, they come close for a while, driven by hydrodynamic interaction, and then move apart, driven by the chemical gradient. We see that when a small droplet falls behind a larger one, the larger droplet can quickly move away because it is faster. We observe the maximum interaction time when the larger droplet falls behind the smaller one. Examining their instantaneous speeds, we note that during the interaction, the small droplet's average speed increases while the large droplet's decreases. This change indicates that the big droplet is pushing the small droplet.

Artificial active matter, like a BZ droplet, helps design a system that can mimic interactions in living systems, such as the run-and-tumble motion of bacteria, the locomotion of amoebas, and their responses to food or temperature gradients. Many groups have found ways to precisely control these artificial swimmers by adding extra nanoparticles and using light to modify the chemical reaction inside. Researchers have also developed interesting applications for these active droplets. They can be used for targeted drug delivery. They can also be used to clean up chemical pollutants by using them as fuel. As we understand more about their dynamics and interactions, we will be able to find new ways of using them to improve our lives and surroundings.

Dr. Shajahan and Dr. Vivek Bharat Meshram's contributions to active matter research are highlighted in his recent publication in Soft Matter (2026) (https://doi.org/10.1039/D5SM01187F). Their study demonstrates how tiny self-propelled chemical droplets interact with one another, particularly when they differ in size. The findings provide new insights into the behavior of active materials and improve our understanding of how simple chemical systems can self-organize and move autonomously, with potential applications in the development of smart soft materials and chemical microsystems.



EMERGING INSIGHT

Why Some Breast Cancers Are Harder to Treat: Understanding Tumor Types and Surgery Challenges

Dr. Gayatri Gogoi
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Dibrugarh – 786002, Assam, India

| Scientific Profile |
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AREAS OF EXPERTISE

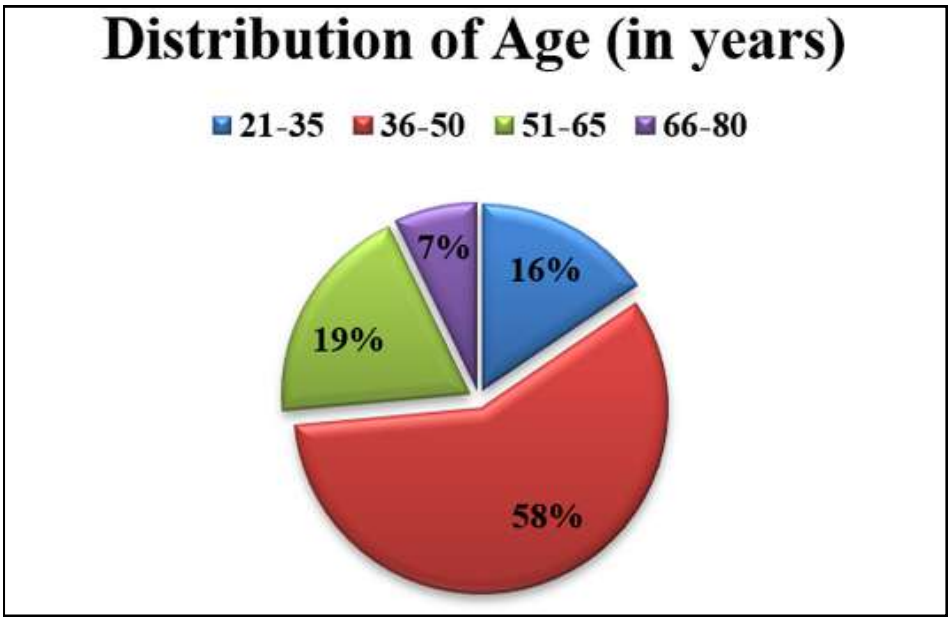
Research on Breast cancer • gall bladder cancer • hematolymphoid malignancies

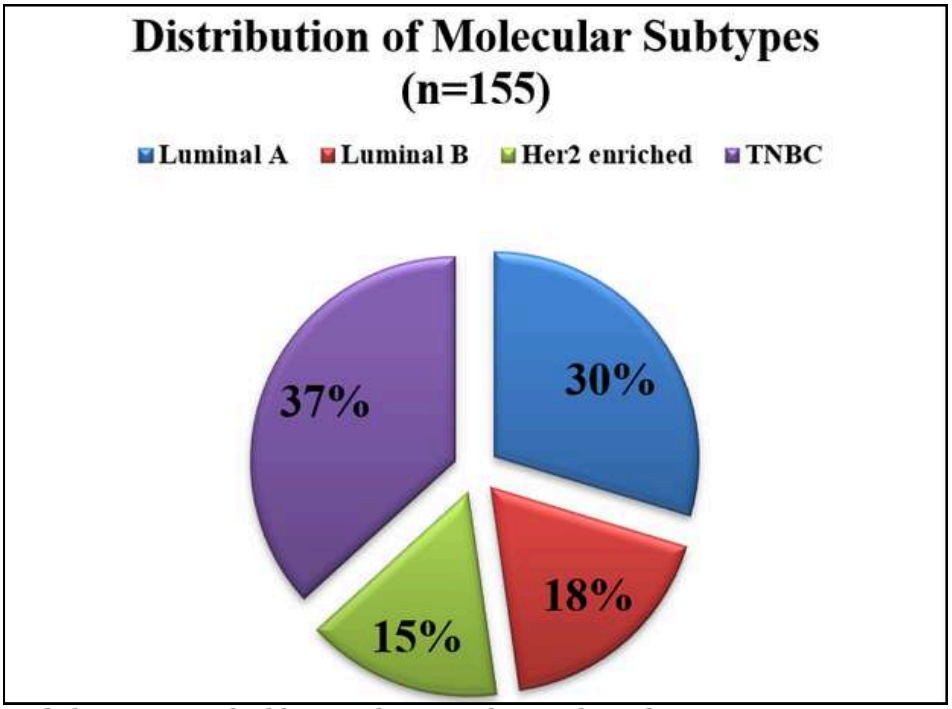
Breast cancer is the most terrifying nightmare for many women as they grow older. “Am I going to be affected even though nobody in my family has suffered from it so far?” “Why do some breast cancers never return after treatment while others recur quickly?” These are common questions that arise whenever breast cancer is discussed. Every two minutes, one woman is diagnosed with breast cancer in United States. In India, every four minutes, one woman is diagnosed with breast cancer in higher stage than USA. We now understand that some breast cancers are much harder to treat than others because breast cancer is not a single disease. It is a heterogeneous disease with different pathological classifications, clinicopathological stages, molecular biology profiles, treatment protocols and different survival patterns.

Many factors are extremely crucial in breast cancer management, beginning with age, co-morbidities, size of the tumour, whether it has reached nearby draining lymph nodes or spread to other organs like the lungs or bones, favourable histologic types, and low or high tumour grades, which areoverall classified according to the World Health Organization (WHO) pTNM staging system. Whether a particular chemotherapy, targeted therapy, hormone therapy, or immunotherapy treatment should be given to a woman diagnosed with breast cancer depends exclusively on the expression or status of certain pivotal test results, as per the guidelines of the American Society of Clinical Oncology and the College of American Pathologists. These include Estrogen Receptor (ER), Progesterone Receptor (PR), and HER2/neu testing. From these reports, molecular subtypes can be derived, which have prognostic and predictive value. When ER and PR are positive but HER2/neu is negative with low cell division, the subtype is called Luminal A. On the other hand, when ER is positive, PR is positive, and HER2/neu may be positive or negative with high cell division, it is categorised as Luminal B. When both ER and PR are negative but HER2/neu is positive, the subtype is called HER2-enriched. Lastly, Triple Negative Breast Cancer (TNBC) is the subtype in which ER, PR, and HER2/neu are all negative.

Luminal A molecular subtype of breast cancer is known for its excellent prognosis, with a 5-year survival rate of 95%. Luminal B is slightly more aggressive than Luminal A and also depends on whether HER2/neu is positive or negative. Luminal A and B are both eligible for treatment with anti-hormone receptor therapy. HER2-positive breast cancers are known for their aggressiveness, but they can be treated with targeted therapies like trastuzumab or pertuzumab. TNBC is the subtype that does not have any specific anti-estrogen or anti-HER2/neu therapy option, making it highly challenging to treat, and it is likely to have a poorer treatment outcome, with nearly 50% survival in contrast to Luminal A.

Unlike the Luminal A subtype, which is predominantly seen in studies from the USA and Europe, studies from Northeast India have shown that Triple-Negative Breast Cancer (TNBC) is the most common molecular subtype among breast cancer patients, followed by Luminal A, Luminal B, and HER2-enriched tumours. Our recent study also valid-





ated that TNBC is highly prevalent, with nearly one in three women diagnosed with breast cancer likely to have the TNBC subtype, which is an aggressive form of the disease. According to Cancer Registry data from the Indian Council of Medical Research, Northeast India has one of the youngest cohorts of breast cancer patients, with an average age at diagnosis of 47 years compared to 54 years for Pan-India and 65 years in the USA. The TNBC molecular subtype showed a strong association with the younger age group. This partly explains why one out of every two women diagnosed with breast cancer in India dies within five years, with survival being even lower in Northeast India.

Our recent publication "Association between molecular subtypes of breast cancer and surgical margin status from Assam, India" investigated the challenge of achieving clearer surgical margins by surgeons during breast cancer surgery.

The goal of surgeons is to remove the entire tumour tissue while maintaining clear surgical margins so that there is no chance of recurrence from any leftover tumour cells. This can be determined by the analysis of surgical margins by pathologists. The presence of cancer cells at the margins indicates a positive margin, which increases the risk of cancer recurrence and is seen in a significant number of patients. Such a situation may require the patient to undergo another surgery.

Our study showed that HER2-enriched tumours had the highest rate of margin involvement, followed by Luminal A, Luminal B, and TNBC cases. Larger tumours and cancers that had spread to lymph nodes were also associated with a higher rate of positive margins. These findings suggest that aggressive tumour types and advanced disease can make surgery more difficult. Our study findings showed considerably large tumour sizes, with 57% of cases measuring 2–5 cm and 38% measuring more than 5 cm, which had direct implications for surgical margin status. Lymph node involvement was observed in 77% of cases, indicating that the cancer was locally advanced and had a direct impact on survival in this cohort. From these findings, the importance of early detection, molecular testing, and proper surgical planning to improve breast cancer treatment outcomes in the Northeast Indian population must be emphasized.

Surgery is an extremely crucial part of breast cancer management because accurate assessment of tum-

our margins during surgery remains a major concern. However, in our study population, nearly 90% of patients underwent full breast removal (modified radical mastectomy), and only 10% were suitable for breast-conserving surgery. Most patients required more extensive surgical procedures due to the larger tumour sizes at presentation. Hence, achieving a negative tumour margin remained a challenge. We were also curious to determine whether TNBC had any association with surgical margin clearance, as TNBC is highly prevalent in this region.

One important result from the study showed a strong predilection for positive surgical margins in patients with larger tumour sizes and the aggressive HER2-enriched molecular subtype. We initially believed that TNBC would have higher margin involvement; however, it showed the least positive margins, surprisingly. We hypothesised that the HER2/neu molecular subtype may exert normal or near-normal physicochemical properties within the tumour tissue, making it difficult for surgeons to differentiate tumour tissue from normal tissue during surgery. There is a possibility that different molecular subtypes produce varying degrees of stiffness, pressure, temperature, optical density, and other physical properties, which may influence how tumour and normal tissues feel during surgical assessment.

Positive tumour margin remained a significant risk factor, placing nearly one out of three women with breast cancer at risk of local recurrence, and it was seen most commonly in the HER2-enriched molecular subtype. TNBC was the largest molecular subtype category, presented at a younger age, and was likely to be associated with poor prognostic parameters, thereby leading to poorer survival. However, the chance of positive margins was less common in TNBC than in other subtypes, probably due to the characteristic physicochemical properties evoked by this molecular subtype, allowing better distinction between normal and tumour tissue. The future direction of this research would involve more stringent margin assessment using radiological methods and frozen section analysis during the intraoperative period to reduce the chances of positive margins, along with the option of neoadjuvant chemotherapy followed by modified radical mastectomy (MRM). Technological characterisation of tumours is important so that surgeons can more precisely predict tumour margins. There is a strong need for solutions that can reduce positive margins during breast cancer surgery by improving the differentiation of tumour tissue from normal tissue. Such innovative methodologies could help bridge the existing technological gap in distinguishing cancerous tissue from normal tissue and thereby reduce the likelihood of positive margin involvement during breast tissue analysis in both the preoperative and intraoperative phases.

Our group is also currently working on multimodal fabricated MEMS-based electrical sensor and piezoelectric micro-machined ultrasound transducers (pMUTs) probe development for accurate intra-operative assessment of tumor margins.

Dr. Gayatri Gogoi's contributions to breast cancer research are reflected in her recent publication in Discover Oncology (2026), (DOI: 10.1007/s12672-026-05085-y), Clinical Cancer Investigation Journal, 2016), https://doi.org/10.4103/2278-0513.197871 and South Eastern European Journal of Public Health), https://doi.org/10.70135/seejph.vi.5026. Her work provides valuable insights into breast cancer molecular subtypes, surgical outcomes, and patient survival, advancing the understanding of breast cancer epidemiology in Northeast India and supporting improved clinical management and personalized treatment strategies.

Acknowledgment: The author gratefully acknowledges the grant received from the Indian Council of Medical Research (ICMR), Government of India, and the Anusandhan National Research Foundation (ANRF) (formerly the Science and Engineering Research Board, SERB), Government of India, for funding the research activities related to this work.

EMERGING INSIGHT

Turning Water into Clean Fuel

Dr. Munmun Ghosh
Chemistry Department, Ashoka University, India

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

AREAS OF EXPERTISE

Bioinorganic Chemistry • Green Hydrogen Generation • CO_2 Reduction Catalysis

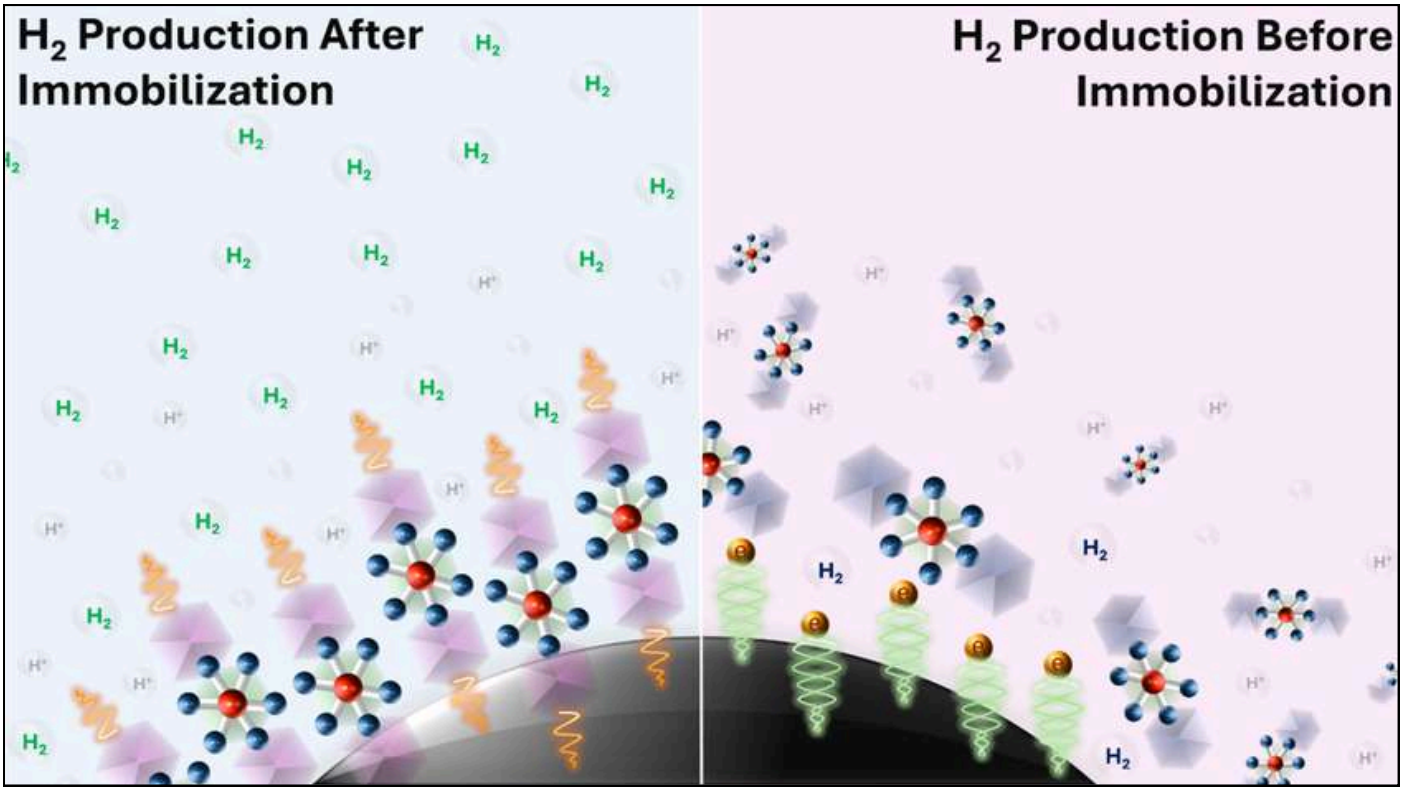
Our interest in working on hydrogen production grew from the need for sustainable energy technologies, and it developed further as we delved into catalytic and electrochemical strategies for efficient water spitting leading to clean fuel generation. To deal with the never ending energy demands and the growing concerns about the climate issues caused by the use of fossil fuels, implication of alternative technologies capable of producing renewable and clean energy is urgently required. The transient nature of existing renewable sources ignited the pursuit for other carbon neutral energy systems and among them hydrogen stand as a promising candidate. Hydrogen generation is a simple reaction involving two electron reduction of two protons. In nature hydrogen is not freely available in their original form, rather they exist in combined form with other elements, such as hydrocarbons or oxides (H_2O). Unfortunately, production of hydrogen from its natural sources are unsustainable, as production from hydrocarbons are economical but not carbon neutral and from water is carbon neutral but not economical. This tug of war between the need for clean and economical practices, creates tension in the field of hydrogen evolution technologies. A feasible solution to this is to cut the cost of hydrogen production from its ubiquitous source, water, using efficient and cheap catalyst. Keeping this aim in mind we were in pursuit of iron based electrocatalyst for hydrogen generation from water. Iron being the most abundant 3d transition metal, electrocatalyst based on iron can be an economically viable solution for carbon neutral hydrogen generation.

In recent years transition metal complexes have emerged as a significant class of electrocatalyst due to their adaptable structural characteristics, ability to exist in variable oxidation state, atom economy, clear catalytic mechanism and so on. A great deal of molecular catalysts has been developed and investigated, many of which have shown satisfactory stability and catalytic rates for hydrogen generation. To be noted majority of this work is dedicated in employing these catalysts under homogenous condition, which lacked practicality. Very recently, this trend has taken a turn, and they have been immobilized over conducting electrodes via both covalent and non-covalent interactions. This initiative has numerous advantages as they offer the qualities of both homogenous and heterogenous catalysts while also mitigating their shortcomings most of the time. An ideal system to achieve the optimum results require minimal synthetic effort for the development, immobilization of the catalyst and have the capability to directly generate hydrogen under renewable conditions. However, majority of the studies in this area of research fails in terms of practicality due to their lack of stability under experimental conditions and challenges in their synthesis. To address this issue, we studied the direct immobilization of para substituted pyridine-2,6-dicarboxylate based iron complexes via electro-oxidation reactions on conducting carbon surfaces. Major highlight of our study is that the para-chloro substituted pyrdine-2,6-dicarboxylate iron complexes gets covalently attached to the carbon electrode under oxidation potentials via radical pathway. The catalyst immobilized carbon surfaces acted as stable cathode electrode during aqueous alkaline hydrogen evolution reaction. Under electrolysis condition the modified electrode showed minimum stability for 150 hours maintaining stable current densities. In addition to demonstrating a novel method for

the direct immobilization of complexes with chloro-substituted aromatic rings through an electrooxidation reaction, this study also demonstrates the adequate stability of pyridine-2,6-dicarboxylate iron complexes under electrolysis conditions during the hydrogen production. This study opens up a new avenue for immobilization of similar catalysts on conducting carbon surfaces for tackling the current energy crisis and it stands as an example for establishing a simple, cost effective synthetic approach to develop stable cathode electrodes for hydrogen production.

Under strong acidic conditions pyridine-2,6-dicarboxylate based iron complexes undergo partial dechelation, resulting the formation of free carboxylic acid arms near the catalytically active iron centre. Hydrogen evolution reaction under acidic condition is thus triggered by the formation of a metal hydride intermediate. But under alkaline condition the complexes exhibit structural rigidity, and this sturdy behavior results in the long term stability of these complexes under aqueous alkaline conditions. Even after immobilization and long term electrolysis studies did not denature the surface anchored catalyst. Besides the novel immobilization approach via electrooxidation reaction, this study introduces a stable molecular iron based cathode electrode for hydrogen evolution reaction. With wide range of similar molecular catalysts and conducting substrates available, this technique ensures that heterogenous hydrogen evolution reaction is viable on variety of their combinations giving limitless possibilities for materials engineering. Further, a major advancement in the field will be studying the activity of these electrodes for direct sea water electrolysis reaction. As the electrode shows stability under aqueous alkaline conditions, its stability in presence of electrode corroding cations and anions should be tested. At present these studies are underway in our lab and we believe the possible outcomes from these studies would mark a place in the evolution of hydrogen evolving catalysts.

Dr. Munmun Ghosh's contributions to sustainable chemistry are reflected in her recent publication in RSC Advances (2026), https://doi.org/10.1039/D5RA09721E which advances the development of bioinspired molecular catalysts for efficient green hydrogen production through alkaline electrocatalytic water splitting. Her work highlights the growing role of innovative catalyst design in enabling cleaner energy technologies and supporting the global transition towards sustainable hydrogen-based energy systems.



EMERGING INSIGHT

Weight-Loss Medicines and Eye Health: What Are We Learning?

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| Scientific Profile |
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AREAS OF EXPERTISE

Endocrinology • Obesity medicine • diabetes and metabolic disease

Glucagon-like peptide-1 receptor agonists, or GLP-1 RAs, have rapidly reshaped the treatment of type 2 diabetes and obesity. Medicines such as semaglutide are no longer niche therapies used only by specialists; they are becoming part of mainstream care because they can improve blood sugar control, reduce body weight, and lower cardiovascular risk. For many patients, that is a remarkable therapeutic advance. But as these drugs move from specialist clinics into wider real-world use, a new question has gained urgency: what are we learning about their effects on the eye?

The answer, at least for now, is nuanced. Most people taking GLP-1 medicines will never develop a serious eye complication, and the current evidence does not support abandoning these highly effective drugs. But pharmacovigilance data, trials, and case reports suggest that rare visual adverse events deserve closer attention. Two patterns stand out. One is worsening of diabetic retinopathy in some patients with diabetes, especially when blood glucose improves very rapidly. The other is rare optic nerve injury such as non-arteritic anterior ischemic optic neuropathy, or NAION, which can cause sudden vision loss and may leave permanent disability. Importantly, optic nerve events have been reported not only in diabetes, but also in some people using GLP-1 medicines for obesity alone.

That is why the issue now matters beyond ophthalmology. In 2025, the European Medicines Agency's safety committee concluded that semaglutide should carry updated product information to reflect non-arteritic anterior ischemic optic neuropathy, or NAION, as a very rare side effect, with a frequency of up to about 1 in 10,000 treated people. The World Health Organization similarly issued a safety alert highlighting the seriousness of the condition and the need for continued vigilance. These actions do not imply that the drug is broadly unsafe. Rather, they signal an important shift in clinical thinking: as use expands, rare harms that were once difficult to detect become part of responsible prescribing and patient counselling.

These signals do not all reflect the same mechanism. Diabetic retinopathy worsening appears linked mainly to the speed and magnitude of glucose lowering in patients who already have retinal disease. Optic nerve events raise different questions about vascular susceptibility, anatomy, and whether semaglutide may act as one contributor among several in a small, predisposed subgroup. In other words, this is not one eye problem but two distinct clinical concerns in two different types of patients.

Two Distinct Eye-Safety Signals

Diabetic retinopathy progression was the first ocular safety signal to attract attention. In the SUSTAIN-6 trial, semaglutide was associated with more diabetic retinopathy complications than placebo, roughly 3.0% versus 1.8%. Later analyses suggested that the excess risk was concentrated largely in patients who already had retinopathy, had poor glycaemic control at baseline, and then experienced a marked early fall in HbA1c. That pattern fits the familiar phenomenon of "early worsening," in which rapid correction of longstanding hyperglycaemia can transiently aggravate retinal disease before longer-term benefit emerges.

The practical lesson is not to avoid

semaglutide in all patients with diabetes, but to identify those who may need closer monitoring when treatment starts. A recent retinal evaluation, awareness of baseline retinopathy status, and caution against pursuing very rapid metabolic change in vulnerable patients may all help reduce avoidable harm. Similar signals have not been consistently reproduced across most other semaglutide trials or across the GLP-1 class as a whole, suggesting a context-dependent risk rather than a universal toxic effect on the retina.

Optic nerve disorders, especially NAION, are the newer concern. NAION is a sudden loss of blood supply to the optic nerve that typically causes painless vision loss in one eye. It already occurs more often in people with diabetes, hypertension, dyslipidaemia, and obstructive sleep apnoea, which complicates interpretation because many people prescribed semaglutide carry the same background risks. Even so, large studies have suggested that semaglutide exposure may be associated with a higher incidence of NAION than expected. The absolute risk remains low, but the seriousness of the outcome has made this a major pharmacovigilance issue.

Many patients who develop NAION have a so-called "disc at risk": a small, crowded optic nerve head with a low cup-to-disc ratio. In simple terms, there is less structural space within the disc, so even modest swelling may further compromise local blood flow and axonal transport. This helps explain why NAION can seem unpredictable: two patients may share similar vascular risk factors, yet the one with an anatomically crowded disc may be more vulnerable to a visual catastrophe. If the drug-associated signal is real, it is likely to affect only a very small subset of exposed patients with this kind of predisposition.

Recent regulatory action has moved this concern beyond isolated case reports. The EMA concluded that NAION should be listed as a very rare adverse effect of semaglutide, and the WHO likewise highlighted the need for continued vigilance. That does not mean most patients face meaningful visual danger. It means a rare event with potentially irreversible consequences has been observed consistently enough to deserve warning and recognition when symptoms occur.

Why Might These Problems Occur?

The biology is still being worked out. In diabetic retinopathy, the explanation is relatively familiar: rapid correction of long-standing hyperglycaemia can temporarily worsen pre-existing retinal disease. In optic neuropathy, the mechanism

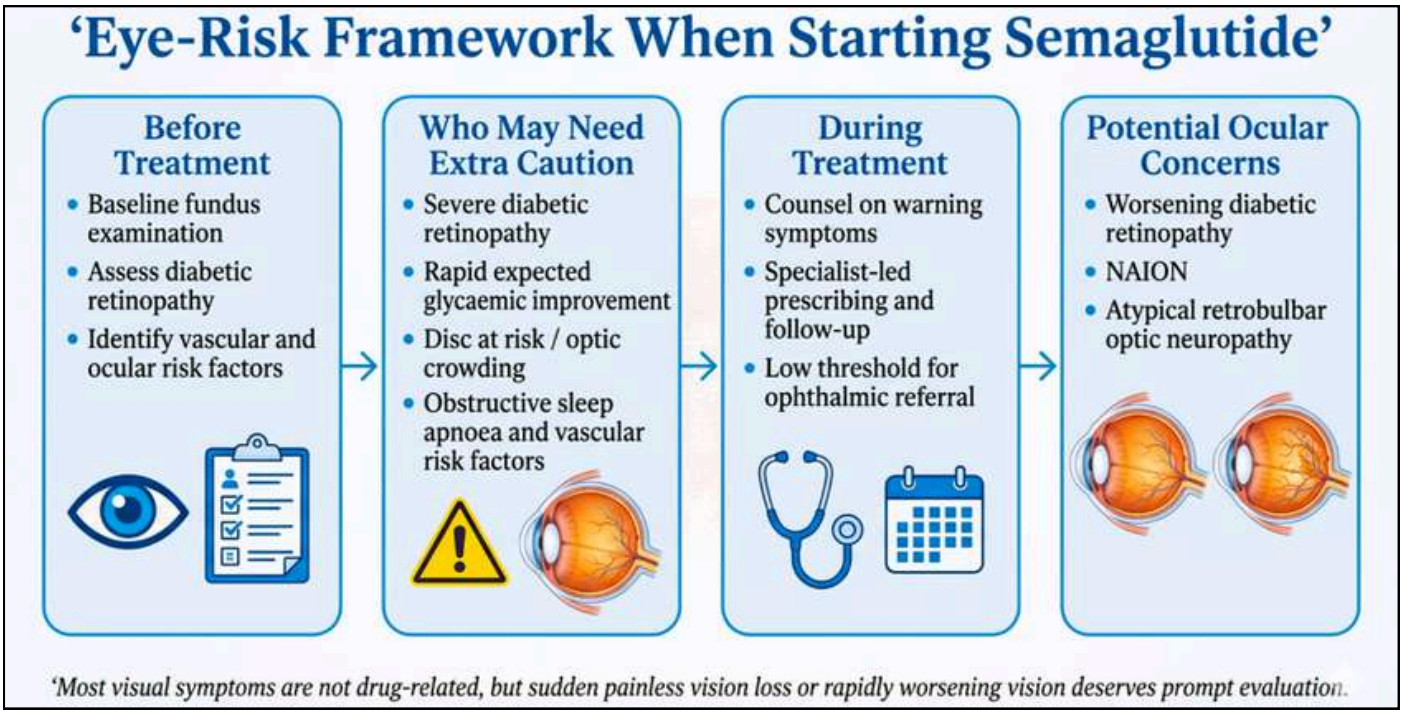

Figure 1. A practical framework for assessing eye risk before and during semaglutide treatment. The figure highlights baseline screening, patients who may need extra caution, ongoing counselling, and the main ocular concerns that should be recognized early.

is less certain. Semaglutide may not directly damage the optic nerve, but could interact with pre-existing vascular vulnerability, sleep-apnoea-related risk, haemodynamic shifts, or disc anatomy in a small subgroup of susceptible patients.

The most realistic model is therefore one of convergence rather than a simple one-drug, one-effect explanation. Vascular disease, optic disc crowding, blood-pressure fluctuations, and treatment-related change may all matter at once. Our own recent experience reinforces that point. To our knowledge, this appears to be the first reported case from India of semaglutide-associated atypical retrobulbar optic neuropathy. We reported a young adult with obesity, obstructive sleep apnoea, and prediabetes who developed acute, painless, asymmetric bilateral visual dysfunction shortly after semaglutide dose escalation. The picture was unusual: there was no optic disc edema, imaging was unremarkable, and visual testing suggested a retrobulbar optic neuropathy with overlapping ischemic and demyelinating features rather than typical NAION. Because the presentation did not fit neatly into a classical syndrome, it serves as a reminder that potential semaglutide-related visual side effects may extend beyond the usual textbook description. That is exactly why clinicians should not wait for a perfect diagnostic label before taking new visual symptoms seriously.

What Should Patients and Clinicians Watch For?

Most visual complaints in diabetic or non-diabetic individuals with obesity who are receiving semaglutide or other GLP-1 receptor agonists will not be attributable to the medication itself. Even so, sudden, painless vision loss, new dimming in one eye, a dark patch in the field of view, or rapidly worsening eyesight deserves prompt evaluation. A baseline fundus examination before starting treatment is highly recommended, especially in patients with diabetes or other ocular risk factors. In diabetic patients, it can identify severe diabetic retinopathy that may be at risk of worsening if glycaemic improvement is rapid; where such retinopathy is present, it should ideally be stabilized and appropriate ophthalmic treatment initiated before semaglutide is started. It may also reveal a low cup-to-disc ratio or optic disc crowding, which could suggest a "disc at risk" in patients vulnerable to NAION. In such patients, counselling should be individualized and should include discussion that this anatomy may represent a predisposing factor, even though the absolute risk remains low and a baseline fundus examination cannot reliably predict who will or will not develop NAION or atypical retrobulbar optic neuropathy. At the same time, clinicians should remember that NAION and retrobulbar optic neuropathy can still occur even when the fundus appears normal, so a normal baseline examination should not create false reassurance.

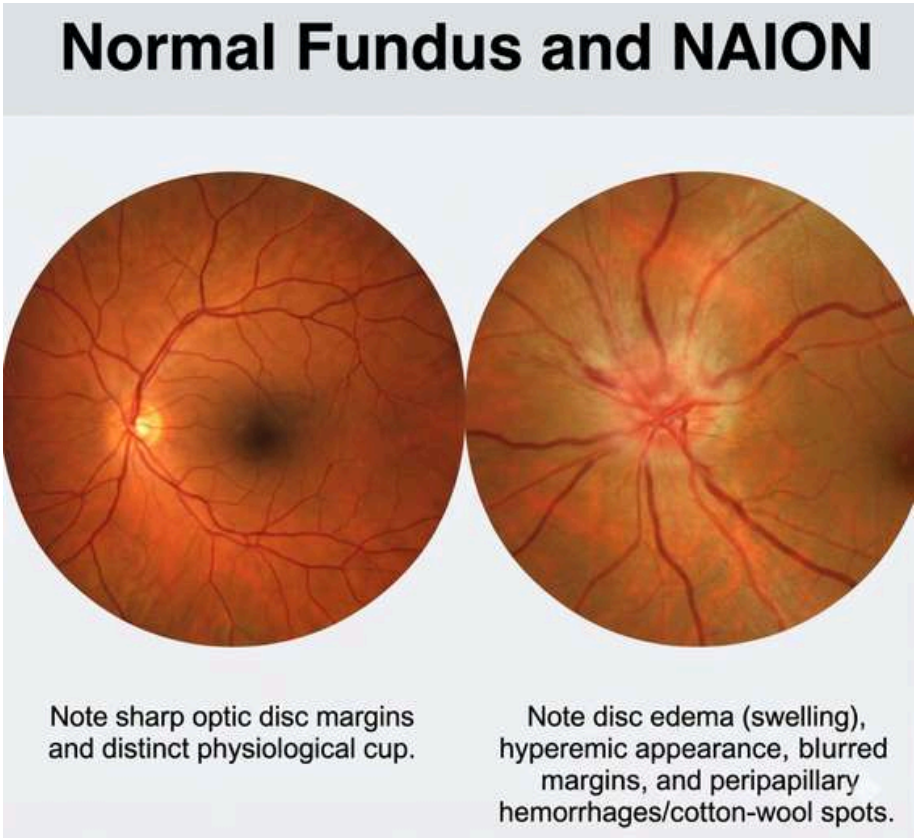

Figure 2. Fundus appearance in a normal optic disc and in non-arteritic anterior ischemic optic neuropathy (NAION). The figure compares a normal fundus with the characteristic fundus changes seen in acute NAION, where optic disc swelling is typically present, while also underscoring that atypical optic neuropathies may occur without these findings.

These Are Not "Take-and-Forget" Medicines

None of this changes the fact that

semaglutide and related GLP-1 medicines are major therapeutic advances. The challenge is not whether they should be used, but how they should be used well. These drugs are better understood as structured therapies that require counselling, dose-escalation planning, and attention to adverse effects across multiple organ systems. The eye has now entered that conversation as an area where rare but meaningful complications may occur.

The Indian context makes this especially important. When a powerful drug suddenly becomes cheap and widely available, it can encourage indiscriminate prescribing, especially in busy general practice settings where clinicians may not always have the time, specialist expertise, or systems needed for close follow-up. Many prescribers may also lack ready access to the ophthalmic evaluation or diagnostic setup required to investigate new visual symptoms in depth. In such circumstances, rare complications can be missed, delayed, or attributed to more familiar causes unless the possibility is actively considered. Wider access should therefore be matched by better counselling, clearer referral pathways, and a lower threshold for ophthalmic review when symptoms appear.

That does not mean every patient needs intensive ophthalmic surveillance. It means prescribers should be selective and practical: know baseline retinopathy status in people with diabetes, discuss warning symptoms clearly, and maintain a lower threshold for review in patients with vascular risk factors, obstructive sleep apnoea, or unexplained prior visual episodes. Given not only the potential for visual adverse effects but also other important complications of treatment, prescribing should ideally remain with specialists such as endocrinologists and experienced physicians who are better equipped to counsel patients, titrate therapy appropriately, and arrange timely follow-up when problems arise.

There is also a pharmacovigilance lesson here. Rare adverse effects become visible only when clinicians notice them, investigate them, and report them. As GLP-1 medicines spread across endocrinology, obesity practice, and general medicine, awareness will determine whether important signals are recognized early or lost in everyday prescribing. In that sense, the semaglutide-eye story is not only about one drug, but about how modern therapeutics should be introduced responsibly when their benefits are large and their rare complications may be serious.

So what are we learning? We are learning that the eye belongs in the safety conversation around weight-loss medicines, not because these drugs are broadly dangerous, but because rare complications become visible only after widespread use. We are learning that diabetic retinopathy worsening and optic neuropathy are not the same problem and should not be discussed as though they are. And we are learning that a low absolute risk does not remove responsibility when the consequence may be permanent loss of vision. Semaglutide and related GLP-1 therapies remain high-impact drugs with real public-health potential. The task now is to pair wider access with better counselling, selective monitoring, and faster recognition of the uncommon patient whose first warning sign may come through the eye.

Prof. Shivaprasad Channabasappa's contributions to the field of diabetes and diabetic eye disease are reflected in his research on the ocular safety of semaglutide and its impact on vision. His work has advanced understanding of semaglutide-associated retinal and optic nerve complications, including diabetic retinopathy progression and rare optic neuropathies, helping to inform safer clinical use of GLP-1 receptor agonists. These findings have been published in leading journals, including Diabetes, Obesity and Metabolism (2018; DOI: 10.1111/dom.13172; 2025; DOI: 10.1111/dom.16316) and JCEM Case Reports (2026; DOI: 10.1210/jcemcr/luag108).

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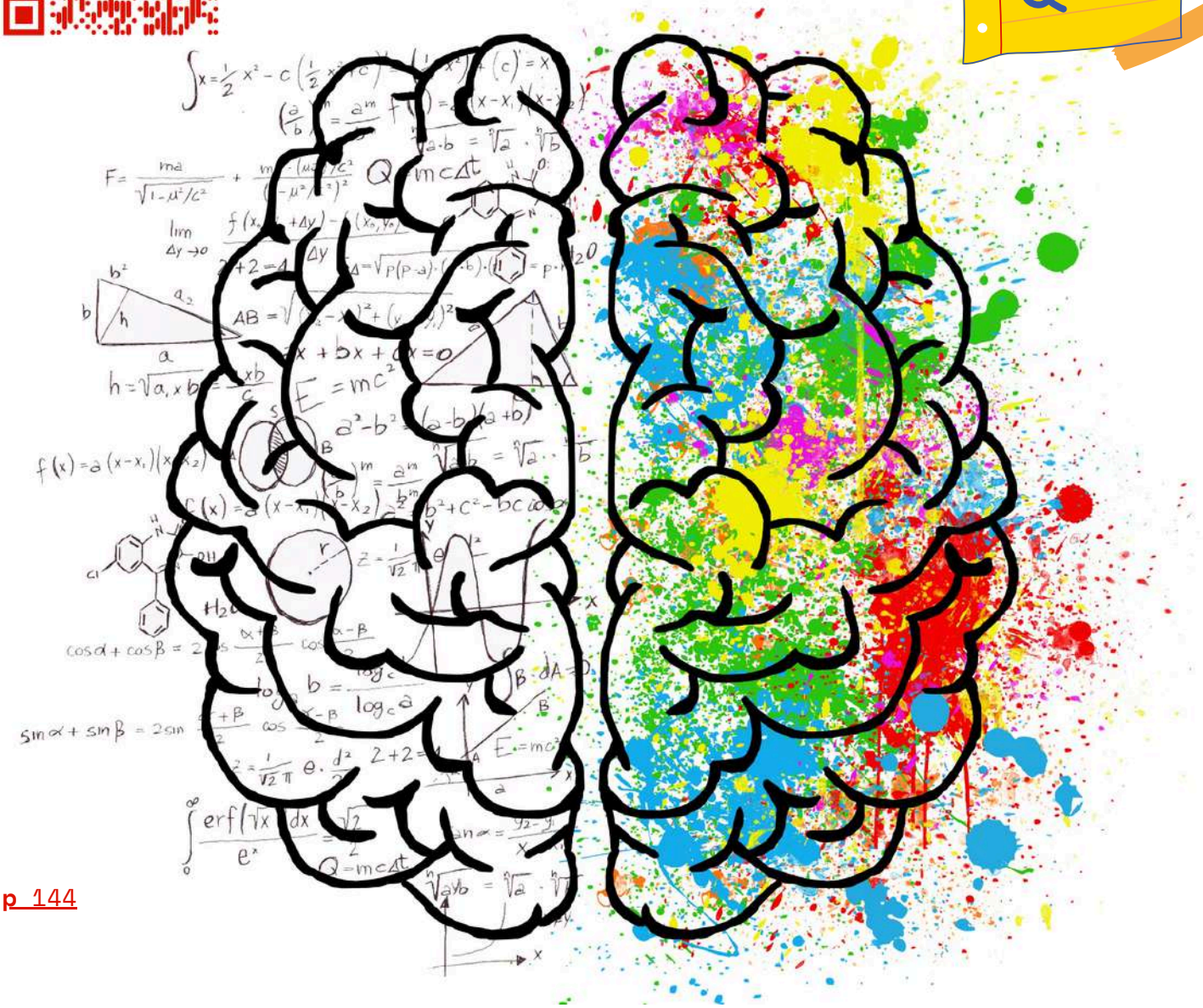
At Rosalind Franklin Council of Scientific Research (RFCSR), we recognize that the pursuit of science is both inspiring and demanding. Alongside the excitement of discovery, researchers often face unique challenges—intense workloads, high expectations, uncertainty about the future, and at times the discouraging experience of non-cooperation within their professional field or the feeling of being stuck in their career path. Such moments can leave even the most dedicated scientists questioning their way forward.

RESEARCHERS LIFELINE RESEARCH HEALTH



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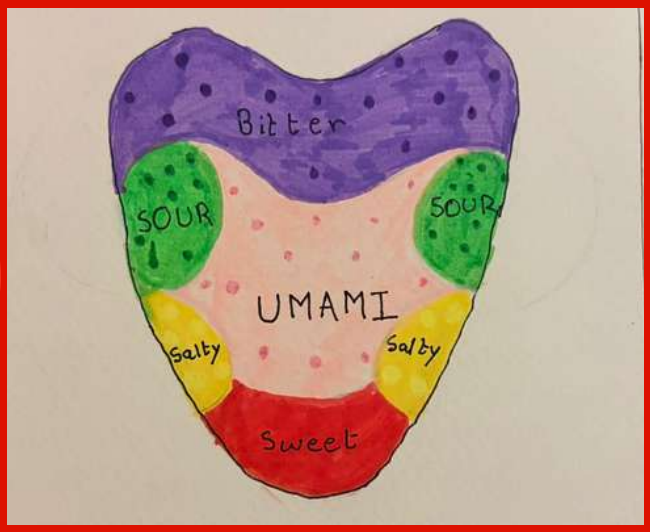
back to school

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!

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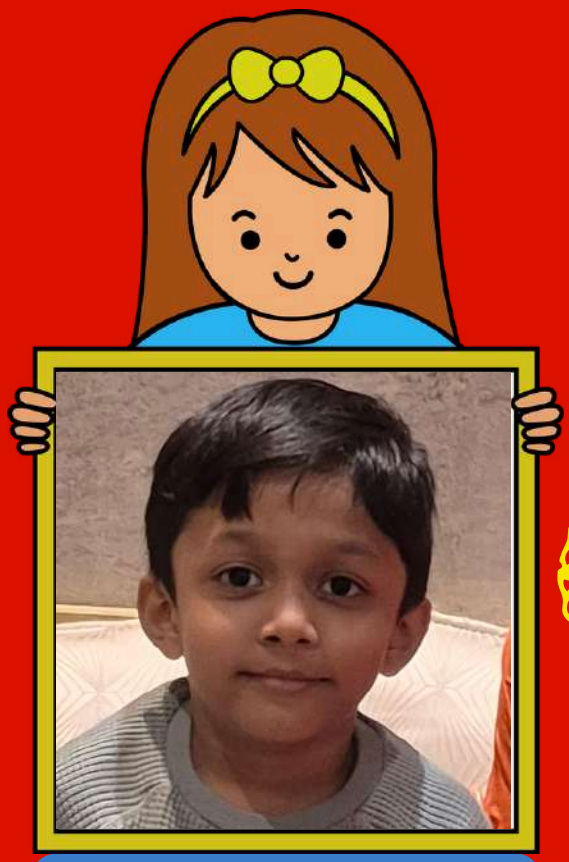
🎨✨ Give your child a chance to shine! Submit their artwork for an opportunity to be featured in Scientific Kids. Send an image along with a brief explanation or inquiry to hello@rfcsr.org

back to school



CURIOUS KID'S

NAME: **Parth Shreyas**

Grade: Class 1

SCHOOL: **DAV UNIT VII**

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.

🎨✨ 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

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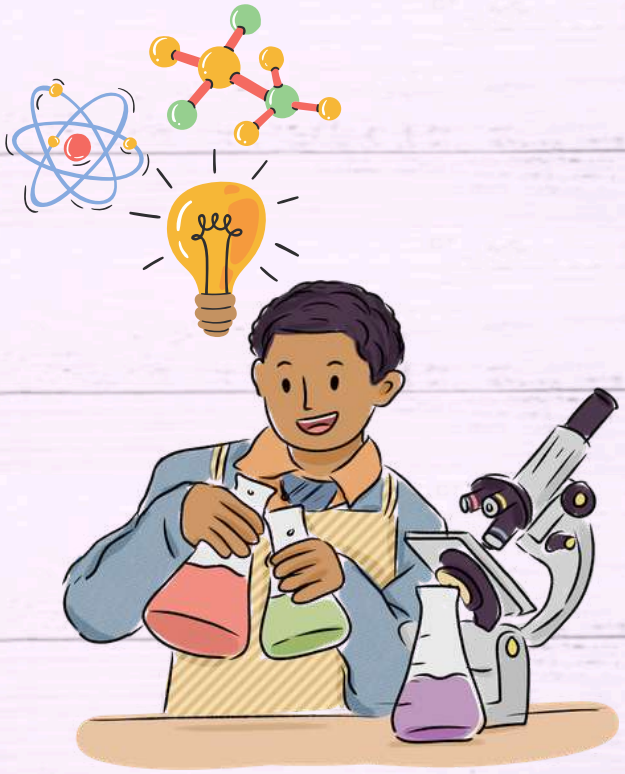

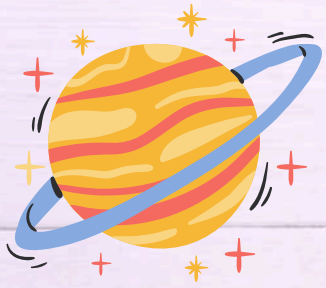

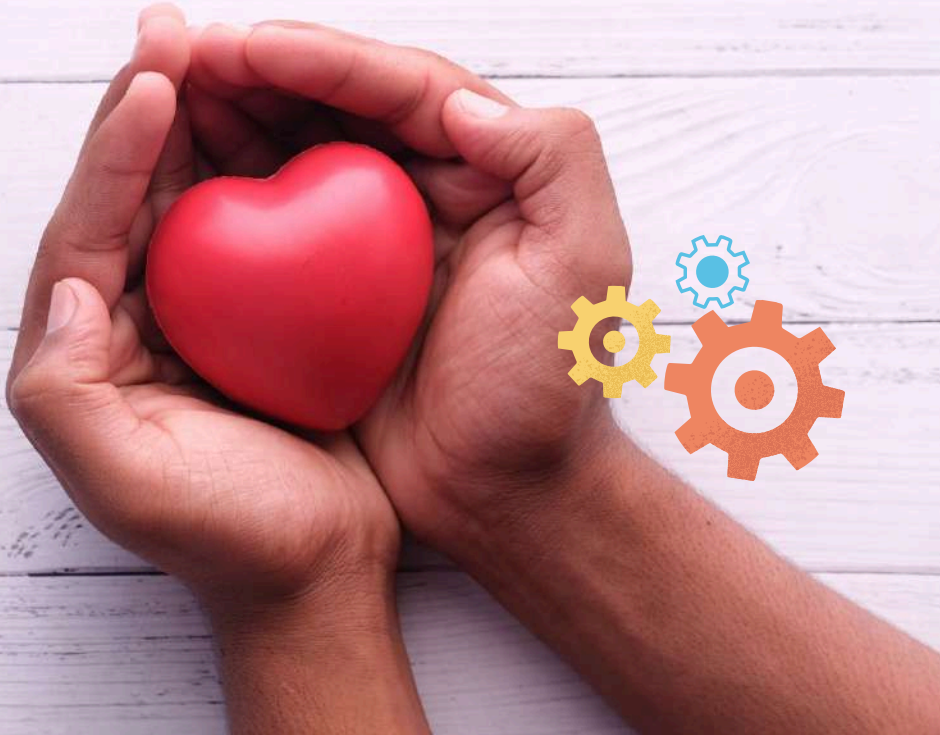

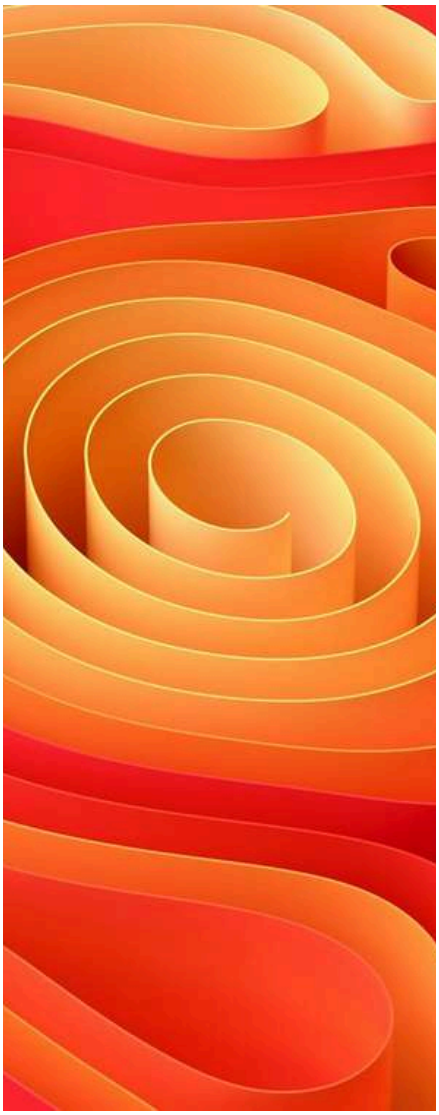

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July 2026

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