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BIOHYBRID CYBORG INSECT

By
Rosalind Franklin
Council of Scientific Research (RFCSR)
August 20, 2026

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Engineered to Dive. Built to Explore.

Scientific Research Empowers Social Progress !

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

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from the LETTER EDITOR

Dr. Animesha Rath
The Editor-in-Chief

Dear Readers,
Science often moves forward by finding new ways around old limitations. This spirit is at the heart of our August 2026 issue of *Science Factors*.

Our cover story introduces a remarkable biohybrid cyborg insect, a cockroach equipped with a miniature system that allows it to remain active underwater for hours. It is a fascinating example of biology and engineering working together to create new technological possibilities.

Beyond the cover, we look to the natural world, where migratory swans offer clues about how viruses move across environments, and to our changing climate, where scientists are exploring whether marine cloud brightening could help weaken El Niño. These stories highlight the close connections between wildlife, climate, the environment, and human well-being.

In medicine, we explore how genetic testing in chronic myeloid leukemia could help explain differences in treatment response, and how genetics is reshaping epilepsy diagnosis when MRI alone cannot provide all the answers. Biotechnology takes us further, with researchers reprogramming yeast to produce life-saving antibiotics and exploring new ways to fight drug-resistant infections beyond conventional antibiotics.

Innovation is also reaching agriculture, where scientists are investigating how crops can better withstand herbicides and other challenges, opening possibilities for more resilient and sustainable food production.

Elsewhere, we explore the biology of our sense of smell, emerging applications of artificial intelligence, advances moving from laboratories into real-world technologies, and new perspectives on public health, sustainability, and the science of tomorrow.

These stories may span very different fields, but they share the same driving force: curiosity and the determination to turn scientific questions into new possibilities.

Welcome to the August 2026 issue of Science Factors.

Happy reading!

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SCIENTIFIC RESEARCH EMPOWERS SOCIAL PROGRESS !

The CONTRIBUTORS

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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. Priyanka

THE COCKROACH THAT LEARNED TO DIVE

FEATURED

On the tropical island of Singapore, sudden rainstorms can quickly flood underground tunnels, drainage systems, and narrow passages. These flooded spaces are often too dangerous for rescue workers to enter and too small for conventional robots to explore. A young robotics engineer named Kai dreamed of creating a machine that could safely reach these difficult places. His team had already developed a remarkable cyborg cockroach, a living Madagascar hissing cockroach fitted with tiny electronic devices that gently guided its movement. Unlike ordinary robots, the cockroach did not need electric motors because its own muscles provided all the power. The electronics simply sent small signals that encouraged it to move left, right, or forward. This made the insect extremely energy-efficient and capable of crawling through spaces that many robots could never enter. Kai imagined these tiny explorers one day helping rescuers search collapsed buildings, inspect damaged pipelines, or explore dangerous environments after floods. However, every experiment ended the same way. The moment the cockroach entered water, it stopped moving. The battery still worked, and the electronics remained functional. The real problem was much simpler, the insect simply could not breathe underwater.

Determined to solve this problem, Kai asked his students a simple question: "How does a cockroach breathe?" Unlike humans, cockroaches have no lungs. Instead, they breathe through tiny openings called spiracles located along the sides of their bodies. Oxygen enters these spiracles and travels through thousands of microscopic air tubes known as the tracheal system, delivering oxygen directly to every muscle and organ. Unlike humans, insects do not use blood to carry oxygen. This breathing system works perfectly on land but fails underwater because the spiracles become filled with water instead of air. Without oxygen, the cockroach quickly suffocates. Kai realized he did not need to redesign the insect because nature had already built an excellent walking machine. Instead, he needed to protect its breathing system. If water could be kept away from the spiracles while fresh oxygen was continuously supplied, the cockroach might survive underwater. Rather than changing biology, Kai decided to combine biology with engineering.

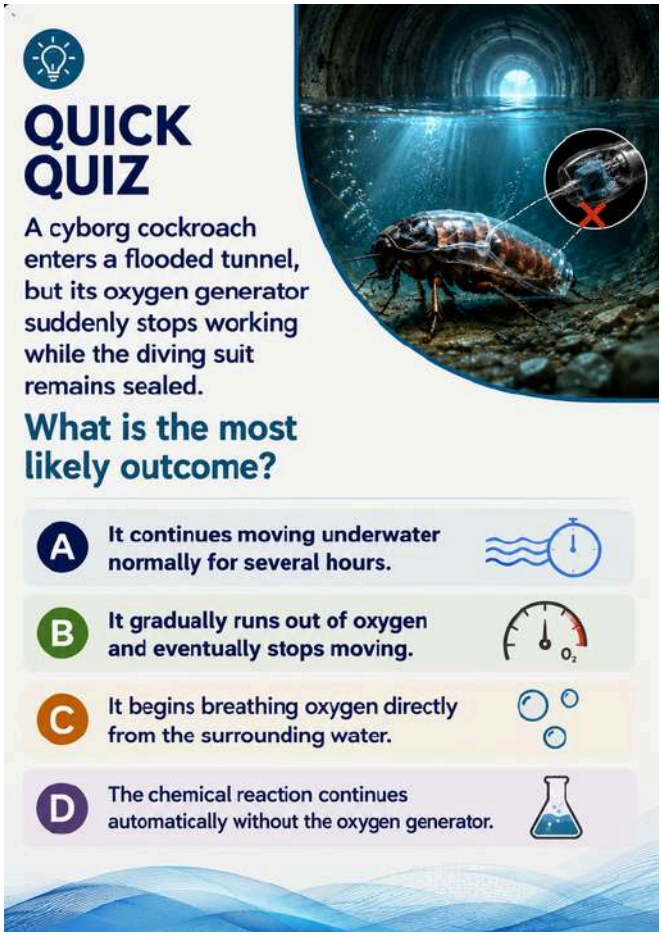
After months of work, the team designed a tiny wearable diving suit specially made for the cockroach. The suit

| By Dr. Priyanka

consisted of three important parts. The first was a lightweight, transparent, waterproof shell that wrapped around the cockroach's abdomen while allowing natural movement. This shell created a sealed chamber that prevented water from reaching the spiracles. Inside the shell sat a miniature oxygen generator. Instead of using bulky oxygen tanks or electric pumps, the researchers relied on chemistry. A cellulose sponge coated with manganese dioxide acted as a catalyst. When a small amount of 3% hydrogen peroxide was added, it broke down into water and oxygen gas through the reaction $2H_2O_2 \rightarrow 2H_2O + O_2$. Because manganese dioxide is a catalyst, it speeds up the reaction without being consumed. The oxygen filled the waterproof chamber and travelled through tiny silicone tubes connected directly to specially designed fittings over the spiracles. A microscopic waterproof membrane allowed only oxygen gas to leave the generator while keeping the chemicals safely sealed inside. This prevented leakage and protected the insect throughout the experiment.

The researchers carefully tested every part of the diving suit before using it underwater. They repeatedly bent the flexible shell, shook the oxygen generator, submerged the system in water, and confirmed that no chemicals leaked. They also found that the chemical reaction produced almost no heat, making the device safe for the cockroach. Finally came the real test. A normal cockroach survived underwater for only about two minutes before running out of oxygen. In contrast, the cockroach wearing the diving suit remained alive and active for two to three hours. It continued breathing oxygen produced by its miniature life-support system while responding normally to remote electrical guidance. The researchers even guided it through a tunnel containing carbon dioxide gas followed by deep water. Ordinary cockroaches quickly became immobile, but the diving-suit cockroach successfully crossed both hazards. Later, by placing the control electronics inside the insect's body instead of carrying them externally, the cyborg cockroach became even slimmer and crawled through underwater gaps only 2 centimetres high, spaces too narrow for many conventional robots.

Watching the tiny explorer emerge safely from the flooded tunnel, Kai smiled. "We never taught a cockroach to swim," he told his students. "We simply understood how nature works and helped it overcome one limitation." His words captured the true importance of the project. This breakthrough was much more than another robot. It showed how biology, chemistry, materials science, and engineering can work together to solve real-world problems. Biology provided a highly efficient walking machine. Chemistry generated oxygen without heavy batteries or tanks. Advanced materials kept water out while allowing oxygen to pass safely, and miniature electronics provided remote control. Together, these technologies transformed an ordinary land-dwelling insect into an amphibious cyborg explorer capable of travelling across both land and water. One day, similar insect-based robots could help locate survivors trapped after floods or earthquakes, inspect underwater infrastructure, monitor hazardous environments, and explore places that are too dangerous or too small for humans and conventional robots. Sometimes, the greatest inventions are not about replacing nature, they are about learning from it.



REFERENCE

FAN, Z., KAI, K., SONG, K. et al. Underwater Suit-Wearing Cyborg Insect Capable of Hours-Long Diving and Terra-Aqua Travel. Nat Commun 17, 5398 (2026). https://doi.org/10.1038/s41467-026-74235-1

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| By Dr. Ipsita Mohanty

WINGS OF MYSTERY: THE HIDDEN VIRAL JOURNEY OF MIGRATORY SWANS

FEATURED

Every winter, Mei, a young wildlife conservation student from Jiangxi Province, China, loved visiting the peaceful shores of Poyang Lake, one of the world's largest freshwater lakes. Thousands of graceful Tundra swans arrived there after flying thousands of kilometers from the icy Arctic. To Mei, these birds were symbols of freedom and endurance. But one morning, while watching the swans feed, she wondered, "What else might these incredible travelers be carrying besides memories of distant lands?" Her mentor explained that migratory birds are famous for spreading influenza viruses across continents, but no one truly knew whether they might also carry the viruses responsible for COVID-19 or MERS. Curious to uncover the answer, Mei joined a scientific team that carefully collected bird droppings from the lake without disturbing the birds. She imagined that every tiny sample held clues from places the swans had visited far beyond China's borders.

Back in the laboratory, Mei expected the answer to appear quickly. The scientists first performed the same PCR test used worldwide to detect COVID-19. To everyone's surprise, every sample tested negative. Many people would have stopped there, believing there was nothing to find. But the team decided to use a much more sensitive technology called metagenomic next-generation sequencing, capable of reading millions of pieces of genetic material at once. Days later, the computers displayed something astonishing. Hidden among countless fragments of bird and bacterial genes were tiny pieces of SARS-CoV-2, the virus responsible for COVID-19. By combining these fragments like pieces of a giant jigsaw puzzle, the researchers reconstructed three nearly complete coronavirus genomes from the Tundra swans. Even more surprisingly, they later found part of the genome of another dangerous coronavirus, MERS-CoV, in a Bar-headed goose from Tibet. Mei realized that although the birds did not appear sick, they had unknowingly

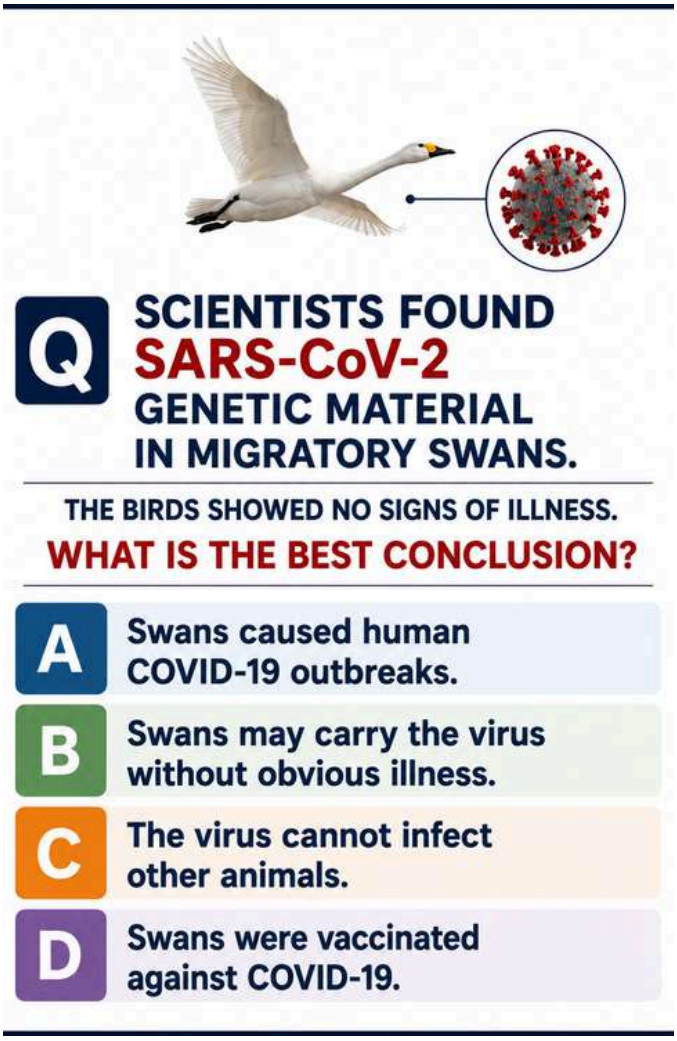
| By Dr. Ipsita Mohanty

carried traces of viruses during their remarkable journeys across continents.

Finding viral genetic material was exciting, but Mei knew another mystery remained. Could these viruses actually interact with bird cells? Every SARS-CoV-2 virus enters cells by attaching to a protein called ACE2, which acts like a lock on the cell surface. The viral spike protein works like a key. If the key fits the lock, infection can begin. The scientists isolated ACE2 proteins from both Tundra swans and Black swans and compared them with the human version. They discovered that the original virus that caused the first COVID-19 outbreak could not attach well to bird ACE2. However, newer variants carrying important mutations, similar to the Alpha, Beta, and Gamma variants, could bind much more effectively. Using an advanced imaging technique called cryo-electron microscopy, they observed the viral spike protein and bird ACE2 fitting together almost atom by atom. Several mutations had strengthened the connection, allowing the viral "key" to fit the bird's "lock" far better than before.

Still, Mei wanted stronger proof. The researchers created harmless pseudoviruses, which look like SARS-CoV-2 on the outside but cannot cause disease. They introduced bird ACE2 proteins into laboratory-grown human cells and exposed them to these pseudoviruses. Just as they had predicted, pseudoviruses carrying the Alpha, Beta, and Gamma spike proteins successfully entered cells containing swan ACE2, while those carrying the original spike protein could not. Although these bird receptors were not as effective as human ACE2, they still allowed viral entry under laboratory conditions. The team also studied the MERS virus found in the Bar-headed goose. While they successfully recovered part of its genome, they found no evidence that it could attach to the bird receptor they tested. This showed that not every coronavirus behaves the same way, and many questions about MERS in birds remain unanswered.

As the winter ended, the swans spread their wings and began the long journey back toward the Arctic. Mei watched them disappear into the clouds with a new appreciation for their incredible lives. These birds were not villains spreading disease, nor were they the proven source of human outbreaks. Instead, they were travelers carrying valuable clues about how viruses move through nature. Their migrations connect wetlands, forests, mountains, and oceans across continents, linking wildlife, livestock, and people in unexpected ways. Mei understood that protecting human health also means understanding animal health and the environment they share, a concept scientists call One Health. By continuing to monitor migratory birds, researchers hope to detect emerging viruses early, understand how they evolve, and prepare for future outbreaks before they become global threats. Sometimes, the greatest scientific discoveries begin not in crowded cities or hospitals, but in the silent flight of a swan crossing the morning sky.



REFERENCE

Cao J, Liu S, Su C, Wang L, Li Z, Qi J, Wang P, Gao GF. Genomic and structural evidence of SARS-CoV-2 and MERS-CoV in migratory birds. Proc Natl Acad Sci U S A. 2026 Jul 7;123(27):e2400023123. doi: 10.1073/pnas.2400023123. Epub 2026 Jun 29. PMID: 42372155; PMCID: PMC13342853.

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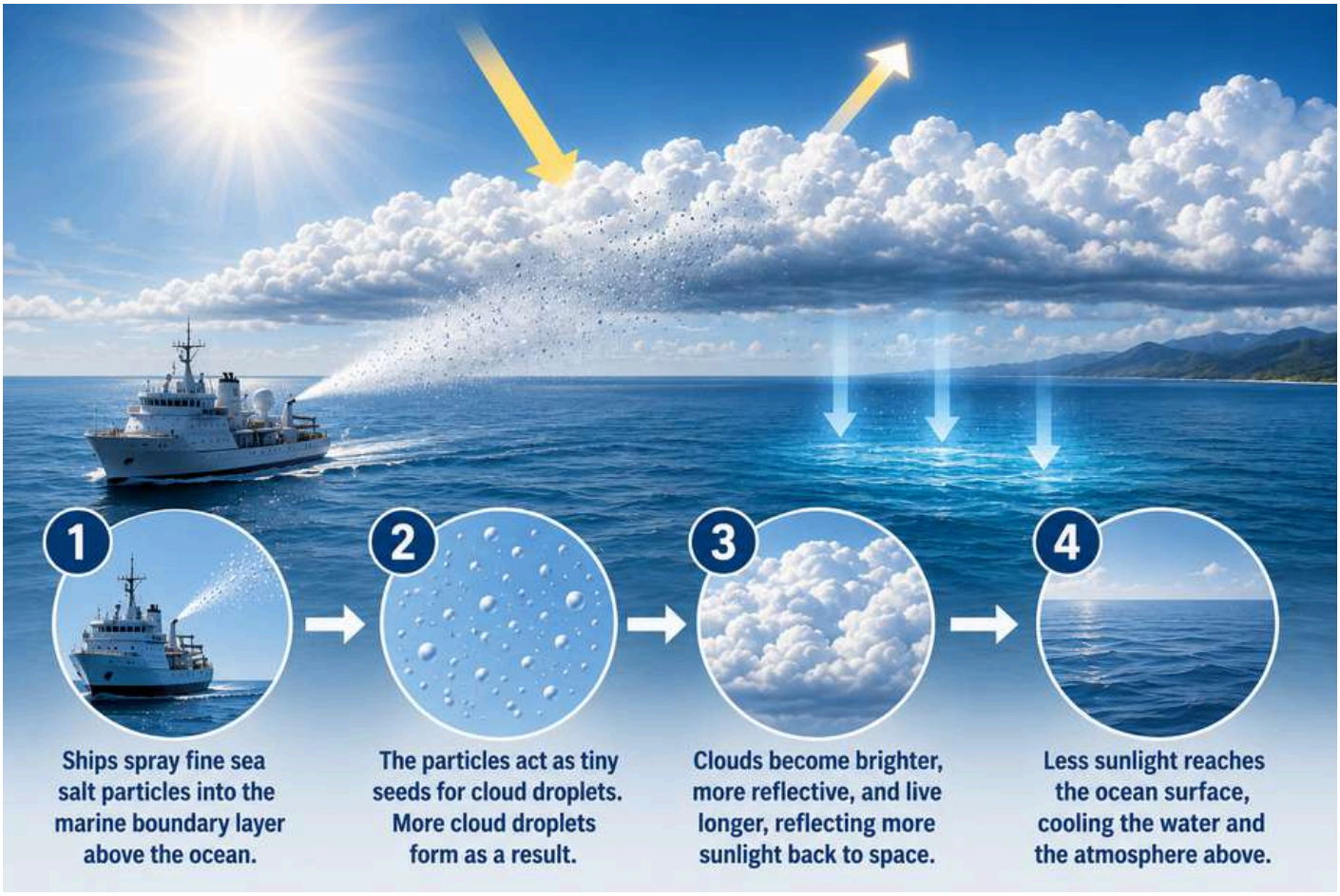
| By Dr. Preeti Sharma

A NEW IDEA TO WEAKEN EL NIÑO

FEATURED

Mei had grown up in the small fishing town of Valparaíso, Chile, where the Pacific Ocean stretched endlessly beyond the cliffs. Every year, she watched the sea carefully because her father's fishing business depended on it. But one year, everything changed. The ocean became unusually warm. Fish disappeared from their usual waters, rainstorms struck places that were normally dry, and distant countries reported droughts, floods, and wildfires. Scientists called this powerful climate event El Niño, but for Mei, it simply meant uncertainty. Curious to understand what was happening, she joined a team of climate researchers at a nearby ocean observatory. There she met Dr. Camila, an atmospheric scientist who explained that El Niño begins when the eastern Pacific Ocean warms and the normal trade winds weaken. As the winds slow down, even more warm water spreads across the ocean, creating a cycle that makes El Niño stronger. The team wondered whether there might someday be a way to gently interrupt this cycle before it became too powerful.

Dr. Camila introduced Mei to an unusual idea called Marine Cloud Brightening. The concept sounded surprisingly simple. Tiny particles of natural sea salt could be sprayed into the air above selected ocean regions. These particles would help marine clouds form many more small droplets. Instead of becoming darker, the clouds would grow brighter and reflect more sunlight back into space. Because less sunlight reached the ocean, the water beneath the clouds would cool slightly. Years earlier, something similar had happened naturally. During the devastating Australian wildfires of 2019–2020, smoke particles drifted across the South Pacific and accidentally brightened clouds over the ocean. Scientists later discovered that these brighter clouds may have contributed to the cooling conditions that developed into a long-lasting La Niña. Inspired by this natural event, Mei's team wondered whether carefully controlled cloud brightening could deliberately weaken a developing El Niño. Since testing



| By Dr. Preeti Sharma

such an idea in the real world would be risky, they turned instead to one of the world's most advanced climate computer models, where every experiment could be performed safely.

Inside the virtual climate model, Mei watched the Pacific Ocean come alive on giant computer screens. The researchers recreated two famous El Niño events, the powerful 1997–1998 event and the 2015–2016 event. Then they tested different cloud-brightening strategies. In one experiment, they started brightening the clouds several months before El Niño reached its strongest stage. In another, they waited until the event was already near its peak. The results amazed everyone. When the cloud brightening began early, the southeast Pacific Ocean cooled enough to interrupt the chain of events that normally strengthens El Niño. The cooling helped preserve the normal trade winds, which in turn reduced the spread of warm water across the Pacific. The famous Bjerknes feedback, the self-reinforcing process that normally amplifies El Niño, became much weaker. During the strongest experiment, the 2015–2016 El Niño almost returned to neutral ocean conditions. However, when cloud brightening started too late, the effect was much smaller because the warming cycle had already become well established. Mei realized that in climate science, timing could be just as important as the strength of the intervention.

As the simulations continued, the team discovered that nature rarely offers simple solutions. Weakening El Niño often caused the following La Niña to appear earlier than expected and sometimes become stronger. Although La Niña benefits some regions, it can also bring severe floods, cold spells, or droughts elsewhere. The computer model also showed unexpected warming in parts of Europe and Asia during some experiments, reminding everyone that Earth's atmosphere is tightly connected across continents. Even though many regions experienced less heat and fewer rainfall extremes during El Niño, not every place benefited equally. Some locations showed little improvement, while a few experienced changes that could potentially become harmful. Mei understood that changing one part of Earth's climate was like gently pulling one thread in a giant web, many other threads moved as well. The climate model was not simply showing success; it was teaching caution. Every result reminded the researchers that understanding the whole Earth system was far more important than finding a quick solution.

Months later, as Mei stood once again on the cliffs overlooking the Pacific Ocean, she reflected on everything she had learned. The study had not discovered a magic way to stop El Niño, nor had it suggested that cloud brightening should be used immediately. Instead, it revealed something even more valuable: by understanding how oceans, clouds, winds, and sunlight work together, scientists might one day develop safer ways to reduce some of the world's most damaging climate extremes. Any future use of Marine Cloud Brightening would require extensive research, international cooperation, careful ethical discussions, and a deep understanding of both its benefits and its risks. Looking across the waves, Mei smiled. The greatest discovery was not that humans could control nature, but that by listening carefully to nature's own lessons, from ocean currents to wildfire smoke and bright clouds, we could better understand the delicate balance that keeps our planet's climate in harmony.

REFERENCE

Jessica S. Wan et al. ,Targeted marine cloud brightening weakens subsequent El Niño.Sci. Adv.12,eadx3012(2026).DOI:10.1126/sciadv.adx3012

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| EXPERT OPINION |

How Does Our Nose Recognize Thousands of Different Smells?

Prof. Pritish Kumar Varadwaj
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Areas of expertise: Systems Biology | Olfaction Science | Machine Learning | Genomics

The smell of freshly brewed coffee may draw us toward the kitchen even before we notice the cup. Smoke can alert us to danger, while a familiar perfume can instantly bring back memories of a place or moment long forgotten. Although such experiences feel automatic, recognizing an odor is actually a complex pattern-recognition process carried out by the nervous system. The process begins when airborne chemicals, known as odorants, enter the nasal cavity during normal breathing or sniffing. These molecules dissolve in the mucus that covers the olfactory epithelium, a specialized sensory tissue located high inside the nose. They then bind to receptor proteins present on the cilia of olfactory sensory neurons. Odorants provide the initial chemical information, but it is the brain that interprets this information and transforms it into the conscious perception of smell.

A code built from combinations

Our understanding of how smell works at the molecular level advanced significantly in 1991, when Linda Buck and Richard Axel discovered a large family of genes responsible for encoding odorant receptors. Humans have about 400 potentially functional odorant-receptor genes, although the exact set of active receptors differs slightly from one person to another. This raises an interesting question: how can only a few hundred receptor types allow us to recognize such a wide range of smells? The answer lies in combinatorial coding. A single odorant can stimulate several different receptors, and each receptor can respond to more than one odorant. As a result, every odor produces a distinct pattern of receptor activity rather than activating a single receptor specifically assigned to smells such as rose, coffee, or smoke.

> *"A few hundred molecular detectors, working through a combinatorial neural code, allow the brain to create our remarkably rich world of smell."*

The olfactory system can be compared to a piano. Although a piano has only a limited number of keys, those keys can be combined to create countless chords and melodies. In much the same way, different combinations of odorant receptors allow the nose to distinguish an enormous variety of smells. The pattern of receptor activation also changes with odor concentration. At low concentrations, an odorant may stimulate only the receptors that are most sensitive to it. As the concentration increases, additional receptors may become involved, altering not only how strong the odor seems but, in some cases, how it is perceived. Natural smells are even more complicated because substances such as coffee, flowers, soil, and food release mixtures containing many volatile compounds. These compoun-

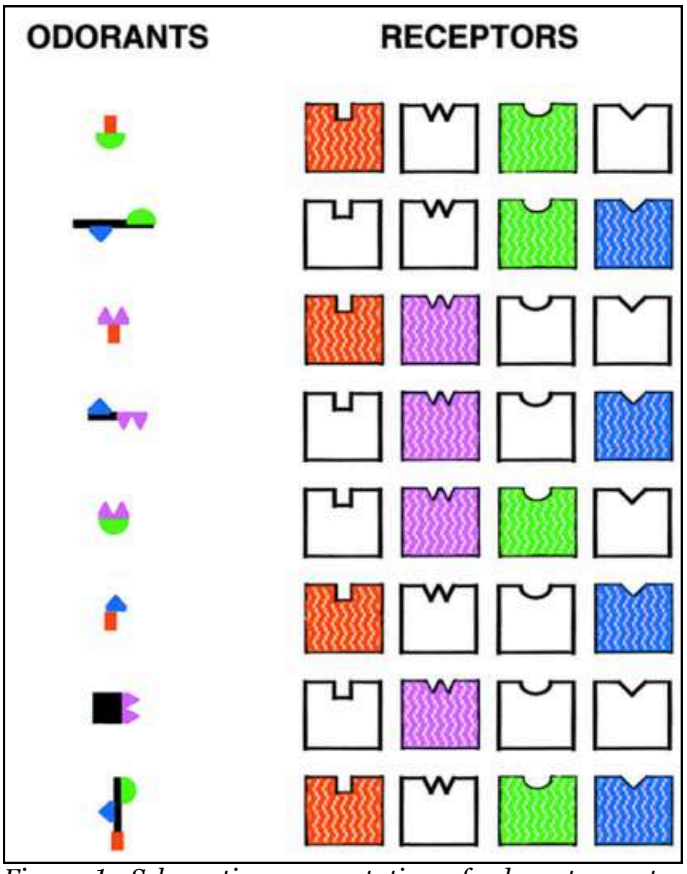

Figure 1: Schematic representation of odorant-receptor interactions illustrating the many-to-many relationship between odorants and Olfactory Receptors.

ds do not always act independently. They may compete for the same receptors, reduce each other's effects, or interact to produce an overall smell that is quite different from the simple combination of its individual components.

Olfactory sensory neurons carrying the same receptor identity are scattered across the nasal epithelium, but their axons converge in the olfactory bulb onto structures called glomeruli. This arrangement pools signals from similar neurons and helps organize the receptor pattern before it is transmitted to the piriform cortex and regions involved in recognition, emotion, learning and memory. The nose therefore detects and organizes chemical information; the brain interprets it. An odorant is a molecule outside the body. An odor is the perception produced when the nervous system combines receptor activity with context and experience.

What can seven smell categories tell us?

Scientists have long searched for primary odors comparable to the primary colors of vision. Smell has resisted such a neat classification because odor molecules differ in size, shape, flexibility, charge distribution, functional groups and volatility. Structurally similar molecules can smell different, while unrelated molecules can receive similar descriptions. A study by Sharma & Varadwaj examined seven widely used categories namely floral, fruity, minty, nutty, pungent, sweet and woody. The researchers assembled a dataset of 1,136 odorants and used computational analysis to investigate pharmacophores the stereo spatial arrangements of molecular features that may influence biological recognition and other structural characteristics. They proposed 19 structural features that could help distinguish the seven groups. The analysis also revealed shared regions of chemical-feature space, helping explain why odor categories overlap rather than forming completely separate boxes. The study does not prove that all smells are constructed from exactly seven primary odors. Instead, the categories provide a practical framework for studying structure odor relationships. Its broader message is that molecular features contain useful statistical signals, although no universal rule can yet translate a chemical structure directly into a predictable human experience. Personal biology further complicates the picture. Genetic variation can change receptor sensitivity. Variants of the receptor OR7D4, for example, influence how people perceive androstenone (mammalian pheromone); some experience it as strong and unpleasant, whereas others detect it weakly or describe it differently. It has been studied and reported that age, gender even personality also shape perception. Perfumers and flavor scientists do not necessarily have more receptor types; training improves attention, sensory memory and vocabulary.

Current challenges and emerging opportunities

Despite considerable progress, scientists still cannot consistently predict how a molecule or a mixture of molecules will smell to a person. Chemical structure is only part of the story, but the odor perception is also shaped by concentration, volatility, nasal airflow, interactions between compounds, and differences in human odor receptors. Natural aromas such as coffee, smoke, flowers, and cooked food may contain dozens or hundreds of volatile chemicals. These compounds can strengthen, suppress, or modify one another's effects, creating a smell that cannot be understood simply by adding together the

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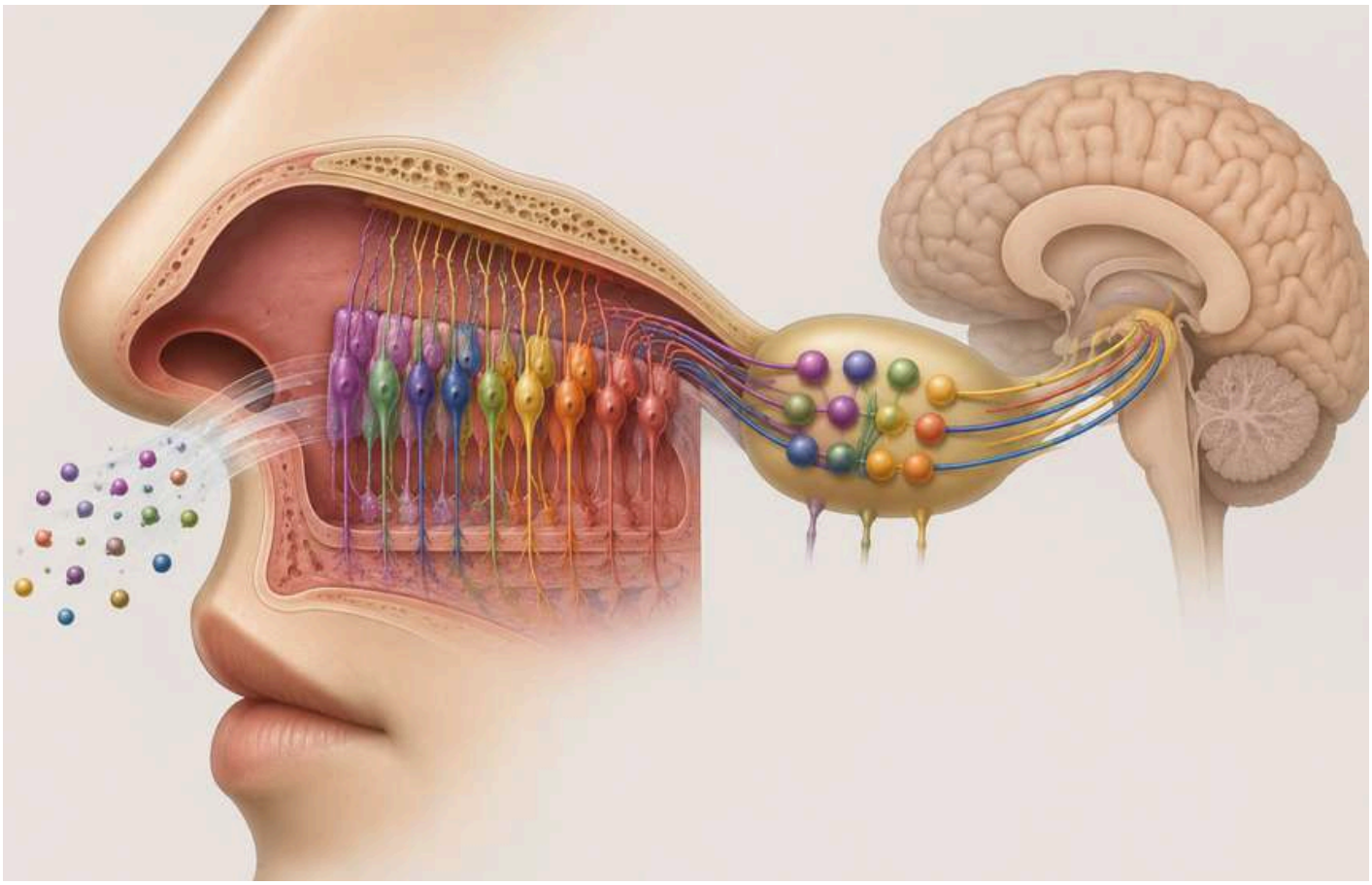

odors of the individual ingredients. The limited quality and diversity of available data create another major challenge. Many olfactory datasets are based on isolated molecules tested under different conditions, concentrations, and naming systems. Descriptions such as “fresh,” “green,” “earthy,” or “musky” may also vary across languages and cultures. Future databases will therefore require standardized testing, chemically verified samples, and sensory panels drawn from more diverse populations.

Resources such as OlfactionBase already provide a useful foundation by linking odorants with receptors, perceptual categories, and known receptor–odorant interactions, but much larger international datasets are still needed [6]. Artificial intelligence may help researchers manage this complexity. Machine-learning models can already predict certain aspects of odor perception from molecular features [7], while graph neural networks have been used to create principal odor maps that connect chemical structure with human sensory descriptions [10]. These tools could support the discovery of new fragrance and flavor compounds, identify unpleasant odors, and reduce the number of molecules requiring laboratory screening.

However, present AI models work best with individual molecules tested under controlled conditions. Their performance is less reliable for complex mixtures, unusual concentrations, and real-world environments affected by humidity, pollution, or changing temperatures. They can estimate how people may describe an odor, but they do not recreate the biological experience of smelling. Electronic and bioelectronic noses offer another promising direction. Sensor arrays could detect food spoilage, hazardous leaks, industrial emissions, poor indoor air quality, or volatile signals linked to plants, microbes, and human health. Their practical use is still limited by changes in temperature and humidity, gradual sensor drift, and poor performance when unfamiliar mixtures are encountered. Systems intended for healthcare, environmental monitoring, or food safety will therefore need standardized evaluation and validation under varied real-world conditions. The wider potential is considerable. Improved smell technologies could reduce food waste, strengthen agricultural storage, detect environmental hazards, and support non-invasive health monitoring. Achieving this will require close integration of chemistry, receptor biology, engineering, artificial intelligence, and culturally diverse sensory resear-

ch rather than treating smell as a purely computational problem.

Future perspective

Future progress will probably combine molecular chemistry, receptor biology, airflow modelling, sensory testing and artificial intelligence. Better datasets could record not only a molecule and its odor label, but also concentration, mixture composition, receptor responses, participant genetics and cultural background. Bioelectronic noses may eventually use biological odorant receptors, receptor-bearing cells or receptor-inspired materials. Such systems could support food-quality monitoring, environmental surveillance, industrial leak detection and analysis of volatile patterns associated with disease. Medical applications require rigorous validation because altered smell or breath chemistry can have many causes. Machines may become excellent chemical detectors, but reproducing human smell will remain difficult. Biological olfaction actively controls sampling through sniffing, adapts to continuing exposure and combines incoming signals with memory, emotion and expectation. Detecting molecules is not the same as experiencing their meaning.

Conclusion

Our nose recognizes many smells without requiring one receptor for every odor. Volatile molecules activate overlapping receptor combinations; the olfactory bulb organizes these patterns; and the brain interprets them using genetics, learning, memory and context. Research on seven odor categories, olfactory databases, AI-generated odor maps and electronic noses is beginning to reveal the logic of this sensory code. It may also lead to better tools for healthcare, food safety and environmental monitoring. The next time coffee, rain or perfume brings back a vivid memory, remember the nose begins the chemical message, but the brain completes the story.

Prof. Pritish Kumar Varadwaj's contributions to this field are highlighted in the publication, in Protein Science (2026) https://doi.org/10.1002/pro.70605. This study explores how human olfactory receptors are organized at the molecular level, revealing the conserved structural patterns that enable our nose to recognize thousands of different smells. The findings provide valuable insights into the architecture and function of olfactory receptors and may support future advances in sensory biology, drug discovery, and computational protein science.

| EXPERT OPINION |

When Sugar Fuels Tuberculosis: Uncovering the Hidden Role of Iron in Diabetic Immunity

Dr. Manoj Raje
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| Scientific Profile | | Organization Link | | Research Lab Page | | Factors Press |

Areas of Expertise: Infectious Biology (TB) | Cell biology | Immunology

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Areas of Expertise: Infectious Biology (TB & Influenza) | Cell death

Diabetes mellitus (DM) is a group of metabolic disorders characterized by occurrence of elevated blood sugar levels for an extended period. Two types are commonly described, namely, type 1 and Type 2 diabetes. Type 1 Diabetes is a chronic autoimmune disease in which the immune system destroys insulin-producing β-cells (beta cells) in the pancreatic islets. Loss of β-cells causes little or no insulin production, leading to elevated blood glucose (hyperglycemia) and lifelong dependence on insulin therapy. In type 2 diabetes, the patient displays insulin resistance. Due to this sugar accumulates in the blood. Tuberculosis (TB) and diabetes are among the most pressing global health challenges of our time. Individually, each disease affects millions of people every year, but together they create a far more dangerous combination. People living with diabetes are three to four times more likely to develop active tuberculosis and often experience poorer treatment outcomes. While this association has been recognized for decades, one fundamental question has remained unanswered: Why does diabetes make people more vulnerable to tuberculosis?

A Long-Standing Scientific Question

This question has driven much of our research. As scientists, we often begin with observations before understanding the underlying mechanisms. Clinicians had long reported that diabetic patients were more susceptible to Mycobacterium tuberculosis, yet the biological explanation remained incomplete. Was elevated blood glucose simply weakening the immune system, or was it fundamentally changing how immune cells function? Finding the answer became the focus of our work.

The Body's First Line of Defense

Macrophages are the body's first responders against M. tuberculosis. These specialized immune cells engulf bacteria and employ multiple defense mechanisms, including the production of inflammatory cytokines, reactive oxygen and nitrogen species, and the restriction of nutrients essential for bacterial growth. Among other nutrients, iron occupies a unique position. While iron is indispensable for normal cellular function, it is equally essential for bacterial survival. As a result, the host carefully controls intracellular iron availability through a process known as nutritional immunity, limiting the

| EXPERT OPINION |

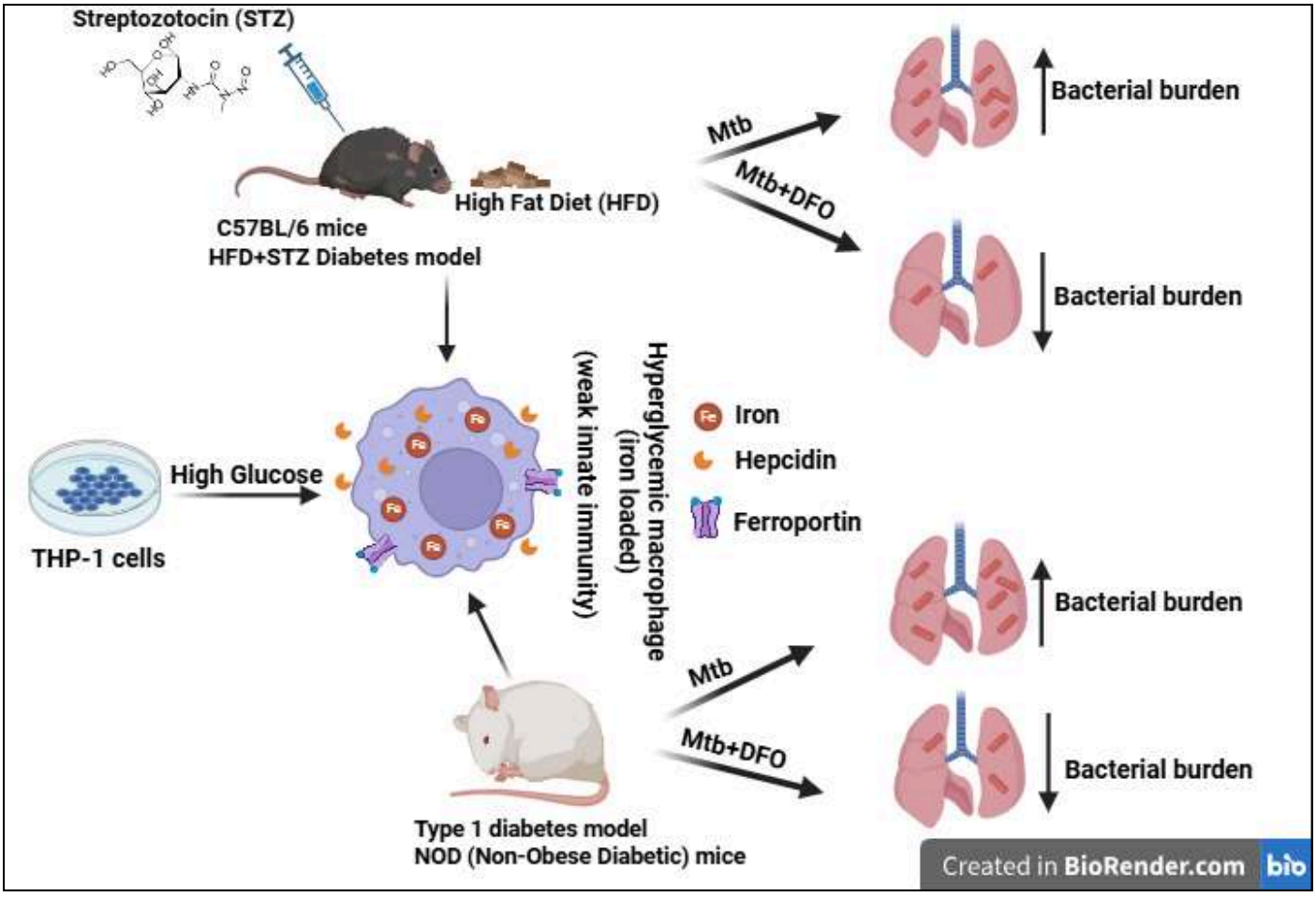

Figure 1: Impact of chronic hyperglycemia on macrophage iron metabolism and innate immune response during Mycobacterium tuberculosis infection.

pathogen's access to this valuable resource. In healthy macrophages, iron homeostasis is maintained through coordinated regulation of iron uptake, storage, recycling, and export. During infection, these pathways are dynamically adjusted to limit bacterial access to iron while preserving cellular function. Elevated glucose levels impair phagocytosis, reduce intracellular bacterial killing, alter cytokine production, delay immune activation, and interfere with cellular metabolism. Together, these changes create a permissive intracellular environment where Mtb can survive and replicate more efficiently. Rather than simply reducing immunity, chronic hyperglycemia rewires immune cell metabolism, disrupts inflammatory signaling, and changes the availability of essential nutrients that both host cells and pathogens compete for. These discoveries are reshaping our understanding of tuberculosis in diabetic patients and opening new opportunities for host-directed therapies.

Following the Evidence

Our scientific journey began by examining how chronic hyperglycemia influences macrophage function. In our earlier work, published in Immunologic Research, we demonstrated that prolonged exposure to high glucose significantly compromises the antimicrobial capacity of macrophages. Hyperglycemic macrophages produced lower levels of reactive oxygen and nitrogen species, displayed reduced inflammatory responses, and were less effective at controlling intracellular M. tuberculosis. These findings confirmed that chronic hyperglycemia directly impairs innate immunity rather than merely accompanying diabetes. Although these results explained what was happening, they raised an even more important question: What causes this immune dysfunction?

Looking Beyond Immunity: The Role of Metabolism

The answer emerged when we shifted our attention from immune signaling to cellular metabolism.

Over the last decade, immunometabolism has transformed our understanding of infectious diseases by demonstrating

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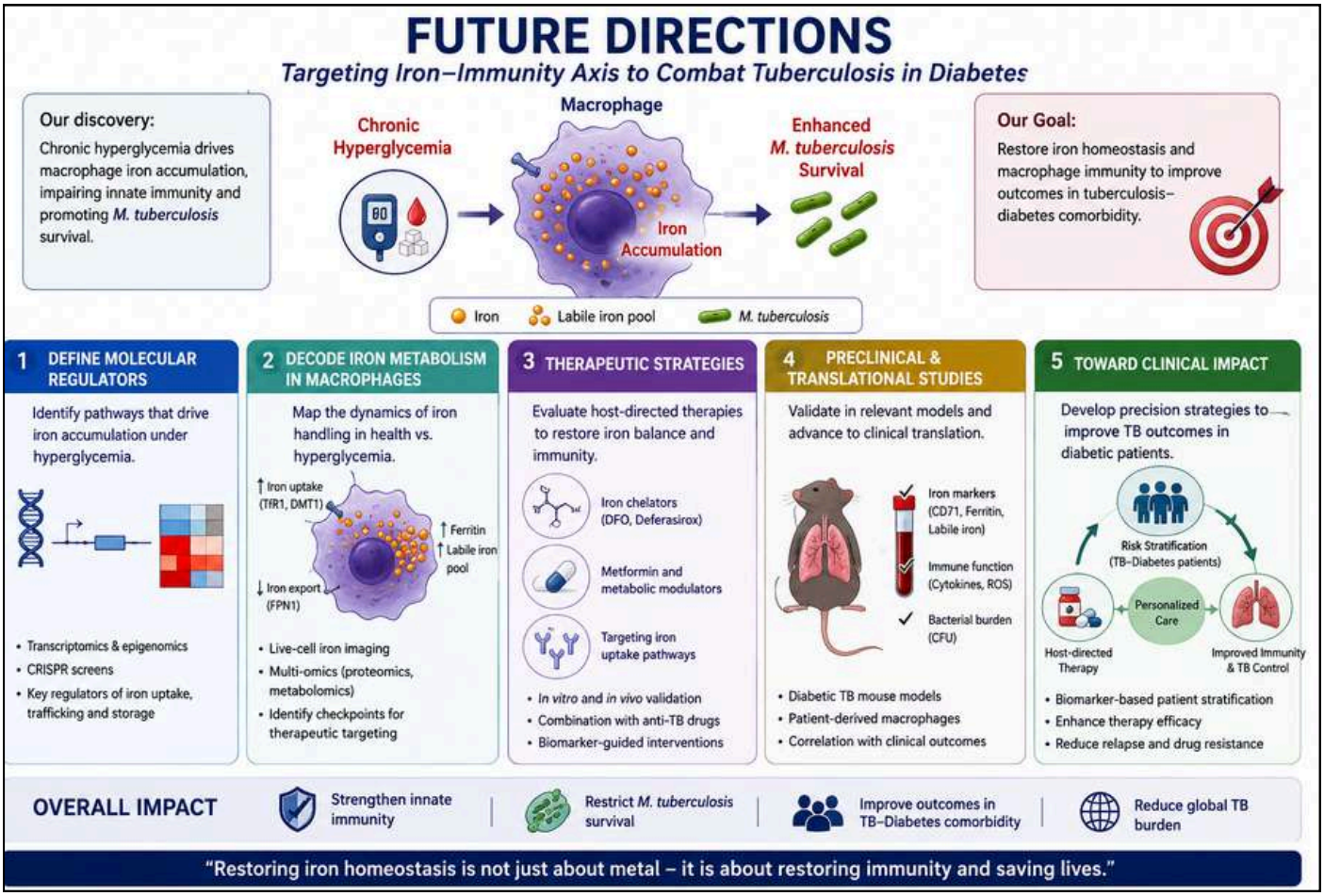

Figure 2: Future directions for targeting macrophage iron dysregulation to improve tuberculosis outcomes during diabetes.

that immune cell function is closely linked to metabolic pathways. Rather than serving only as a source of energy, metabolism actively regulates how immune cells respond to pathogens. We therefore asked whether chronic hyperglycemia was altering metabolic pathways that influence macrophage antimicrobial function.

Iron: The Missing Piece

One pathway immediately captured our attention: iron metabolism. In our recent study published in Iscience CellPress, we discovered that chronic hyperglycemia profoundly disrupts intracellular iron homeostasis. Instead of maintaining tight control over iron availability, macrophages exposed to prolonged high glucose accumulated excessive intracellular iron. We found that hyperglycemia enhanced iron uptake while promoting iron retention, leading to expansion of the labile iron pool-the readily available form of iron that intracellular pathogens can exploit. Rather than restricting bacterial access to iron, hyperglycemic macrophages unintentionally created an iron-rich intracellular environment that favored M. tuberculosis survival. The consequences extended well beyond nutrient availability. Iron accumulation altered macrophage biology itself. Excess iron promoted oxidative stress, disrupted antimicrobial defense mechanisms, and weakened the ability of macrophages to eliminate intracellular bacteria. In other words, chronic hyperglycemia reprogrammed immune cells into an environment that was increasingly permissive for bacterial persistence.

Can We Restore the Immune System?

Perhaps the most encouraging aspect of our study was its therapeutic implication. By pharmacologically reducing intracellular iron levels, we restored macrophage antimicrobial function and significantly lowered bacterial burden in diabetic mouse models of tuberculosis. These findings provide proof-of-concept that targeting host iron metabolism could complement conventional anti-tuberculosis therapy. Rather than attacking the pathogen directly, host-directed therapies strengthen the immune system itself, potentially improving treatment outcomes

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while reducing the likelihood of antimicrobial resistance. Our other study reveals that Anti-diabetic drug metformin provides benefits beyond glucose control by reprogramming macrophage iron metabolism during tuberculosis infection. Metformin limits intracellular iron availability and enhances mitochondrial ROS production, creating an unfavorable environment for Mycobacterium tuberculosis survival. These findings highlight iron modulation as a promising host-directed therapeutic approach against tuberculosis, especially in diabetes-associated TB. The significance of these discoveries extends beyond tuberculosis. Iron dysregulation is increasingly recognized by a wide range of infectious and inflammatory diseases. Our findings suggest that metabolic disorders fundamentally reshape immune cell function by altering nutrient homeostasis, opening new opportunities to investigate how metabolism influences susceptibility to diverse pathogens.

Looking Ahead

Our work has uncovered iron metabolism as a crucial link between diabetes and tuberculosis, but many questions remain. Moving forward, we aim to identify the molecular regulators that drive iron accumulation in macrophages and explore therapies that restore immune function by targeting host metabolism. We hope these discoveries will pave the way for more effective, personalized treatments for tuberculosis and other infectious diseases influenced by metabolic disorders. Another major challenge is understanding the remarkable diversity of macrophages found throughout the body. Alveolar macrophages, recruit monocyte-derived macrophages, and tissue-specific macrophage populations differ substantially in their metabolism and immune functions. Whether hyperglycemia affects each population similarly remains unknown. Recent advances in single-cell RNA sequencing, spatial transcriptomics, proteomics, and metabolomics now provide powerful tools to dissect these cell-specific responses at unprecedented resolution. These technologies will help identify distinct macrophage states associated with protection or disease progression in diabetic conditions.

Acknowledgements: Dr. Raje acknowledges financial support of Indian Council of Medical Research (ICMR) by way of Emeritus fellowship. Audience-engaging graphical illustration was created with BioRender and assistance from ChatGPT (OpenAI) and further refined based on the authors' scientific concepts and expertise.

Dr. Manoj Raje and Dr. Gaurav Kumar Chaubey's research explores how changes in metabolism affect the body's immune response to tuberculosis. Their studies show that high blood sugar and disturbed iron balance weaken immune cells, making it easier for Mycobacterium tuberculosis to survive. They also demonstrate that improving iron balance and reprogramming immune cell metabolism with drugs such as metformin can help restore the body's natural defenses. Their recent findings have been published in iScience (Cell Press) (DOI: 10.1016/j.isci.2026.116156), Immunologic Research (https://doi.org/10.1007/s12026-024-09462-z), and Biomedicine & Pharmacotherapy (https://doi.org/10.1016/j.biopha.2025.118314).

> *Diabetes silently weakens immune defenses, creating a favorable environment where Mycobacterium tuberculosis can survive, replicate, and drive severe disease outcomes*

| EXPERT OPINION |

Beyond Muscle Strength: How Skeletal Muscle Shapes Health and Disease

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Areas of Expertise: Skeletal Muscle biology | Molecular Metabolism | Disease biology | Tissue Homeostasis | Stem cells and regeneration | Cancer

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Skeletal muscle is one of the largest organs in the human body and plays a critical role not only in movement and posture but also in maintaining metabolic health. It is the primary site of insulin-stimulated glucose disposal, accounting for more than 75% of insulin-mediated glucose uptake. Consequently, skeletal muscle is a major regulator of whole-body glucose homeostasis and is among the first tissues to develop insulin resistance. These functions underscore its central importance in maintaining metabolic balance and overall health.

The functional units of skeletal muscle are multinucleated cells known as muscle fibers or myofibers. Skeletal muscles contain different types of myofibers, each specialized for distinct physiological functions. Broadly, they are classified into slow-twitch (Type I) and fast-twitch (Type II) fibers.

Slow-twitch fibers contract relatively slowly but are highly resistant to fatigue. Rich in mitochondria, they generate energy primarily through oxidative phosphorylation, making them ideally suited for endurance activities such as walking, cycling, and long-distance running (Figure 1). In contrast, fast-twitch fibers contract rapidly and generate greater force but fatigue more quickly. They rely predominantly on glycolysis to meet their energy demands and are essential for explosive activities such as sprinting, jumping, and lifting heavy loads (Figure 1). Fast-twitch fibers are further classified into subtypes that differ in their contractile and metabolic properties.

Muscle fiber identity is determined by the specific myosin heavy chain (MyHC) proteins they express. Slow fibers express MyHC-slow, whereas fast fibers express MyHC-IIa, MyHC-IIx, or MyHC-IIb (Figure 1). The relative abundance of these fiber types varies among individuals and is influenced by genetics, age, physical activity, and training. Importantly, skeletal muscle remains highly adaptable throughout life, with regular exercise modifying both the metabolic and functional characteristics of individual fiber types.

Among all muscle fiber types, slow myofibers exhibit the greatest capacity for glucose uptake because they express higher levels of the glucose transporter GLUT4 (Figure 1). Recent studies have shown that exercises specifically targeting slow muscles, such as the soleus push-up, can significantly improve whole-body glucose regulation. These observations highlight the untapped therapeutic potential of skeletal muscle and particularly slow-twitch fibers in

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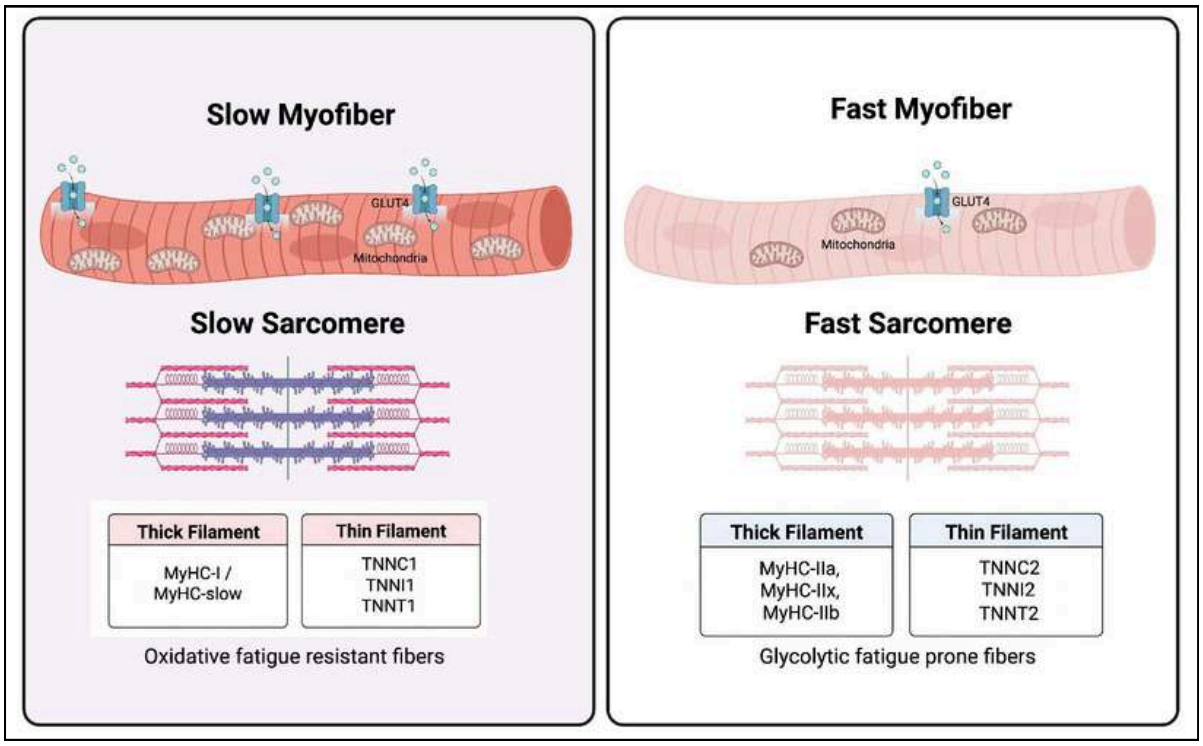

Figure1: Comparison of slow-twitch (oxidative, fatigue-resistant) and fast-twitch (glycolytic, fatigue-prone) myofiber structural characteristics and MyHC protein isoforms.

preventing and treating metabolic diseases.

Why Your Muscles Matter for Managing Blood Sugar?

Diabetes has emerged as one of the fastest-growing global health challenges, with India bearing one of the world's largest disease burdens. Physical inactivity and prolonged sedentary behaviour are major contributors to insulin resistance and type 2 diabetes. Yet the role of skeletal muscle in regulating metabolism often receives far less attention than organs such as the pancreas or liver.

Extended periods of inactivity impair the metabolic function of skeletal muscle by reducing glucose uptake, disrupting insulin signalling, and compromising mitochondrial function. Because skeletal muscle is responsible for clearing most of the glucose from the bloodstream after a meal, even modest declines in muscle health can substantially affect blood glucose regulation. These observations emphasize that maintaining healthy skeletal muscle is fundamental to preventing metabolic disease.

Discovering a New Link Between Muscle Health and Diabetes

A recent study from our laboratory has uncovered a previously unknown molecular mechanism linking skeletal muscle health to whole-body metabolism. The work, recently published in Science Advances, demonstrates how the loss of a single muscle-specific contractile protein can directly trigger insulin resistance and metabolic dysfunction.

Our study identifies a previously unrecognized role for MyHC-slow, the contractile protein encoded by the Myh7 gene, in maintaining systemic metabolic health. Beyond its well-established function in muscle contraction, MyHC-slow appears to regulate mitochondrial function, antioxidant defence, and glucose metabolism through the NRF2 signalling pathway, revealing an entirely new connection between muscle structure and metabolic regulation.

Individuals with type 2 diabetes often exhibit a reduction in slow muscle fibers and decreased expression of MyHC-slow. To determine whether this loss contributes directly to disease development, we generated genetically engineered mice lacking MyHC-slow specifically in skeletal muscle. This model enabled us to investigate the biological consequences of losing this single contractile protein.

What Happens When MyHC-slow Is Lost?

Eliminating MyHC-slow from skeletal muscle initiated a cascade of pathological changes that closely resembled the early features of type 2 diabetes.

Skeletal muscle atrophy: Loss of MyHC-slow resulted in

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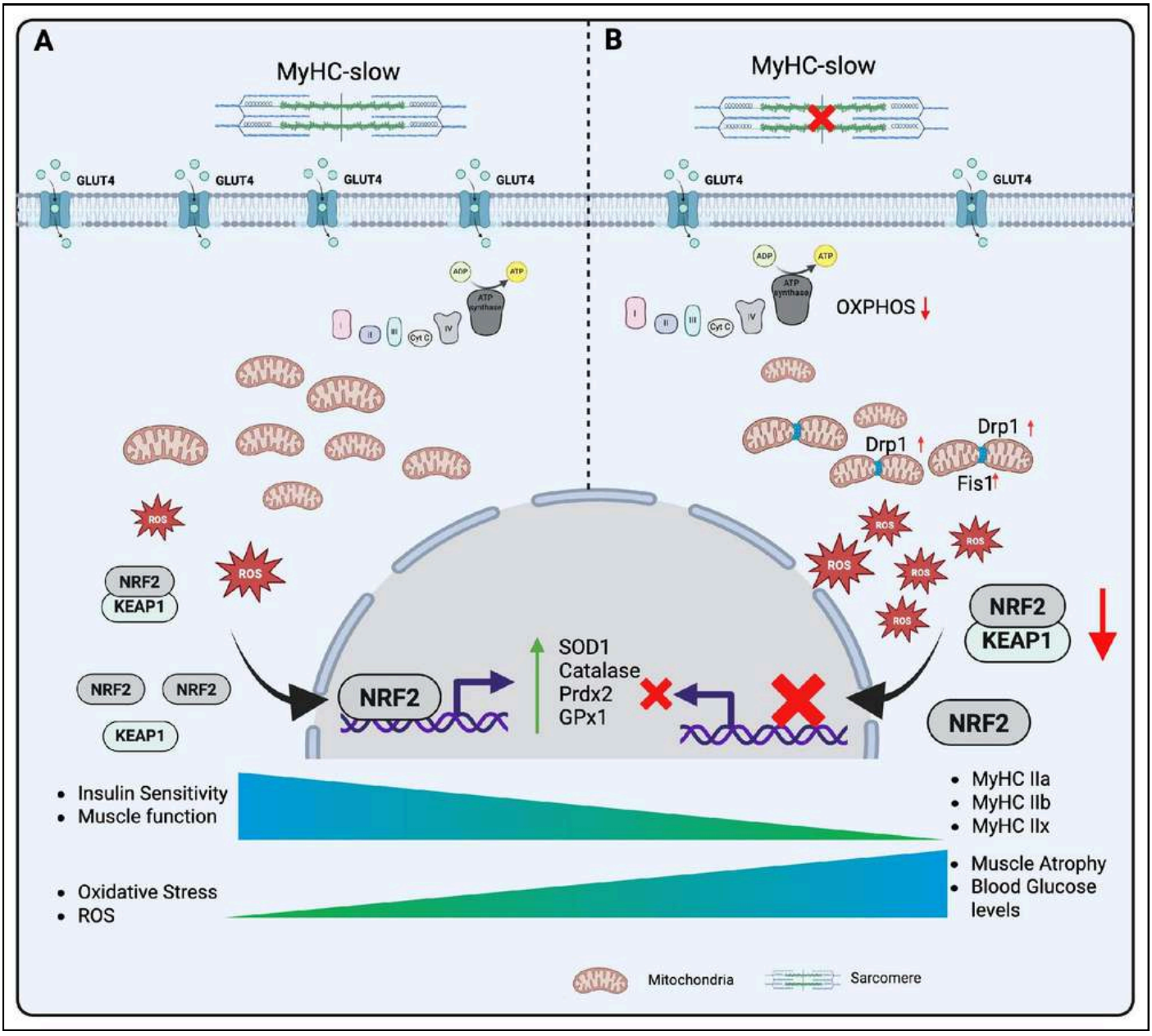

Figure 2: Model. (A) Presence of MyHC-slow results in normal oxidative phosphorylation levels and mitochondrial dynamics which maintains normal blood glucose levels, increased insulin sensitivity, GLUT4 levels, NRF2 signaling and MyHCs. (B) Absence of MyHC-slow results in reduced oxidative phosphorylation levels and increased mitochondrial fission, leading to increased ROS generation, muscle atrophy and a significant reduction in NRF2, GLUT4 and MyHCs, causing reduced insulin sensitivity.

selective degeneration of slow-twitch fibers, muscle atrophy, reduced muscle mass, diminished force production, and impaired muscle function.

Mitochondrial dysfunction and oxidative stress: The absence of MyHC-slow severely disrupted mitochondrial structure and function, leading to excessive production of reactive oxygen species (ROS). The resulting oxidative stress compromised cellular energy production and impaired muscle metabolism (Figure 2).

Reduced glucose uptake and insulin resistance: Diseased muscle showed a marked reduction in GLUT4 expression, limiting insulin-stimulated glucose uptake. This defect ultimately led to systemic insulin resistance and impaired blood glucose control (Figure 2). Suppression of the NRF2 antioxidant pathway: One of the most striking findings was the profound reduction in activity of the NRF2 signalling

pathway, the master regulator of cellular antioxidant defence. Reduced NRF2 activity weakened the muscle's ability to neutralize ROS, further amplifying oxidative damage, mitochondrial dysfunction, and metabolic failure (Figure 2).

Therapeutic Targeting: Restoring the NRF2 Antioxidant Pathway

Having identified suppression of NRF2 as a key event, we investigated whether restoring this pathway could rescue muscle function. We treated the MyHC-slow-deficient mice with sulforaphane, a naturally occurring compound abundant in cruciferous vegetables such as broccoli that is known to activate NRF2.

The results were highly encouraging. Activation of NRF2 reduced oxidative stress, restored mitochondrial function, improved muscle health, and significantly rescued the metabolic defects caused by the loss of MyHC-slow. These findings identify the NRF2 pathway as a promising therapeutic target for metabolic disorders characterized by skeletal muscle dysfunction.

The Bigger Picture

For many years, muscle contraction and metabolism were viewed as largely independent biological processes. Our study challenges this traditional view by demonstrating that the proteins responsible for muscle contraction also play fundamental roles in regulating cellular metabolism and whole-body glucose homeostasis.

These findings reveal that skeletal muscle is not merely a tissue for movement but also a critical regulator of metabolic health. By uncovering a molecular link between muscle structure, mitochondrial function, antioxidant defence, and insulin sensitivity, our work opens new opportunities for developing therapies for diabetes, metabolic syndrome, and muscle-wasting disorders.

Looking Ahead

Our findings raise several important questions that will guide future research.

First, it will be essential to determine whether similar mechanisms operate in humans. Analysing skeletal muscle biopsies from individuals with type 2 diabetes, metabolic syndrome, and age-related muscle loss (sarcopenia) will help establish the clinical relevance of MyHC-slow and NRF2 in metabolic disease.

Second, although sulforaphane showed considerable promise in our preclinical studies, further work is needed to evaluate its long-term safety, pharmacological properties, and clinical efficacy. The development of next-generation NRF2 activators with greater muscle specificity could provide even more effective therapeutic options.

Finally, an important unanswered question is how the loss of a structural muscle protein leads to suppression of NRF2 signalling. Understanding the molecular communication between the sarcomere, mitochondria, and the nucleus including mechanotransduction pathways and epigenetic regulation will provide deeper insight into how skeletal muscle controls whole-body metabolism.

Together, these studies have the potential to reshape our understanding of skeletal muscle biology and establish new strategies for preventing and treating diabetes and other metabolic diseases.

Authors have focused on muscle biology, metabolism, and disease mechanisms. This background directly shaped the current study, where the team uncovered a previously unrecognized role for the contractile protein MyHC-slow in regulating whole-body metabolism, linking its loss to insulin resistance and identifying NRF2 activation as a potential therapeutic strategy for diabetes.

> *Skeletal muscle is not merely a tissue for movement—it is one of the body's most important regulators of blood sugar and metabolic health*

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Moving Beyond Myths: What Science Really Says About Pornography and Mental Health

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Areas of Expertise: Suicide Prevention and Mental Health | Motivation and Attachment Theories | Higher Education Research

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Pornography remains one of the most controversial topics in discussions of mental health. Whenever we discuss pornography, we are more likely to hear two contrasting narratives about it. One suggests pornography as a genuine threat that can lead to depression, compulsive use, wrecked relationships and in extreme cases, suicidal ideation. The other dismisses concerns altogether, presenting pornography as a harmless expression of sexuality, another form of entertainment in the modern digital era. But neither of these perspectives turns out to be purely true. However, a growing body of scientific evidence indicates a more nuanced picture, where the psychological context plays a more central role than the exposure to understand the mental health outcomes.

The rapid expansion of internet access has made pornography more accessible especially to young adults. The rapid change led various professionals such as researchers, therapists, educators, and lawmakers, to figure out the relationship with mental health. But even after decades of research, the findings remain ambiguous and inconsistent. Some studies show links to psychological distress, whereas other studies report weak or no independent association between these two once broader psychological factors are taken into account. Rather than suggesting one group of researchers is correct, while another is wrong, these inconsistencies may signal a fundamental issue: perhaps we have been asking a very simple question for a complex behavior. Instead of debating whether pornography is universally harmful or harmless, researchers increasingly pose a more refined question: under which conditions, for which individuals, and through what mechanisms does pornography use come to be associated with mental health outcomes?

Looking Beyond Exposure

Earlier pornography research was primarily focused on a central question: how much people use it. Frequency and duration have traditionally been used as indicators of the psychological risk but only these are not sufficient to explain the nature of human behavior. Two people may engage in the same behavior for entirely different reasons such as one driven by curiosity, another by loneliness, another is out of habit. This is where contemporary psychological research shows different perspective. People use digital media for varied reasons such as curiosity,

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sexual exploration, pleasure, entertainment or escape from distress, anxiety and loneliness. These motivations reflect deeper psychological needs. This growing recognition shifted research beyond measuring exposure to understand the motivations behind it.

This evolving perspective provided the conceptual foundation for our recent study which examined pornography use, motivational patterns, depression and suicidal ideation among 541 young adults. As we reviewed literature, we noticed that most studies were focused on the quantity of pornography use. Instead of presuming watching more pornography will lead to poorer mental health, we framed our question from a different angle. We asked whether people's motivations for watching pornography might give a better understanding of psychological well-being.

Understanding the "Why" behind Pornography Use

Our findings suggested that depressive symptoms remained the strongest predictor of suicidal ideation across all analyses. This is consistent with long-standing clinical research in suicide where emotional distress plays a central role in suicidal thinking. It aligns with the contemporary theory of Integrated Motivational Volitional Model (IMV) of suicide, that conceptualizes psychological distress as a proximal factor of suicidal ideation. We also found that pornography exposure has a limited independent association with suicidal ideation once depression was controlled. In other words, emotional health provides more information about mental health than pornography exposure itself. What surprised us most was not what pornography exposure explained but what it did not explain.

Perhaps the story became more interesting when we shifted our focus from "how much?" to "why?". People engage with pornography for various reasons such as curiosity, sexual exploration, pleasure, excitement or escaping from difficult emotions. Although this behavior may appear similar on the surface, these experiences stem from different psychological needs. The psychological mo-

tivations underlying these processes are fundamentally different and should not be treated as functionally equivalent. Our findings also revealed that using pornography as a way of coping or avoiding emotional distress has an association with suicidal ideation, where pleasure-driven motivations showed a different pattern. It suggests that rather than treating pornography as inherently "good" or "bad", the importance of understanding the psychological context provides a better insight. When it is used as coping or managing emotions, it might reflect underlying psychological vulnerabilities which need attention. Conversely, treating all pornography use as equally risky might overlook the individual differences that are relevant to understand mental health.

Our findings have broader implications for research and clinical practice. Public debates about pornography tend to polarize in two extremes where one portrays it as inherently harmful and the other dismisses the concerns altogether. However, our findings suggested a more nuanced picture of this. No single behavior determines the psychological consequences on its own, factors like individual vulnerability, emotional experiences, relationships, and personal history play a role. These factors shape how people engage with pornography and what does it imply to their psychological well-being. For some, it might reflect curiosity or exploration, for others it may become a way of coping or managing difficult emotions. Understanding this complexity moves far beyond the academic research. Framing pornography as universally harmful will increase the risk of stigmatization and discourage open conversation about sex and mental health. Conversely, dismissing concerns altogether might overlook individuals with compulsive or problematic pornography use (PPU). A balanced scientific perspective acknowledges both realities by encouraging us to understand the psychological context in which the behavior occurs. For clinicians, this perspective should go beyond the simple assessment of asking someone "do you watch pornography?" or "how much time they spend on watching pornography"? to how the individual is coping with stress, how they are feeling emotionally, quality of their relationships and whether they are struggling with deeper emotional difficulties.

> *"Psychological vulnerability and emotional health often provide greater insight into mental health outcomes than pornography exposure alone."*

Looking Ahead

Despite decades of research on pornography and mental health, some important questions remain unanswered. One of the greatest challenges lies in the term "pornography use", which is used as single and uniform behavior even though it is shaped by different factors such as their motivations, cultural background, relationship context, personal values and individual vulnerabilities. Treating these as a single phenomenon might overlook the differences relevant for understanding mental health. Much of the existing evidence comes from cross-sectional studies relying on self-reported behavior making it difficult to understand the temporal relationships between pornography use and psychological well-being. Longitudinal research will be particularly helpful in clarifying these relationships and understanding how motivations, emotional health, and media use evolve across different stages of life. Cross-cultural research is equally important to understand how cultural attitudes toward sexuality influence pornography use and its psychological consequences, as attitudes are shaped by different cultural, social and moral norms. These challenges highlight an important shift in the direction of future research related to porn studies and mental health.

Looking ahead, future research should move towards person-centered approaches that seek to understand not only whether a behavior is associated with psychological risk but also for whom, under which circum-

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stances and why. Scientific progress often begins when researchers ask different questions. Rather than simply portraying pornography as harmful or harmless or viewing it from the lens of technology or morality, researchers should shift their focus to better understand the motivations, emotional contexts, and psychological needs underlying pornography use. Perhaps the most important question is no longer whether pornography is simply harmful or harmless, but why people use it, under what circumstances, and how those experiences relate to their emotional well-being. Asking better questions may ultimately lead to a more balanced and evidence-informed understanding of both human behavior and mental health.

Chandreyee Roy and Dr. Ahmed Sameer contribute to suicide prevention research by examining how digital media, psychological vulnerability, and behavioral factors interact to influence mental health. This article extends their recent work by highlighting the importance of understanding motivations and psychological context, rather than exposure alone, in explaining the relationship between pornography use and mental health.

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CAN WE TEACH CROPS TO OUTSMART HERBICIDES, THE WEED KILLERS?

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Areas of Expertise: Plant RNA Biology | Alternative Splicing | CRISPR-Based Gene Regulation | Stress Genomics and Epigenetics.

Plants cannot walk away from danger. When exposed to drought, pathogens, extreme temperatures or agricultural chemicals, they must rapidly adjust their internal biology to survive. This remarkable flexibility is controlled not only by the genes plants possess, but also by how those genes are switched on and off. This distinction is becoming increasingly important in weed management. Herbicides remain among the most effective tools for protecting crops from weeds, which compete for water, nutrients, light and space. However, repeated use of the same herbicides has driven the evolution of resistant weed populations. Treatments that once worked reliably are becoming less effective, creating a growing challenge for farmers and agricultural researchers worldwide.

For many years, herbicide resistance was viewed mainly as a genetic problem. A mutation might alter the protein targeted by a herbicide, preventing the chemical from binding effectively. Alternatively, a plant might produce more of the target protein or break down the herbicide before it reaches a harmful concentration. These mechanisms remain central to our understanding of resistance, but they do not explain every case. A more dynamic regulatory layer may also be involved: the epigenome.

Beyond the DNA Sequence

The epigenome can be thought of as a collection of molecular instructions that control how the information contained in DNA is used. Unlike a mutation, an epigenetic change does not alter the letters of the genetic code. Instead, it can influence whether a gene is active, silent or ready to respond to a particular signal. One of the most important epigenetic modifications in plants is DNA methylation, in which small chemical groups are added to specific regions of DNA. Depending on where it occurs, methylation can control gene activity, influence nearby regulatory elements or help maintain genome stability. This matters because herbicide responses are probably controlled by the action of several genes, whose regulation could influence whether a plant is damaged by a herbicide or able to tolerate it. Scientists are therefore beginning to ask whether herbicide tolerance can arise not only through DNA mutations, but also through changes in the way existing genes are regulated.

Small RNAs as Molecular Guides

A particularly fascinating plant pathway is RNA-directed

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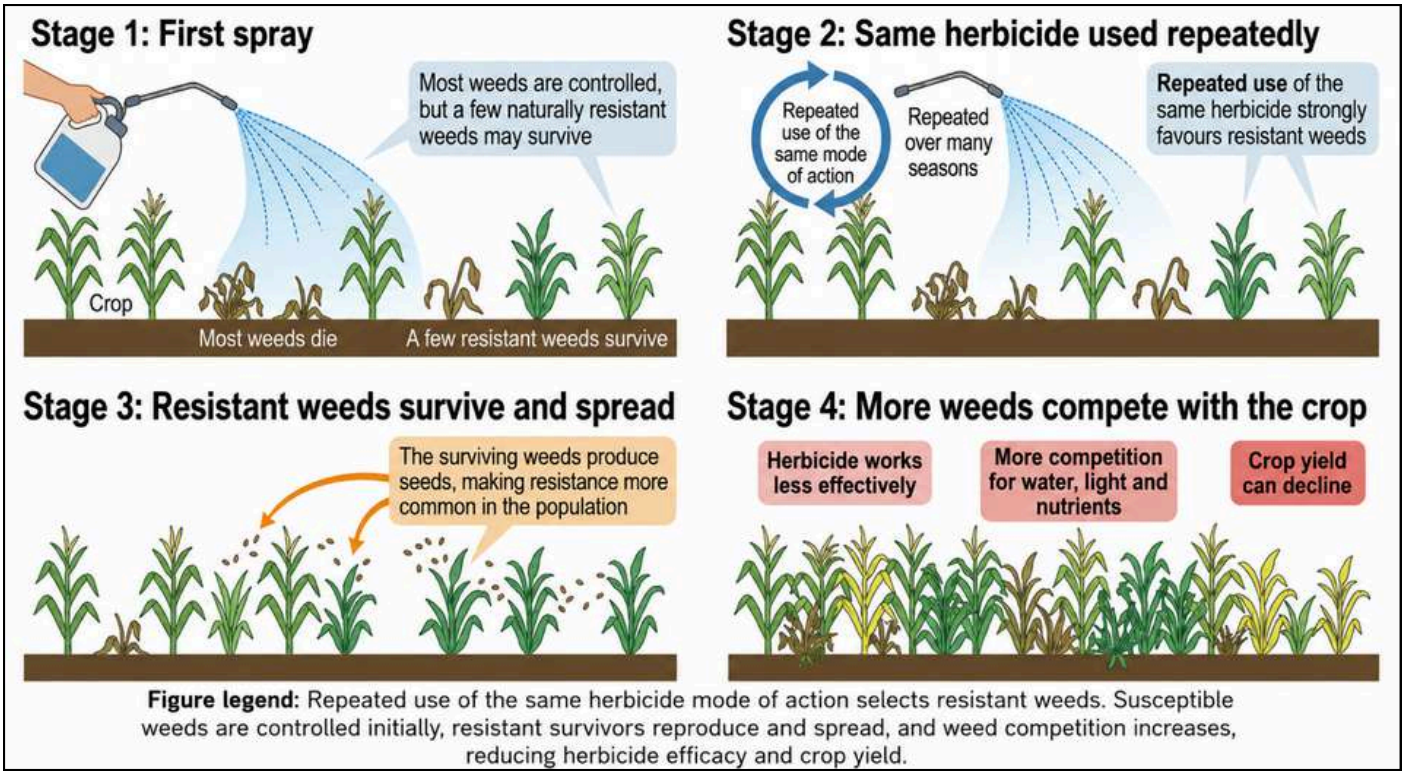

Figure 1: Development of herbicide resistance through repeated use of herbicides with the same mode of action, leading to survival, reproduction and spread of resistant weeds, increased crop competition and reduced yield.

DNA methylation (RdDM). In this natural process, plants produce small RNA molecules that recognize matching regions of the genome. These small RNAs act like molecular address labels, guiding protein complexes to particular DNA sequences. Once the correct location is found, the cellular machinery can cause DNA methylation and influence the activity of that region.

RdDM is already known to play a major role in silencing transposable elements, protecting genome stability and regulating interactions between genes and nearby repetitive DNA. Increasing evidence also links epigenetic regulation with plant responses to environmental stress. The exciting possibility is that this natural system may eventually become programmable. By designing RNA signals that guide methylation to selected genomic regions, researchers could potentially adjust the activity of genes associated with herbicide detoxification, transport, sequestration or stress signalling, without permanently changing the DNA sequence. Thus, RdDM offers a promising biological route for developing herbicide-tolerant crops in the future.

From Observing Epigenetic Changes to Engineering them

Several technological advances have brought this idea closer to experimental testing. Whole-genome methylation analysis can now reveal where DNA methylation differs between herbicide-sensitive and resistant plants. Small-RNA sequencing can identify the RNA molecules associated with these regions, while transcriptome analysis shows which genes become more or less active. In our recent article published in the Journal of Experimental Botany (https://doi.org/10.1093/jxb/erag094), we proposed combining these approaches to identify regulatory regions linked to herbicide responses and then testing whether targeted changes in their epigenetic state alter herbicide tolerance. Together, these technologies can help researchers identify epialleles, different regulatory states of the same DNA region that are not caused by changes in its underlying sequence. Some epialleles are short-lived, whereas others may persist through plant development or even be transmitted to future generations.

CRISPR technology has also moved beyond conventional DNA editing. A modified Cas protein called dCas9 can be directed to a selected genomic region without cutting the DNA. When joined to proteins that add or remove epigenetic marks, dCas9 may allow researchers to alter gene activity at a chosen location. This represents an important change in thinking. Instead of rewriting a gene, we may be able to adjust its regulatory setting.

The Questions we still need to answer

The largest challenge is separating cause from consequence

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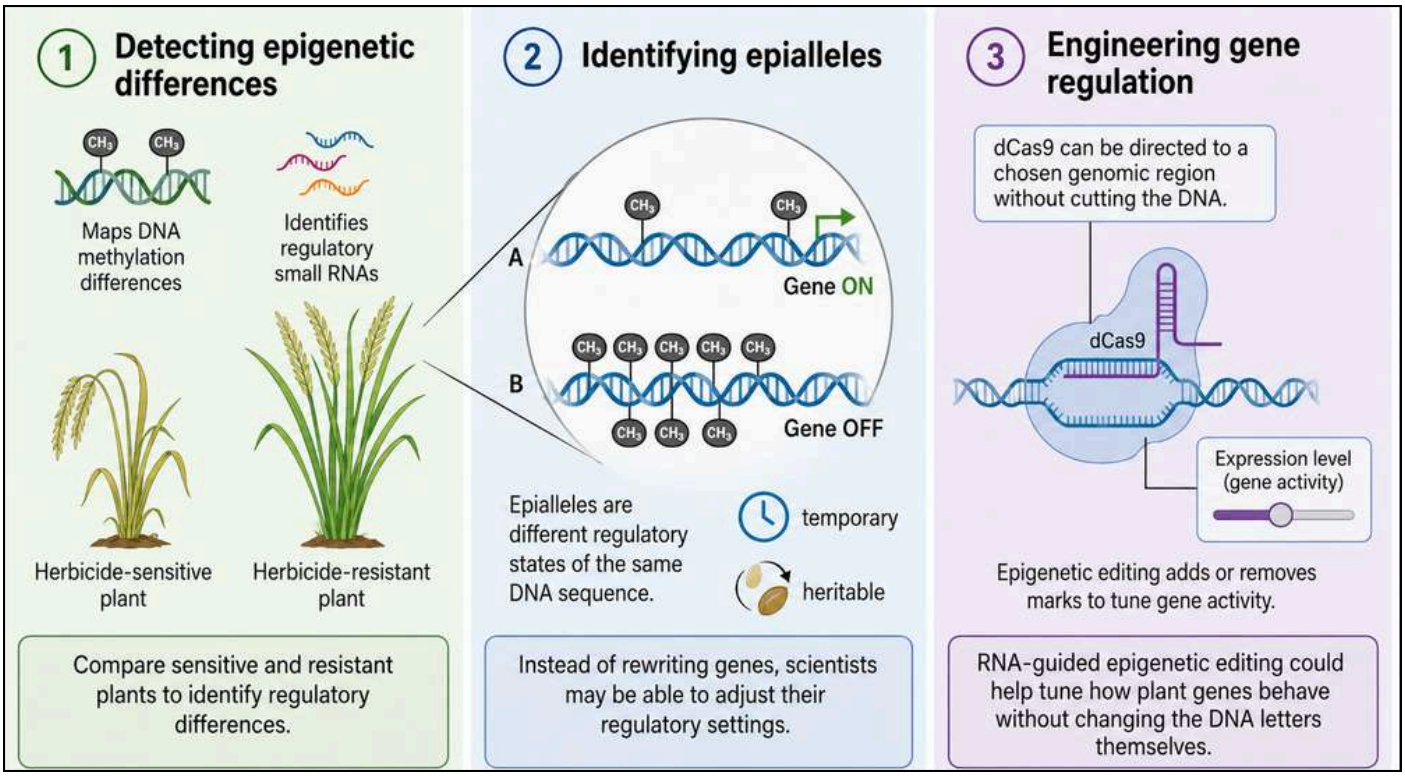

Figure 2: From detecting associated epigenetic differences to engineering gene regulation for generation of herbicide-resistant plants.

A methylation change found in a resistant plant might contribute to resistance, but it could also result from herbicide exposure or be linked to nearby genetic differences. Association alone is therefore not enough. Candidate epigenetic changes must be directly manipulated and tested. Stability is another major question. Some epigenetic states disappear when the trigger is removed. Others may persist across cell divisions or generations. Temporary regulation could be valuable when reversible protection is desired, whereas stable epialleles might be useful for breeding. What matters most is that their behavior can be predicted.

Precision must also be carefully examined. Methylation introduced at one location could affect neighboring genes or interact unexpectedly with other regulatory regions. A modification that improves herbicide tolerance might also lead to undesirable traits. Finally, laboratory results must be tested under realistic agricultural conditions. Crop genotype, soil, climate, herbicide dose and developmental stage could all influence the stability and effectiveness of an engineered epigenetic state.

> *The important question is no longer only what genes a plant carries, but how flexibly and precisely those genes can be controlled.*

The Road Ahead

RNA-guided epigenetic crop improvement is a promising but still emerging field. We now possess powerful methods for mapping epigenetic variations and increasingly precise tools

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for altering gene regulation. What remains to be demonstrated is whether these changes can produce predictable, stable and agronomically useful trait such as herbicide tolerance. Further, these technologies should not be viewed as a reason to increase reliance on herbicides. They must complement crop rotation, mechanical weed control, diversified herbicide use and resistance monitoring.

The real promise of RdDM lies in expanding the crop-improvement toolbox. By controlling existing genes rather than permanently rewriting them, RNA-guided epigenetics may offer a more flexible way to develop crops that respond intelligently to agricultural challenges. The field is now moving from asking whether epigenetic changes accompany herbicide responses to asking whether we can deliberately and responsibly control them. Answering that question could open an entirely new chapter in sustainable crop management.

Prof. Jain and Dr. Sen's contributions to this field are highlighted in their publication, in the Journal of Experimental Botany (2026) https://doi.org/10.1093/jxb/erag094. Their work explores how RNA-guided epigenetic technologies could help develop herbicide-tolerant crops by precisely regulating existing genes without permanently changing the DNA sequence. This research opens new possibilities for sustainable crop improvement and future weed management strategies.

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How We Create Meaning Through Words, Images, and Gestures

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A year ago, my student Riya Jain and I analysed thirty audio recordings of people telling us the worst day of their lives. Half our participants had their their hands taped loosely to their sides; the rest were free to move as they spoke. We weren't listening to what they said. We were timing the silences.

Across 4,242 individual pauses, a pattern emerged. Long silences; those stretching past a second, tied to searching for a feeling rather than a fact: grew more frequent when people recounted painful memories. When we prevented people from gesturing, those long pauses grew more frequent still, in both the emotional and the neutral stories. Stop the hands, and the mind works harder to find words. That study, just published in Acta Psychologica, sits alongside a decade of work I've done on how meaning gets built out of language, image, gestures and translation, and all of it points to the same conclusion: no single channel carries meaning on its own. Words, pictures, and gestures are jointly constructing something none of them could produce alone.

What words actually do

We tend to imagine communication as parcel delivery: a thought wrapped in words, handed over, unwrapped intact. My

> *The next time you watch someone search for the right word, watch their hands too. They may already be saying it.*

own research keeps running into evidence against this. In an fMRI study with Prof. Bipin Indurkhya (Poland) and Prof. Elisabetta Gola (Italy), we showed participants uncaptioned pairs of images meant to be read metaphorically, with no language involved at all. If metaphor were a purely linguistic operation, dressed up in pictures, we shouldn't have seen much happening in the brain's language centres. Instead, interpreting the visual metaphors reliable activated the inferior frontal gyrus (BA47), a region central to language processing. Language switches on even when there isn't a word in sight. That tells us something important: "verbal" and "visual" are not two separate meaning-making systems that occasionally borrow from each other. They are two entry points into one shared conceptual apparatus.

This matters more than ever now that machines are doing a growing share of our reading and writing for us. In work with Dr. Barnali Chaudhary on philosophical translation in the age of large language models, we argued that AI translation tools produce fluent, plausible sentences without anything resembling the interpretive judgment a human translator brings to a conceptually dense text, the decision about which of several possible senses an author intended, given the argument three pages

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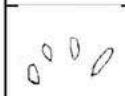
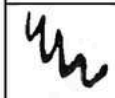
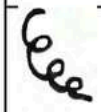
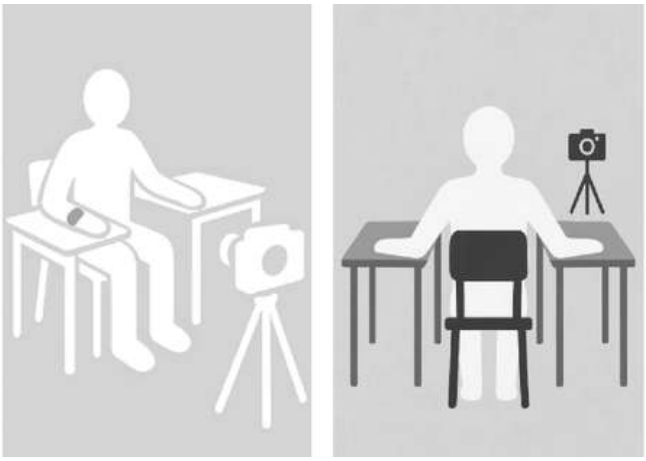
Pictorial rune	Name for rune	Typical location and orientation
	Speed lines	Behind or parallel to a person or object, often indicating direction.
	Three types of movement lines	In various orientations around or parallel to a body part or other object.
	Droplets	In multiples in halo-like fashion around a person's head.
	Spikes	In multiples in halo-like fashion around a person's head or other object.
	Spiral	Usually in multiples in halo-like fashion around a person's head, sometimes singly, parallel to a body part.
	Twirl	Usually single, appearing more or less horizontally behind an agent or vertically above a person's head.

earlier and the tradition it belongs to. We called the resulting redistribution of responsibility "distributed translational agency": the human translator shifts from primary author to epistemic supervisor, checking outputs whose fluency can mask an absence of genuine understanding.

We tested that suspicion more directly in a follow-up study with Dr. Barnali Chaudhary, comparing how humans and large language models interpret metaphors. We scored interpretations along two dimensions: how embodied they were (grounded in bodily, sensory experience) and how culturally accurate, with a third measure of phenomenological depth as the outcome. Human interpretations were well predicted by both embodiment and cultural grounding. For the models, both predictors explained far less of the variation, and yet the models expressed more confidence in their answers than the humans did. What they produced looked like understanding and wasn't grounded in much of anything: surface-coherent but phenomenologically thin, metaphor as statistical pattern- matching rather than something built from a body that has actually felt sharpness, warmth, or weight.

What images do that sentences cannot

Pictures are not simply words in disguise. They have their own grammar, one I've spent years trying to map. In an early study, I paired a photograph of the Taj Mahal with one of wine bottles, conceptually unrelated, but the marble minarets and the slender bottle necks share a shape. Using eye-tracking, we found that people register this kind of low-level perceptual similarity: in shape, colour, texture, before they consciously register any conceptual connection between the two images. That subconscious pull is often what starts a metaphorical reading in the first place; perceptual similarity is not decoration on top of the metaphor, it's frequently the mechanism that gets it started.



How the image is composed then changes how strongly the metaphor lands. In another study, I compared pictorial similes - two images simply placed side by side, implying "this is like that" - against hybrid pictorial metaphors, where the two concepts are fused into a single object: a man's head merged with a chicken's, rather than a man drawn beside one. The fused, hybrid versions were felt more strongly than the side-by-side similes, but only when viewers encountered them cold, without a caption spelling out the comparison. Juxtaposition merely suggests a search for similarity.

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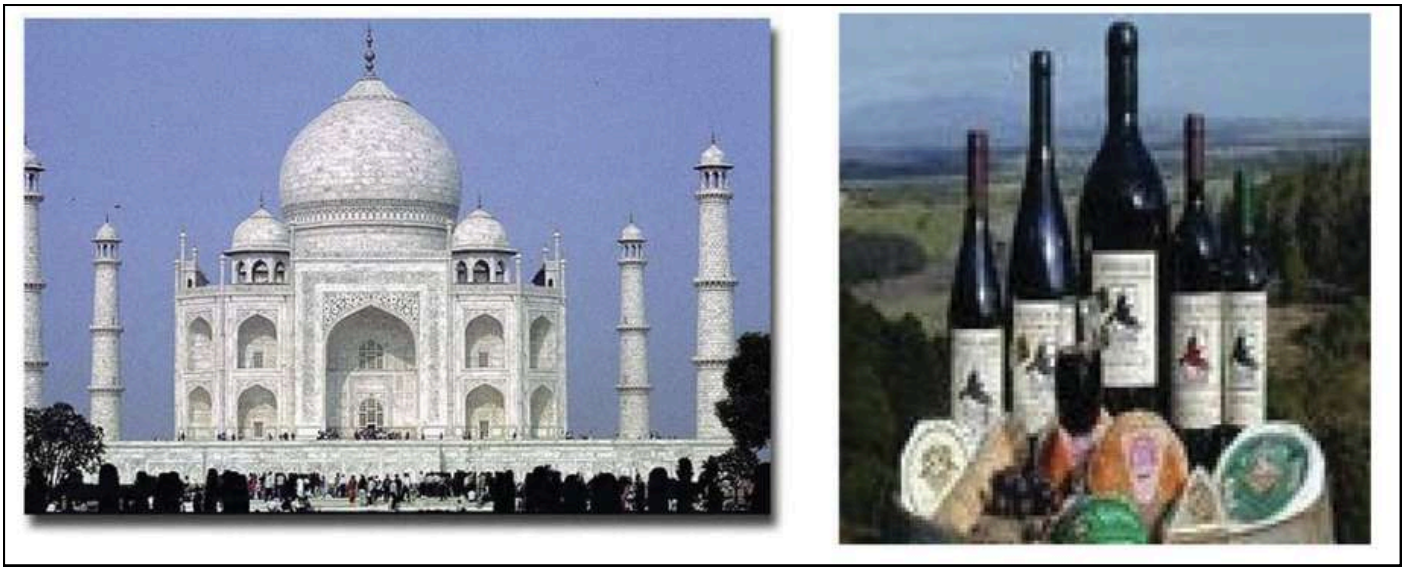

Fusion forces the resolution: it transforms how you see one thing by making you look at it through another, within a single depicted space. Even the smallest pictorial marks turn out to carry systematic meaning. In research on the flourishes cartoonists draw around characters' heads: what comics scholars call “pictorial runes” or “emanata”, we found that droplets and spikes read as generic emotional arousal, spirals read specifically as negative emotion, and twirls read as confusion or dizziness. No one teaches readers this vocabulary explicitly. It's absorbed the way a child absorbs grammar, through exposure, and it does real interpretive work that no caption is doing for the reader.

The hands are thinking too

Which returns me to the tape on my participants' wrists. Gesture is often treated as decoration: hand-waving that accompanies the real communicative work happening in speech. Our data point the other way. When we physically restricted gesture, we weren't suppressing a communicative flourish; we were removing a channel that appears to help speakers organize memory, regulate emotion, and search for words, especially under emotional load. The long pauses that grew when hands were tied down look like the audible residue of a cognitive system working without one of its usual tools.

Meaning as a shared construction

What ties an fMRI scanner, an eye-tracker, and a stopwatch on silent pauses together is a single claim: meaning-making is distributed across modalities that we've studied in isolation largely for disciplinary reasons, not because the mind treats them separately. A word activates conceptual machinery that overlaps substantially with what a picture activates. A picture fuses two concepts into one depicted space and encodes emotion in the curl of a line, things a sentence structurally cannot do. A gesture carries part of the cognitive load of finding the words in the first place. None of these channels is a mere illustration of what's “really” happening in language.

This has stakes well beyond the seminar room. As large language models increasingly mediate how we write, translate, and converse, our own data suggest real caution about what fluency is telling us. A model can produce a metaphor interpretation, or a translated sentence, that reads as confident and coherent while remaining, by the measures we used, considerably thinner than a human one: ungrounded in the embodied and cultural experience that gives our own language its depth. If we want machines, classrooms, or communication design to actually traffic in meaning rather than merely simulate its surface, we need to keep building the fuller picture: not just what words say, but what images do and what hands are doing while the words are still being found.

Dr. Ojha's contributions to this field are highlighted in the recent publication, in Acta Psychologica (2026) (https://doi.org/10.1016/j.actpsy.2026.107287). This study investigates how gestures and emotions influence the way people speak while recalling personal experiences. The findings show that restricting gestures and recalling emotional memories specifically affect longer pauses in speech, providing new insights into the cognitive processes involved in communication, memory, and meaning-making.

| EXPERT OPINION |

Rewiring medicine: In the age of ‘Electroceuticals’

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

Areas of Expertise: Neuromodulation | rewiring | neural circuits

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Areas of Expertise: Neurorehabilitation | neural restoration | electrotherapy

Neuromodulation is among the fastest-growing branches of medicine in this century. Although it is often associated with flagship procedures such as deep brain stimulation (DBS), its scope extends far beyond the brain. In recent years, advances in implants and wearable technologies have made it increasingly feasible to target distant peripheral organs and modulate their function through neural pathways. This expanding field marks the emergence of electroceuticals, therapies that use electrical stimulation to influence biological function and treat disease.

Electroceuticals are bioelectronic implants or wearable devices that stimulate the nervous system to treat disease (Figure 1).

Their therapeutic effect is based on targeted stimulation of a neural node, pathway, or nerve within the central or peripheral nervous system, with the goal of modifying the output of the affected end organ.

DBS is an established therapy for Parkinson’s disease and other movement disorders. It is also being used increasingly for psychiatric disorders and pain. By stimulating specific brain nuclei, DBS can modulate the output of motor, sensory, or limbic circuits and reduce disease-related symptoms.

A similar principle applies to spinal cord stimulation (SCS) and peripheral nerve stimulation (PNS), both of which are widely used in patients with chronic pain. Functional electrical stimulation (FES) of peripheral nerves can also enhance motor activity and improve rehabilitation outcomes.

The concept of electroceuticals is now extending beyond brain disorders to a wide range of systemic conditions, including diabetes, post-traumatic stress disorder, fibromyalgia, asthma, obstructive sleep apnea, incontinence, erectile dysfunction, and acute renal dysfunction.

Temporary or permanent implants that target the peripheral or autonomic nerve supply of affected organs may improve end-organ function without producing broad systemic effects.

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Electrical impulses are the language of the body's neural networks. Nearly every organ and physiological function is regulated by circuits of neurons communicating through these signals. As this understanding advances, electroceuticals are likely to play an increasingly important role in controlling and modifying both neurological and non-neurological diseases.

Brain Disorders and Electroceuticals

Over the past two decades, therapeutic brain stimulation has transformed the treatment of movement disorders. Deep brain stimulation (DBS) is now regarded as one of the most technologically advanced tools in the neurosurgical armamentarium, building on more than 50 years of clinical experience with therapeutic brain stimulation and more than a century of human brain stimulation research. DBS acts by modulating activity within targeted neural structures. High-frequency stimulation is commonly described as producing effects such as "neuronal jamming" or "depolarization blockade," which can reduce abnormal circuit activity and improve symptoms.

> *From deep brain stimulation to wearable nerve stimulators, electroceuticals are rewiring the future of care.*

Although DBS is best established for movement disorders such as Parkinson's disease, its use has expanded to several other neurological and neuropsychiatric conditions, including psychiatric disorders, chronic pain, cognitive disorders, epilepsy, and addiction.

Other Implanted Neuromodulation Therapies

DBS is not the only invasive electroceutical therapy in current use Other implanted neuromodulation approaches include motor cortex stimulation (MCS) for chronic pain, spinal cord stimulation (SCS) for pain and,

Figure 1:Bioelectronic therapy offers the promise of focal, non-generalized, and noninvasive treatment

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increasingly, for selected cases of paraplegia, peripheral nerve stimulation (PNS) for migraine and chronic focal pain, vagus nerve stimulation (VNS) for epilepsy and other disorders, and responsive neurostimulation (RNS) for epilepsy.

Wearable and Noninvasive Stimulation

In addition to implanted devices, wearable and noninvasive stimulators are becoming increasingly common. Commercially available examples include head-worn stimulators for headache and migraine, wearable vagus nerve stimulators for anxiety and insomnia, and external stimulators for back pain or peripheral nerve pain in the hands and legs. Functional electrical stimulation (FES) has also been adapted into wearable bands and external systems designed to support motor activation and rehabilitation.

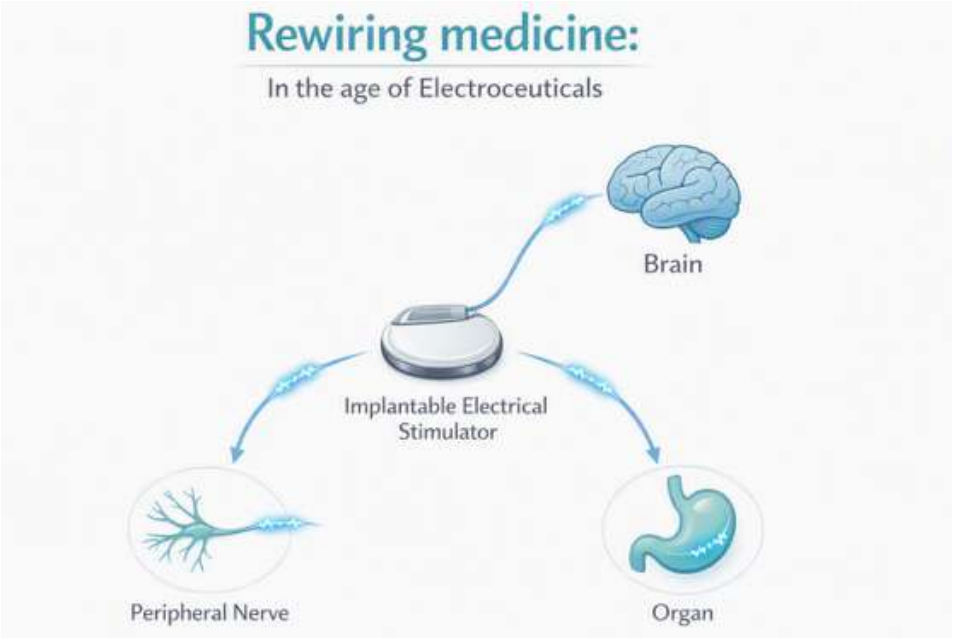
Electroceuticals Beyond the Brain

Electrical modulation is no longer limited to the brain; it is increasingly being explored for the functional regulation of other organs (Figure 2). Hypoglossal stimulation for obstructive sleep apnea (OSA) is now commercially available. Wearable posterior tibial nerve stimulators have been used for stress incontinence, while tracheal implants that selectively stimulate the sympathetic plexus in the tracheal wall have been proposed to help abort acute asthma attacks. Neck-worn stimulators targeting the carotid sinus and renal artery-stimulating stents have both been investigated for hypertension. Other potential applications include wearable stimulation for erectile dysfunction and dysmenorrhea, modulation of hepatic vessel tone in portal hypertension, and immune regulation through sympathetic stimulation. In peripheral vascular disease and unstable angina, electrical stimulation has also shown promising therapeutic potential.

The Future of Electroceuticals

In the near future, treatment for many common conditions may shift from taking a pill to using targeted wearable stimulation. Instead of relying solely on medication for a headache or abdominal pain, a patient may simply place a wearable stimulator over the head or abdomen to deliver localized therapy. Similar approaches could help reduce the burden of stress incontinence by delivering brief bursts of stimulation to the posterior tibial nerves during daily activities.

This approach offers a key advantage over systemic pharmaceutical therapy: it can modulate specific neural pathways, nerves, or organs without exposing the entire body to medication. By providing focal, non-generalized, and noninvasive therapy, electroceuticals have the potential to transform the treatment of a wide range of diseases and become an important part of the future of medicine.



Dr. Milind Deogaonkar and his team's contributions to the field are highlighted in several publications, including Neurology India (2020) 10.4103/0028-3886.302451, 10.4103/0028-3886.198271 in Neuromodulation (2016) 10.1111/ner.12346 . These studies demonstrate how neuromodulation can be used to treat chronic pain, movement disorders, and neurological disorders, while advancing our understanding of how targeted electrical stimulation reshapes neural circuits to improve patient outcomes.

Figure 2: By modulating neural pathways, electroceuticals can influence the function of distant organs.

| EXPERT OPINION |

Reprogramming Yeast to Produce Life-Saving Antibiotics

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

Areas of expertise: Metabolic engineering | Synthetic biology | Systems biology

Antibiotics are among modern medicine's greatest achievements, yet the way we manufacture many of them has barely changed in decades.

Penicillins and cephalosporins, the β-lactam family that still accounts for a large share of the antibiotics prescribed worldwide, are made by growing filamentous fungi such as Penicillium in large fermenters. These fungi are capable producers, but they grow slowly, are difficult to engineer genetically, and leave little room to redesign the molecules they make. Drug-resistant infections already contribute to well over a million deaths each year, and the pipeline of genuinely new antibiotics has thinned. As resistance rises and the demand for new and modified antibiotics grows, the question of where and how we produce these compounds has become as important as the biochemistry itself.

β-lactam antibiotics belong to a class of natural products called non-ribosomal peptides. Most proteins are made by ribosomes, which read the cell's genetic code to string amino acids together in a set order. Non-ribosomal peptides are built differently: giant, multi-part enzymes called non-ribosomal peptide synthetases assemble them piece by piece, working like molecular assembly lines. Each section of the enzyme selects, activates, and stitches together a specific building block, including unusual amino acids the ribosome never handles. This machinery gives the resulting molecules extraordinary chemical diversity; antibiotics, immunosuppressants and anticancer agents all emerge from it. That same complexity also makes them exceptionally difficult to produce outside the organisms that evolved to make them.

> *"Relocating antibiotic production into a fast, safe, well-understood yeast could make drug discovery more flexible and better prepared for rising resistance."*

The first committed step toward every β-lactam antibiotic is a small three-part molecule with complex nomenclature: δ-(L-α-aminoadipyl)-L-cysteinyl-D-valine, shortened to ACV. A single, very large enzyme called ACV synthetase assembles it from three amino acids and then flips one of them into a mirror-image form. ACV is the rate-limiting precursor of the entire pathway, but in its natural hosts it is consumed almost as quickly as it is made, which makes it nearly impossible to isolate and study on its own. This reflects a broader theme in drug discovery: many valuable molecules come from organisms that are hard to grow or genetically manipulate.

Building Antibiotics in a Better Host

For years, metabolic engineers have pursued an appealing alternative: moving complex biosynthetic pathways into 'chassis' microbes that are fast-growing, safe, and easy to engineer. Then came the synthetic biologists that started doing this

in a modular plug and play manner and made sure the genetic codon usage matched. The same logic underlies engineering yeast to make the antimalarial artemisinin and bacteria to produce human insulin. A landmark 2017 study showed that baker's yeast could be engineered to produce penicillin, proving that these assembly-line enzymes can function in yeast at all. The natural next question is whether the same can be done in a host actually built for industrial-scale production.

Engineering Yeast to Produce the First Building Block

That is the question our team set out to answer using *Pichia pastoris* (also known as Komagataella phaffii), a methylotrophic yeast widely used in biomanufacturing. It is recognized as safe, grows to very high cell densities on inexpensive defined media, and allows new genes to be integrated permanently into its genome, so the engineered strain stays stable without constant chemical selection. We rebuilt the minimal ACV pathway from the ground up. Two genes were computationally redesigned and optimized for the yeast: pcbAB, which encodes the large ACV synthetase from Penicillium chrysogenum, and *npgA*, a small activating enzyme from Aspergillus nidulans that switches the synthetase on. Both were integrated directly into the genome under a methanol-controlled switch, and mass spectrometry confirmed that the engineered yeast produced genuine ACV, the first time this pathway has been reconstructed in *P. pastoris*.

Improving Production Through Evolution

Our first strain made only trace amounts, around 5 nanograms per milliliter. Two complementary strategies raised output roughly ten- to twelve-fold. Simply feeding the cells the three amino-acid building blocks lifted production to about 60 nanograms per milliliter. Separately, adaptive laboratory evolution, growing the strain for 40 days (roughly 300 generations) under a controlled gradient nutrient pressure, yielded a variant producing about 50 nanograms per milliliter.

Sequencing that evolved strain was revealing: the cells had spontaneously rewired their own protein-making machinery, acquiring mutations in the systems that process transfer RNA and in a ribosomal protein, apparen-

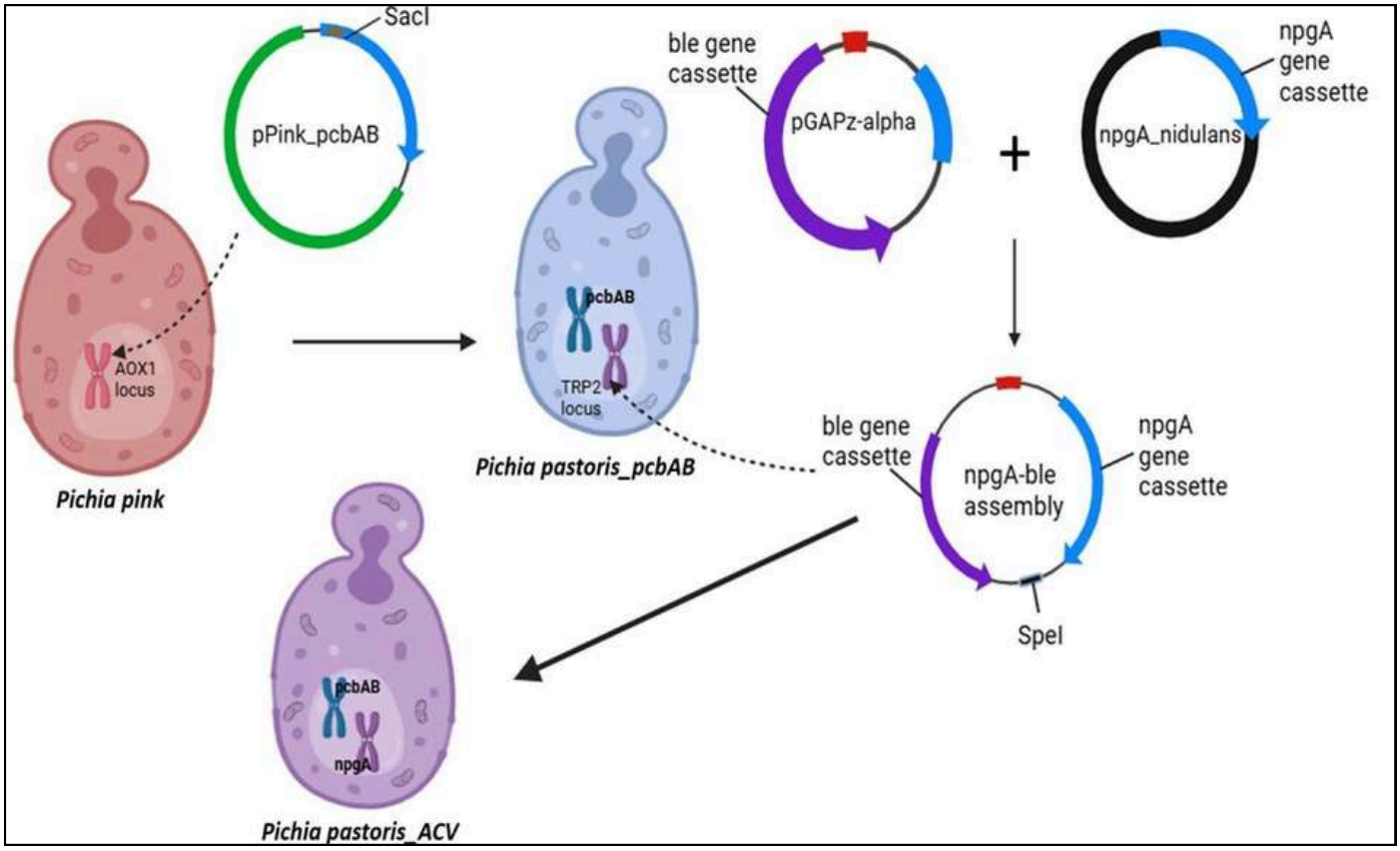

Figure 1: Step-by-step construction of the ACV-producing strain. The redesigned pcbAB gene (encoding ACV synthetase) is first integrated into the AOX1 locus of the Pichia pink strain, then the activating npgA gene is integrated at the TRP2 locus, yielding the final engineered P. pastoris_ACV strain that carries the complete minimal pathway.

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tly to cope with the burden of building such a large enzyme. A genome-wide look at gene activity reinforced the picture, showing hundreds of genes shifting to boost energy supply and replenish the pathway's raw materials.

Two honest caveats matter. The amounts produced are still modest, nanograms per milliliter, far below what industrial manufacturing would require. And we also observed an intriguing disconnect: the evolved strain made more ACV even though the introduced genes were less active (in terms of expression levels) than before. It is a useful reminder that in living cells, turning up a gene does not automatically turn up the product; the behavior of the entire biomolecular network and the crosstalk between diverse biomolecules and pathways is what counts.

Toward the Next Generation of Antibiotics

There is a further, longer-term prospect. Because non-ribosomal peptide synthetases are modular, researchers are beginning to swap and rearrange their sections (the synthetic biology paradigm) to make entirely new peptides

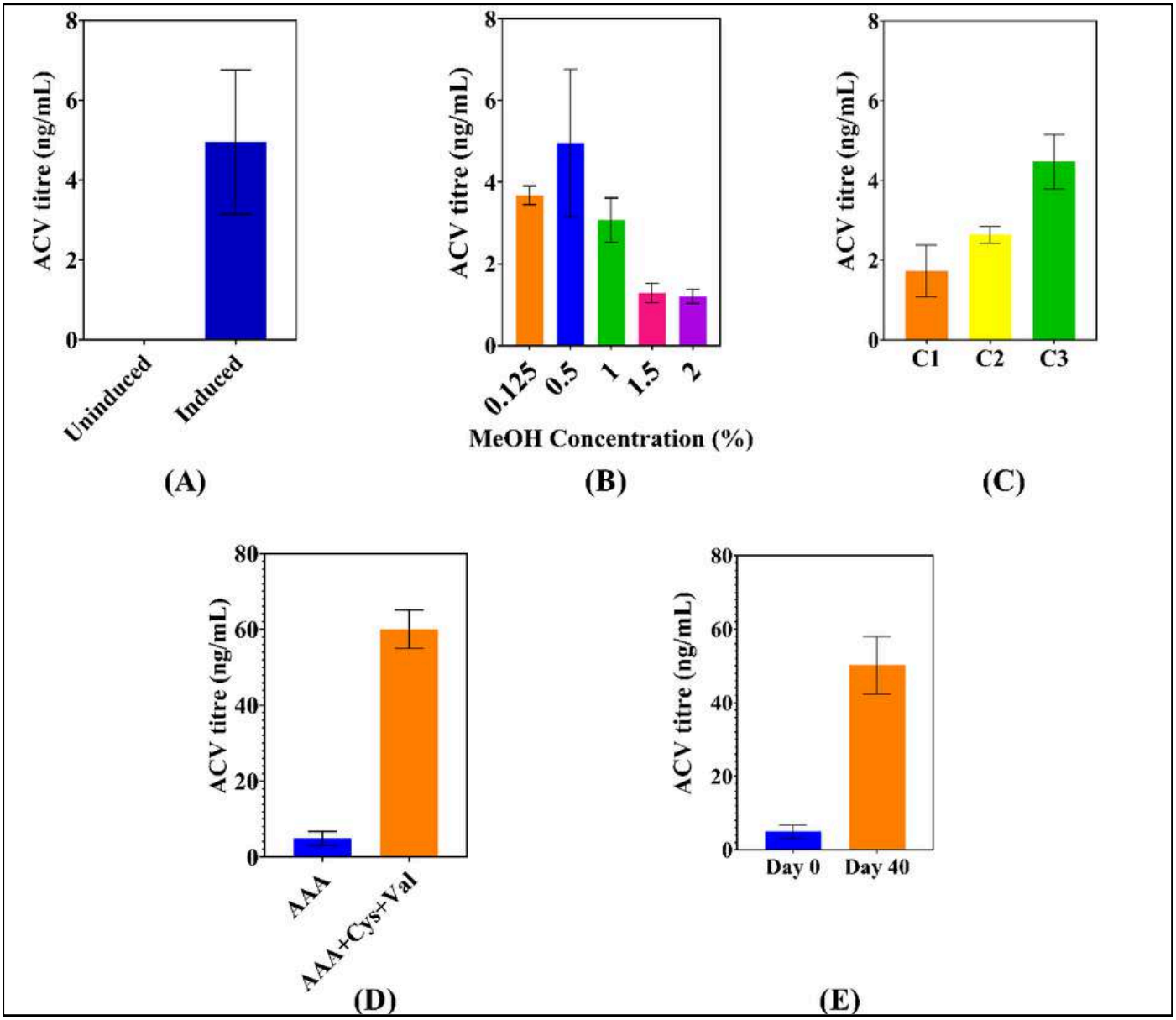

Figure 2: ACV production measured by mass spectrometry. (A) Precursor is made only when the pathway is switched on (induced vs. uninduced). (B) Effect of the methanol inducer concentration, optimal at 0.5%. (C) Feeding the building-block amino acid at different growth stages. (D) Supplying all three amino-acid precursors raises titre roughly 12-fold, to ~60 ng/mL. (E) A strain improved by 40 days of adaptive laboratory evolution reaches ~50 ng/mL (Day 40 vs. Day 0).

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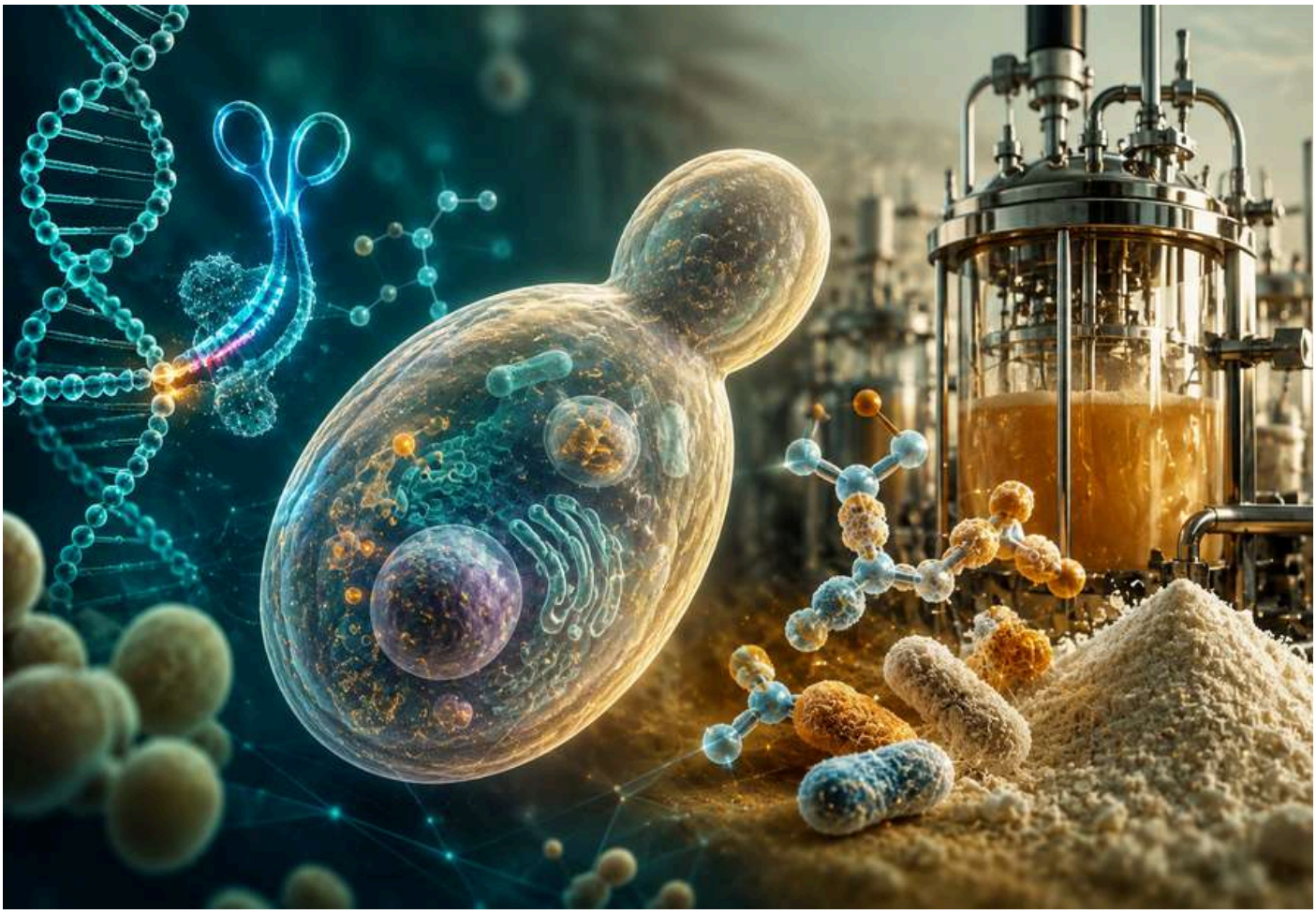
that nature never produced. A host that reliably expresses these enzymes is the essential platform on which such ‘designer’ antibiotics could one day be built, a way to stay ahead of resistant bacteria rather than merely reacting to them.

Establishing that a robust industrial yeast can host even one such assembly line is a prerequisite for that longer-term goal, and a reason the result matters beyond the specific molecule we chose to make.

The significance of this work lies less in the quantity produced than in the demonstration itself. It establishes P. pastoris as a workable, general-purpose chassis for non-ribosomal peptides, one of the most challenging classes of natural products, and lays out a repeatable blueprint: design synthetic genes, feed key precursors, apply evolution, and read the cell's response at the systems level to guide the next round. The road to industrially useful titres is still long, and the central challenges are clear: supplying enough of the right precursors, easing the metabolic burden of a giant foreign enzyme, and closing the wide gap in yield. But given how many antibiotics, and other medicines, originate in organisms we can barely cultivate, the ability to relocate their production into a fast, safe, well-understood yeast could make antibiotic discovery and manufacturing more flexible, more sustainable, and better prepared to keep pace as resistance evolves.

Dr. Anu Raghunathan's contributions to this field are highlighted in the publication, in ACS Omega (2026) (https://doi.org/10.1021/acsomega.5c11638). Her research focuses on engineering microbial "chassis" hosts for the sustainable production of complex therapeutic molecules. In this study, her team successfully engineered the industrial yeast Pichia pastoris to produce ACV, the first key building block of β-lactam antibiotics, using synthetic biology, adaptive laboratory evolution, and systems-level analysis. This work provides a promising platform for future antibiotic discovery and sustainable biomanufacturing.



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Beyond the Bruises: experiences from a crisis centre for domestic violence and abuse

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

Areas of expertise: Obstetrics & Gynecology | Domestic Violence and Women's Health | Maternal & Fetal Medicine

When 32-year-old Meena (name changed to protect identity) married, she hoped for a secure and happy life with her husband. Instead, over the next eleven years, she found herself trapped in a cycle of control, humiliation, and fear. Her husband struggled with alcohol dependence and was unable to provide for the family. Meena even took a loan through a women's self-help group so he could purchase an auto-rickshaw and earn a livelihood. He promised to repay the loan but never did. As the debt mounted, the burden fell entirely on her. She faced pressure from lenders, borrowed money from relatives to make repayments, and endured constant criticism from her husband. He blamed her for the family's financial problems, belittled her efforts, and repeatedly undermined her confidence. Eventually, the abuse escalated. One night, after an argument, he physically assaulted her and threw her out of the house.

Meena's story is not unique. It reflects the experiences of countless women whose suffering remains invisible because it leaves no obvious physical scars.

Domestic violence and abuse (DVA) is often imagined as physical assault resulting in visible injuries. Yet for many women, the most devastating wounds are not seen. Emotional manipulation, verbal degradation, financial control, social isolation, and reproductive coercion frequently occur behind closed doors, leaving profound and lasting consequences for health and wellbeing. At our hospital-based crisis center in South India, our team examined the experiences of 299 women who sought support for domestic violence and abuse over a one-year period. The findings offer an important glimpse into the realities faced by survivors and highlight the crucial role healthcare institutions can play in identifying and responding to violence.

> *"The deepest wounds of domestic violence are often invisible."*

A Hidden Crisis in Plain Sight

Domestic violence remains one of the most widespread violations of women's rights worldwide. While national surveys estimate that nearly one in three women experience some form of intimate partner violence during their lifetime, many cases remain unreported due to fear, stigma, financial dependence, and concerns about family disruption. Our study found that most survivors seeking help were in their reproductive years, with an average age of

34 years. Nearly three-quarters were married, and in more than three-fourths of cases, the perpetrator was the husband. These findings reinforce the reality that violence frequently occurs within relationships that are expected to provide safety and support. Violence was observed across educational and occupational strata, emphasizing the need for universal screening approaches rather than targeted screening based on perceived socioeconomic risk.

The Abuse We Don't See

One of the most striking findings was that emotional abuse was the most common form of violence, affecting 86% of survivors. Verbal abuse was reported by more than 80%, while almost 70% experienced economic abuse. Economic abuse in these cases also extended beyond coercive financial control to include debt bondage, wherein the perpetrator creates or transfers debt obligations to the survivor, representing an insidious mechanism of control that limits autonomy and reinforces dependency. These forms of violence often receive less attention than physical assault but can be equally, if not more, damaging. Survivors described experiences ranging from humiliation and intimidation to financial restrictions that limited their independence and ability to leave abusive relationships.

The findings challenge the misconception that domestic violence is only about physical harm. Instead, many women endure multiple overlapping forms of abuse that collectively erode self-esteem, autonomy, and mental health.

The Impact on Health

The consequences of domestic violence have a major impact on health. More than half of survivors had sustained physical injuries. However, the emotional burden was even more significant. Nearly 96% reported psychological distress, including symptoms of depression, impaired concentration, anxiety, and suicidal thoughts. The study also identified reproductive health consequences, including unwanted pregnancies and genital injuries. Evidence shows that abuse worsens in pregnancy in over 30% cases resulting in miscarriages, preterm birth and growth restriction. These findings underscore the close relationship between domestic violence and reproductive health outcomes, an area that often remains under-recognized in clinical practice.

For healthcare professionals, these observations reinforce an important message that domestic violence is not merely a social issue. It is a critical health issue with implications for physical, mental, sexual, and reproductive wellbeing. Healthcare interactions during pregnancy provide a crucial opportunity for identifying women experiencing DVA and initiating early intervention. Professional guidelines recommend routine inquiry about DVA during antenatal care and emphasize the role of healthcare providers in ensuring safe disclosure, documentation, and referral.

The Role of Family and Social Structures

While husbands were the primary perpetrators, the study also highlighted the influence of extended family dynamics. Interference by in-laws, dowry-related pressures, and extramarital relationships emerged as common themes contributing to abuse. Alcohol use was reported among nearly half of perpetrators, consistent with international evidence linking substance misuse and increased violence severity. These findings demonstrate how individual behaviors interact with broader social and cultural factors to perpetuate abuse.

Why Survivors Often Remain Silent

Despite the severity of violence experienced, only about one-third of survivors had reported the abuse to the police, and just one in ten had initiated legal proceedings. Government of India offers legal protections under the Protection of Women from Domestic Violence Act (PWDVA). The police department also has women safety teams (e.g. SHE teams in Telangana) and One Stop Crisis Cetres to support victims of DVA. The gap

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between experiencing violence and pursuing legal action reflects the many barriers survivors face. Fear of retaliation, economic dependency, concern for children, social stigma, and lack of awareness of available protections all contribute to delayed or absent reporting. The fact that most survivors lacked documentary evidence of abuse further illustrates the challenges women encounter when seeking justice.

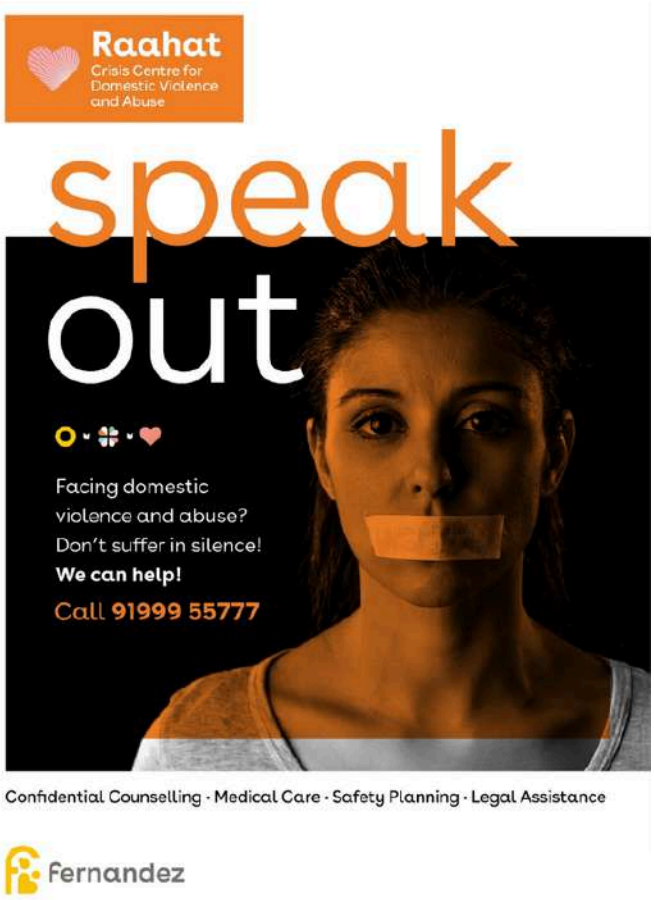
Healthcare as a Gateway to Support

Perhaps the most important lesson from our study is the unique role healthcare institutions can play in responding to domestic violence. Many survivors first interact with healthcare providers before approaching law enforcement or legal services. Hospitals therefore represent a critical opportunity for early identification, documentation, counselling, and referral.

Our Raahat crisis center provides an integrated model of care that combines medical support, psychological counselling, legal guidance, livelihood assistance, and community outreach. Survivors access the center through multiple pathways, including center helpline number (figure 1), direct walk-in, referral by healthcare professionals within the hospital, police referral, and community outreach mechanisms. Trained counsellors conduct intake assessment, crisis intervention, risk assessment, and documentation. The center also collaborates with government services and partner non-governmental organizations to ensure timely access to police assistance, legal support, and livelihood opportunities for survivors depending on their individual needs. Such multidisciplinary approaches acknowledge that recovery requires more than treatment of injuries alone.

The way forward

Domestic violence and abuse is a complex public health challenge that affects women across educational, occupational, and socioeconomic backgrounds. Our findings demonstrate that emotional and economic abuse are highly prevalent and frequently coexist with physical and sexual violence. As healthcare systems increasingly embrace patient-centered care, routine inquiry about domestic violence should become a standard component of reproductive and women's health services. Hospitals must be equipped not only to treat the consequences of violence but also to help prevent further harm through timely support and intervention. Creating safe spaces where survivors are heard, believed, and supported is not simply



good clinical practice but an essential step toward improving women's health and advancing gender equity.

Meera sought help from our crisis centre and understood that what she had endured was not simply a difficult marriage but a pattern of domestic violence and abuse. With counselling, legal guidance, and support to secure employment, she gradually rebuilt her life and achieved financial independence. Meera's journey from abuse to independence is testament to the fact that every time a survivor is heard, believed, and supported; the cycle of abuse is weakened. Recognising the hidden forms of violence is the first step toward creating safer lives for women and healthier communities."

Dr. Maimoona Ahmed's contributions to this field are highlighted in the recent publication, in the International Journal of Gynecology & Obstetrics (2026) (https://doi.org/10.1002/ijgo.71245). This study highlights how timely medical care, counseling, legal support, and economic empowerment can help survivors of domestic violence rebuild their lives and achieve long-term independence.

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. Sourav Kumar

THE TINY PATCH THAT WATCHES THE BRAIN AT NIGHT

In the bustling halls of Georgia, where brilliant engineers and doctors worked together to solve the mysteries of the human body, lived a young biomedical engineer named Georgia. She had always been fascinated by one simple question: What happens inside our brain while we sleep? Every night, our brains work silently, repairing cells, storing memories, and washing away harmful waste. Yet no one could watch this hidden cleaning process without putting people inside giant MRI machines or using uncomfortable laboratory equipment. Georgia dreamed of creating something different, a tiny, soft patch that people could wear comfortably at home. Together with her friend Seoul, a neurologist from Seoul National University, she believed that understanding the sleeping brain could help prevent diseases such as Alzheimer's long before symptoms appeared. But before they could help people, they first had to prove that their little invention could truly see what was happening deep inside the brain.

After many months of work, Georgia created a small, flexible forehead patch no larger than a few coins placed together. Instead of cameras, it carried tiny lights that shone harmless near-infrared beams into the forehead. These invisible lights could travel through the skin and skull before bouncing back to a small detector. By studying how different colors of light returned, the device could estimate changes in oxygen-rich blood, oxygen-poor blood, and, most importantly, brain water. Brain water was special because it moved together with the brain's natural cleaning fluid, called cerebrospinal fluid. If the cleaning system became more active during sleep, the amount and movement of water inside the brain would also change. The patch was soft enough to bend with the forehead, light enough to forget it was even there, and wireless so people could sleep naturally without being connected to bulky hospital machines. Before trusting it, Georgia and Seoul tested it carefully while volunteers walked, rested, exercised, and even briefly held their breath. Each activity produced predictable changes in brain water, proving that the tiny patch was faithfully recording real biological signals instead of random noise.

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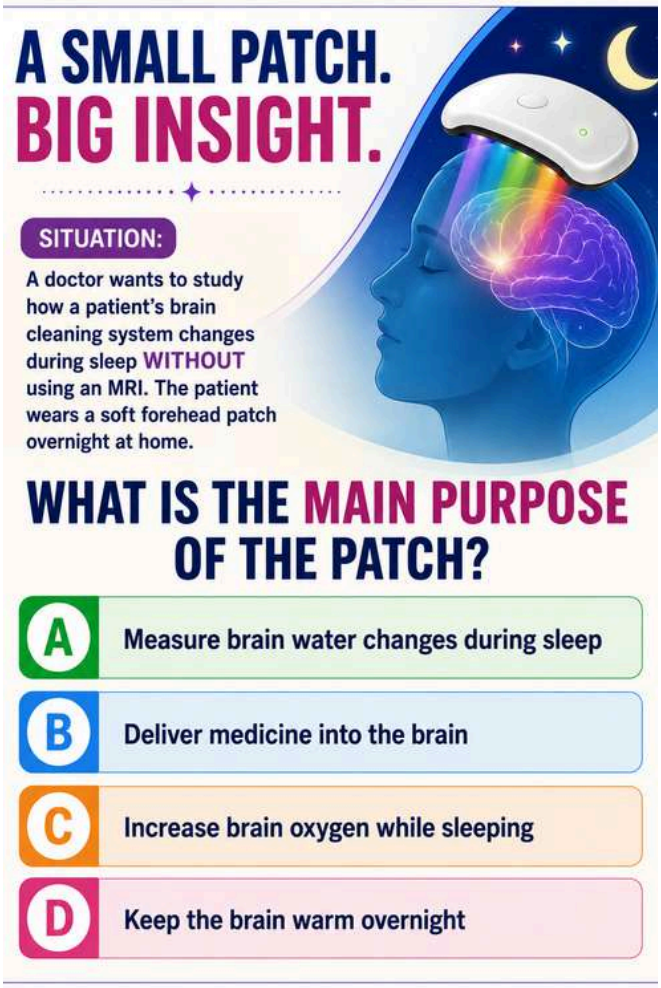
Now came the greatest challenge. Volunteers took the patch home and wore it while sleeping through the night. Alongside it, they also wore a standard sleep-monitoring system that recorded their brain waves and eye movements. As the hours passed, Georgia watched the incoming data with excitement. Whenever the volunteers entered deep non-REM sleep, the patch showed a steady rise in brain water. At the same time, breathing became slower and more regular, heart rhythms stabilized, and the brain produced powerful slow waves. It was as if an invisible cleaning crew had begun its night shift. However, when the sleepers entered REM sleep, where dreams are most vivid, brain water levels gradually fell, breathing became less regular, and the heart rhythm changed again. Using artificial intelligence, Georgia and Seoul taught their computer to recognize these sleep stages automatically by combining traditional brain-wave recordings with the new brain-water signals. To their amazement, the changes in brain water happened almost exactly at the same time as the transitions between different stages of sleep, revealing a close connection between sleep and the brain's nightly cleaning activity.

The discovery soon sparked excitement far beyond their laboratories. Researchers from hospitals, universities, and neuroscience centers began asking whether the tiny forehead patch could one day become a routine part of healthcare. Imagine visiting your doctor after a poor night's sleep and simply sharing data collected from a comfortable patch worn at home instead of spending hours inside a sleep laboratory. Parents could monitor children's sleep more naturally, older adults might be screened for early signs of neurological disorders, and scientists could follow how the brain changes over months or even years without expensive imaging equipment. The little patch had transformed from a simple engineering project into a powerful new window into the sleeping brain.

Months later, the discovery attracted attention from scientists around the world. For the first time, people could study the brain's hidden water movements without expensive hospital scanners or invasive procedures. Although Georgia and Seoul knew that the patch could not directly see the brain's cleaning fluid itself, it provided a valuable window into the natural processes that occur while we sleep. They imagined a future where millions of people could wear a comfortable forehead patch at home, allowing doctors to monitor sleep quality, study brain health, detect early signs of neurological diseases, and evaluate whether treatments were helping the brain repair itself. Their invention reminded everyone that some of the most important work our bodies perform happens quietly each night while we are asleep. Sometimes, understanding life's greatest mysteries does not require building larger machines, it simply requires creating a gentler way to listen to nature's smallest signals.



REFERENCE

Seunghyeb Ban et al. ,A soft wearable near-infrared spectroscopy system for detecting brain water dynamics linked to glymphatic activity during sleep.Sci Adv.12,eaed2056(2026).DOI:10.1126/sciadv.aed2056

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| By Dr. Priyangana Deb

BEYOND HABITAT LOSS: THE BRIDGES THAT KEEP NATURE ALIVE

In the peaceful countryside surrounding Cambridge, there lived a young ecologist named Cambridge. Every morning, Cambridge wandered through meadows, forests, and open fields with a notebook in hand, believing that every landscape had a story to tell. One spring morning, Cambridge noticed something unusual. A thriving cactus field that had once stretched across the countryside had become scattered into many tiny islands of green. Between these patches were wide stretches of dry land where tall grasses had been cut short. Tiny cactus bugs that once moved freely between cactus plants now struggled to find safe paths. Cambridge wondered, “Is it only the loss of habitat that harms these insects, or does the way we divide the land matter just as much?” Determined to uncover the truth, Cambridge joined forces with three friends, Florida, Wisconsin, and Wake Forest, each representing the universities where the study had been carried out. Together, they promised to solve one of ecology’s biggest mysteries.

The team built an enormous outdoor experiment unlike anything they had attempted before. Across twenty-seven carefully designed landscapes, they planted more than three thousand patches of prickly pear cactus, the only home of a tiny insect called the cactus bug. Every landscape started with exactly the same number of cactus patches so that every insect had an equal beginning. Then the scientists slowly changed the landscapes. In some places, they removed a small amount of cactus, while in others they removed much more. In certain landscapes, the remaining cactus stayed in a few large patches, while in others it was broken into many small islands. Finally, they changed the surrounding environment itself. Some landscapes were left with tall natural grasses where insects could hide and travel safely. Others had the vegetation cut short, exposing every travelling insect to predators and harsh conditions. Cambridge smiled and said, “We are not only testing how much habitat remains. We are testing whether the world surrounding that habitat decides who

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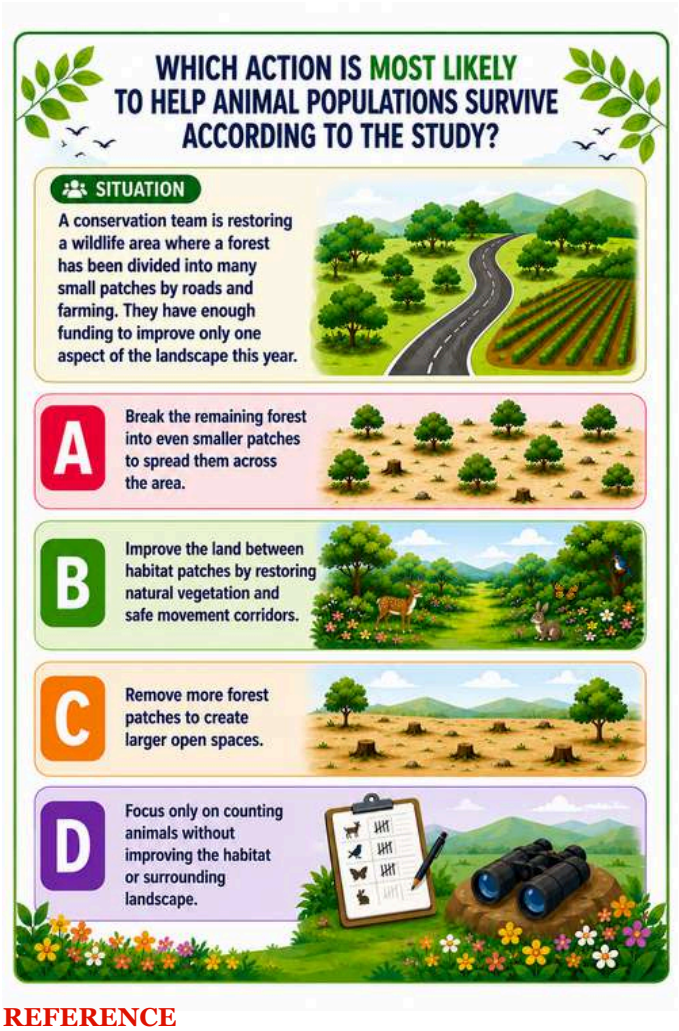
survives." Then they patiently observed the cactus bugs month after month, year after year, following more than a dozen generations of insects.

As the seasons passed, the scientists began seeing patterns that surprised even them. Whenever large areas of cactus disappeared, the insect populations shrank. That was expected. But something else became clear. When the remaining cactus patches were broken into many tiny pieces, the bugs found it harder to survive. Yet the greatest surprise came from the land between those patches. In landscapes where the surrounding vegetation remained healthy and natural, many insects successfully crossed from one cactus patch to another, found mates, and produced the next generation. However, where the surrounding vegetation had been cut short, the journey became dangerous. Many insects died before reaching another patch, and entire populations slowly declined. Florida explained, "The habitat is like a group of islands, but the sea between those islands decides whether travellers reach their destination." Cambridge realized that protecting the habitat alone was not enough. The surrounding landscape acted like a bridge or a barrier between isolated homes.

The team then carefully compared every landscape they had created. Surprisingly, they discovered that healthy surroundings were most valuable when habitats were still connected in a few large patches rather than being broken into countless tiny ones. Many scientists had believed the opposite: that the surrounding landscape mattered most only after habitats became highly fragmented. But Cambridge and friends found that once habitats became extremely fragmented, the patches themselves often became too small to support stable populations. Wake Forest looked across the experimental fields and quietly said, "Nature is teaching us that survival depends on three things working together: the amount of habitat, how it is arranged, and the quality of everything surrounding it." Wisconsin added, "We cannot judge a forest by looking only at what remains. We must also understand the neighbourhood around it."

Before announcing their discovery, the four friends searched through thousands of previous scientific studies. To their surprise, very few experiments had tested habitat loss, fragmentation, and surrounding landscape quality together. Their work filled an important gap in ecological science and offered a powerful message for the future.

Cambridge gathered students, conservationists, and farmers beneath a large oak tree and shared the lesson. "Saving nature is not simply about protecting isolated habitats," Cambridge said. "We must also care for the spaces between them. Those grassy fields and natural corridors are living bridges that allow life to continue." Inspired by this idea, communities restored native vegetation and reconnected fragmented habitats. Slowly, the cactus bugs began travelling safely again, proving that protecting biodiversity means caring not only for habitats themselves but also for the landscapes that connect them.



REFERENCE

Fletcher, R.J., Smith, T.A.H., Jones, M. et al. Landscape quality drives ecological responses to habitat loss and fragmentation. Nat Ecol Evol 10, 1265–1272 (2026). https://doi.org/10.1038/s41559-026-03095-1

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| By Dr. Avijit Das

DIETARY MEDICINE: THE LOST RECIPES THAT COULD HEAL THE FUTURE

Long ago, at the foot of Mount Kilimanjaro in Tanzania, there was a lively village called Mlimani. The people there followed traditions that had been passed down for generations. Every morning, children helped gather fresh vegetables from nearby farms, grandparents prepared fermented foods using old family recipes, and neighbors shared meals under large acacia trees. Among the villagers lived a curious teenager named Amani, who loved asking questions. "Why do we always eat these traditional foods?" he often wondered. "The city shops sell colorful packets of snacks and sugary drinks. Aren't those more modern?" His grandmother simply smiled and replied, "Food is not just something that fills your stomach. It teaches your body how to stay healthy." One day, a group of visiting scientists from KCMC University in Moshi, Tanzania, arrived in the village. They explained that the traditional foods of Kilimanjaro were becoming rare because more people were choosing processed foods. They hoped to understand how these ancient eating habits affected the human body before they disappeared forever.

The scientists invited Amani to join their research. First, they asked some volunteers to eat a typical Western-style diet filled with processed foods, sugary drinks, refined bread, and packaged snacks for two weeks. Others continued eating the village's traditional meals made from millet, bananas, beans, vegetables, fruits, and naturally fermented foods such as the local drink mbege. Throughout the study, the researchers carefully collected blood samples, stool samples, and health measurements. Using powerful modern technologies, they examined the tiny organisms living inside people's intestines, the gut microbiome, along with the activity of their immune systems and metabolism. The results surprised Amani. After only two weeks of eating processed foods, many volunteers showed signs of increased inflammation, and their bodies began responding differently to food. Even the helpful bacteria inside their intestines started changing. But when people returned to their traditional meals and drank mbege again, many of these harmful changes began to reverse. Amani realized that food could quietly influence the body long before a person actually became sick.

Curious to learn more, Amani traveled with the scientists to meet researchers from Makerere University in Uganda, Diponegoro University in Indonesia, Nitte University in India, and Universidade Federal de Minas Gerais in Brazil.

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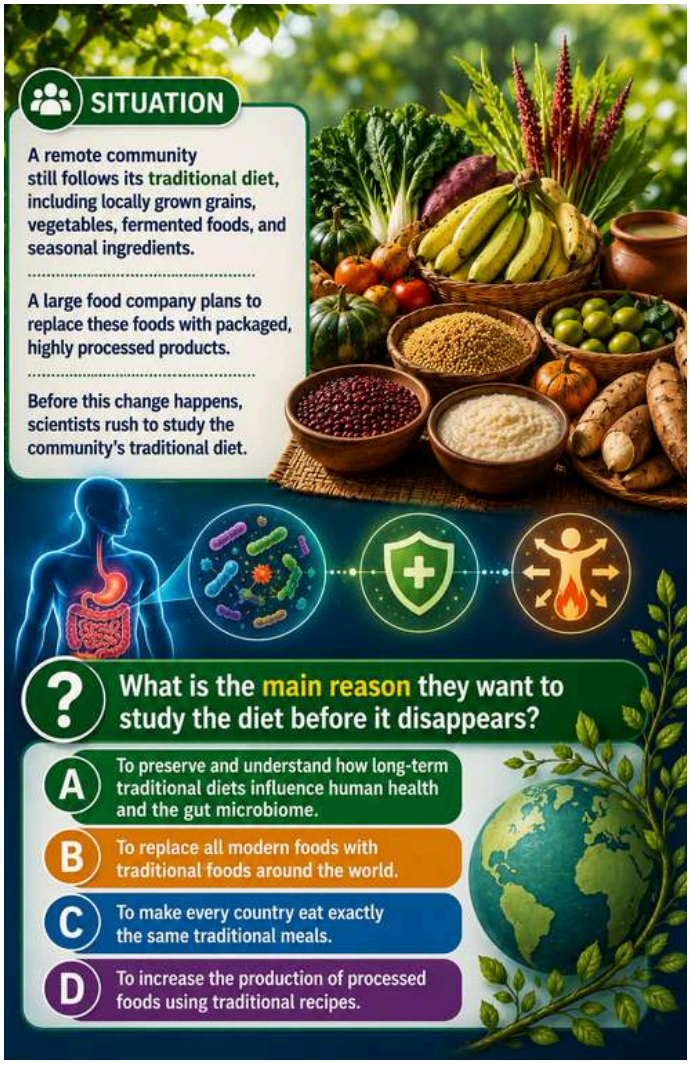
Each team shared stories from their own countries. They explained that every region had unique heritage diets shaped by local plants, climate, farming methods, and family traditions. Some communities fermented grains, others cooked colorful vegetables with local spices, while others relied on beans, roots, fruits, or seafood. These diets had developed naturally over hundreds of years and had quietly trained the immune system, supported beneficial microbes, and influenced metabolism. Yet everywhere, supermarkets and fast-food restaurants were replacing these traditional meals with similar processed foods. Although modern food systems provided convenience and year-round availability, they were also making diets across the world look increasingly alike. The scientists feared that once these traditional food cultures disappeared, future generations would never know how they had protected health or interacted with the human body.

One evening, while looking at maps filled with foods from different countries, Amani asked, "Can we save this knowledge before it disappears?" The scientists smiled and introduced him to a bold new idea called the World Diet Initiative. They explained that it would have two parts. The first would create a World Diet Atlas, a global collection describing traditional diets from every region. It would record local ingredients, cooking methods, fermentation techniques, meal timing, fasting traditions, and even customs such as families eating together. The second part, called the World Diet Project, would study how these diets affected immunity, metabolism, and the gut microbiome using the same scientific methods in every country. Researchers would collect biological samples and create an international biobank, allowing scientists to compare traditional diets fairly across continents. The initiative would also respect local communities by ensuring that they remained owners of their own knowledge while sharing discoveries with researchers around the world.

Years later, Amani became one of the scientists leading new studies across Africa and beyond. As he watched children once again enjoying traditional meals prepared by their grandparents, he remembered his grandmother's words: "Food teaches the body." He realized that the greatest treasure was not simply preserving old recipes, but preserving the biological knowledge hidden within them. Every traditional meal represented hundreds of years of interaction between people, plants, microbes, and the environment. If these diets vanished without being studied, humanity could lose clues for preventing obesity, diabetes, heart disease, and many other illnesses. Inspired by this mission, scientists from many countries joined hands through the World Diet Initiative to document these heritage diets before they disappeared forever. Their goal was not to prove that every traditional diet was perfect, but to understand the remarkable diversity of human nutrition and use that knowledge to build healthier futures for people everywhere.



REFERENCE

de Mast, Q., Brown, C.V., Mwakasungura, F. et al. Studying vanishing dietary diversity before it is lost: the World Diet Initiative. Nat Med (2026). https://doi.org/10.1038/s41591-026-04520-5

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| By Dr. Dhanashree Mundhe

REPURPOSING MEDICINES TO SLOW AGING

In the busy city of Boston, where scientists at Northeastern University and Harvard Medical School worked together to solve some of medicine's biggest mysteries, a young researcher named Nora loved asking difficult questions. Every day, she visited hospitals and met older people who suffered from heart disease, diabetes, memory loss, and weak muscles. "Why does aging cause so many different diseases?" she wondered. Her friend Harvey, from Harvard Medical School, smiled and replied, "Because aging is not just one problem. It is like a city where many roads, bridges, and power stations begin to fail at the same time." Nora knew that scientists had already discovered thousands of genes linked to aging, but no one knew how to use this knowledge to find better medicines. Creating a completely new drug could take more than ten years, so she asked a different question: "What if some medicines already sitting on pharmacy shelves could also slow aging?" Harvey thought it was a brilliant idea, and together they began searching for hidden connections between aging genes and existing medicines.

Their first challenge was enormous. They gathered information about 2,358 genes that previous studies had linked to aging. As Nora spread the data across a giant digital map, she noticed something surprising. The genes did not appear randomly. Instead, they gathered into small neighborhoods, each responsible for one of the 11 hallmarks of aging, such as damaged DNA, unhealthy mitochondria, worn-out stem cells, poor communication between cells, and shortening telomeres. Harvey compared it to a city map. "Imagine every gene is a house," he explained. "Houses with similar jobs naturally form neighborhoods." Even more interesting, some important genes acted like busy crossroads connecting several neighborhoods. One famous gene, TP53, was involved in seven different aging hallmarks. This discovery helped the scientists realize that aging is not caused by one broken system. Instead, many biological systems are connected like roads in a large city. If one neighborhood begins to fail, others are affected too.

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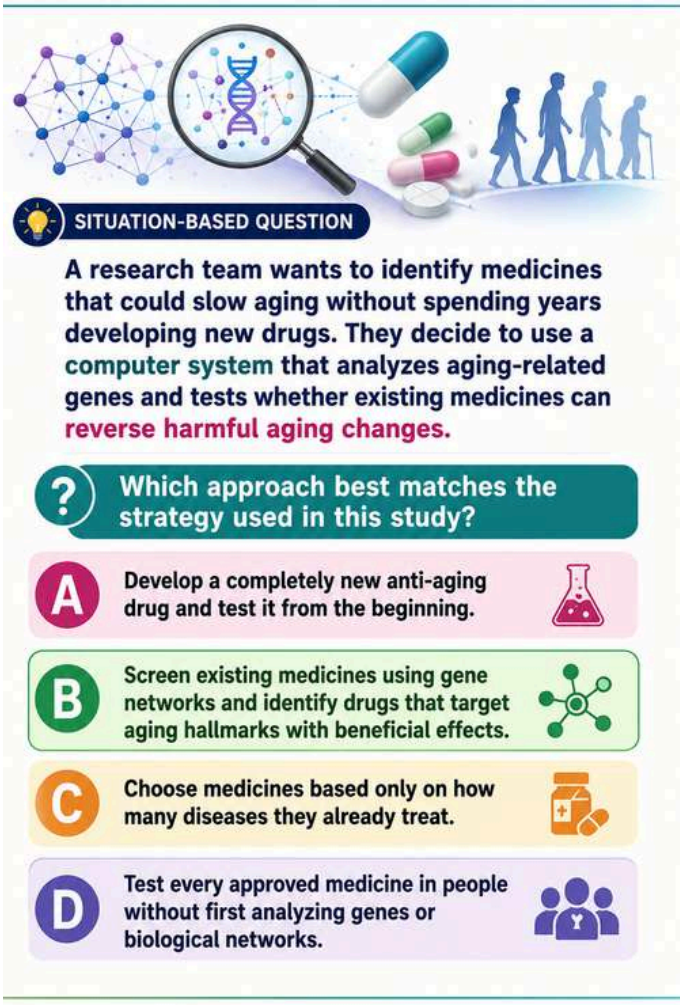
Now came the exciting part. Nora and Harvey collected information on 6,442 approved and experimental medicines. Instead of testing each drug one by one in the laboratory, they created a clever computer system that searched for drugs located close to each aging neighborhood in the gene network. They called this measurement network proximity. However, Harvey quickly noticed a problem. "A medicine may reach the right neighborhood," he said, "but it might repair the damage—or make it even worse." So they invented another tool called pAGE. This tool compared how each drug changed gene activity with the changes normally seen during aging. If a medicine reversed harmful aging changes, it received a positive score. If it strengthened those harmful changes, it received a negative score. Finally, they combined both ideas into one powerful system called SHARP, which could identify medicines that not only reached aging pathways but also pushed them toward healthier conditions.

Before trusting SHARP, Nora wanted proof that it really worked. She tested it using medicines already known to increase lifespan in mice and drugs currently being tested in human clinical trials for healthy aging. To her delight, SHARP successfully recognized nearly all of these medicines. The computer system then searched through thousands of other drugs and discovered 370 medicines that might influence one or more hallmarks of aging. Among the drugs with enough genetic data, several appeared capable of promoting healthier aging, while others seemed likely to speed aging and should therefore be studied carefully. Even more exciting, the scientists found that different medicines targeted different aging hallmarks. Some worked best on damaged mitochondria, others on stem cells, while others affected cellular senescence or nutrient sensing. It became clear that no single medicine could solve every aging problem. Instead, different drugs might one day be combined to protect different parts of the body's aging network.

As the sun set over Boston, Nora looked at the colorful network glowing on her computer screen and smiled. She realized that the greatest discovery was not a new drug but a new way of finding drugs. Instead of spending many years creating medicines from scratch, scientists could use biological networks and gene activity to uncover hidden uses for medicines that already existed. Harvey nodded in agreement. "We may never find one magic anti-aging pill," he said, "because aging is far too complex. But if we understand each hallmark and choose the right medicine for each one, we may help people stay healthier for much longer." Their work gave scientists around the world a powerful roadmap for exploring healthier aging. Although every prediction still needs careful testing in laboratories and clinical trials, the journey that began in the research centers of Northeastern University and Harvard Medical School opened an exciting new path toward extending healthy human life.



REFERENCE

Gross, B., Ehlert, J., Gladyshev, V.N. et al. Network-driven discovery of repurposable drugs targeting hallmarks of aging. Nat Aging 6, 1516–1531 (2026). https://doi.org/10.1038/s43587-026-01161-8

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By Dr. Poulami Chakraborty

THE HIDDEN HELPERS: HOW NEIGHBORING PLANTS REWIRE ROOT MICROBIOTA

In the peaceful meadows of Leiden, where scientists at Leiden University studied the secret lives of plants, a young grass named Leida loved watching the colorful plants around her. Tall grasses swayed in the wind, bright flowers bloomed nearby, and clover spread gently across the ground. Although they all shared the same field, Leida believed they were always competing. "Everyone must be trying to steal my water, sunlight, and nutrients," she thought. One morning, her wise friend Martijn, a researcher from Leiden University, smiled and asked, "Have you ever wondered if your neighbors might also help you?" Leida laughed. "How could that be? Plants cannot talk or share food." Martijn knelt beside her and gently brushed away some soil. "You may not see it," he said, "but beneath your roots lives a hidden world of billions of tiny bacteria. These invisible helpers might decide whether your neighbors become your rivals or your friends." Curious, Leida agreed to help Martijn uncover the mystery hidden beneath the soil.

Martijn began by growing six different grassland plants, including grasses, flowering herbs, and clovers, each in its own pot. As weeks passed, every plant quietly changed the soil around its roots. They released tiny chemicals that attracted different groups of bacteria, leaving behind what Martijn called a soil microbial legacy. "Think of it like leaving footprints in the soil," he explained. "Even after a plant is gone, its tiny bacterial friends remain behind." After creating these different soils, Martijn planted Leida again. Sometimes she grew alone. Sometimes she grew beside another grass just like herself. Other times she shared her pot with a completely different neighbor, such as a flowering herb or a clover. Some pots contained rich living soil full of bacteria, while others contained sterile soil where almost all the microorganisms had been removed. Leida expected the same result every time, that neighbors would slow her growth, but Martijn believed the tiny bacteria might tell a different story.

As the plants grew, the results surprised everyone. In the sterile soil, Leida struggled whenever another plant grew beside her. Without helpful microorganisms, the plants competed fiercely for every drop of water and every bit of

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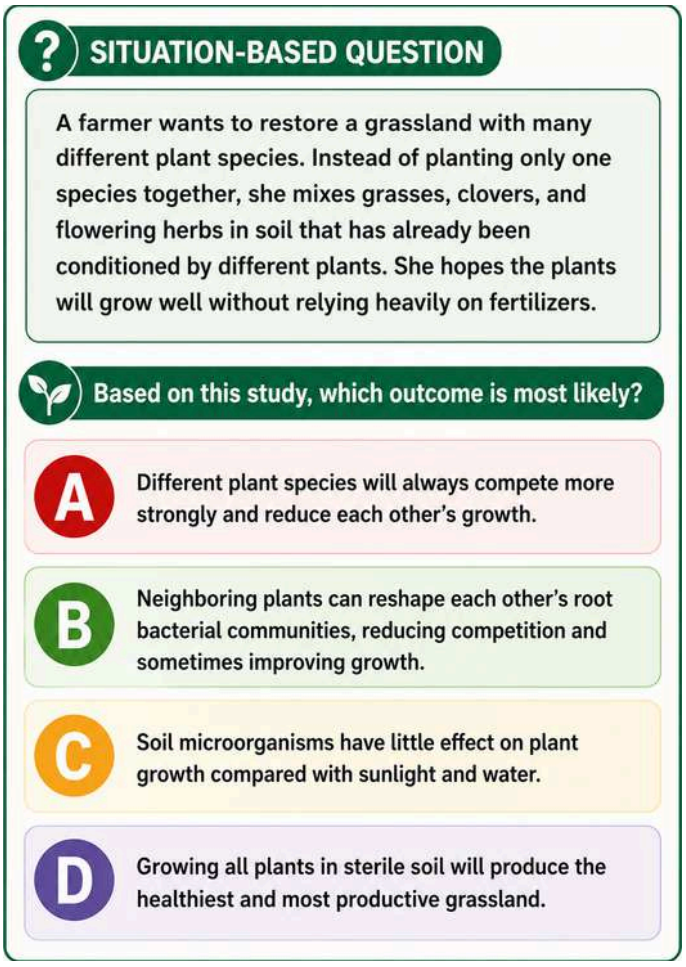
nutrition. But everything changed in the living soils. When Leida grew beside a different plant species, she often became healthier than expected. Sometimes she even grew just as large as when she was growing completely alone, and in several cases she grew even larger. Martijn then looked closely at the bacteria living on Leida's roots. He discovered something remarkable. Whenever Leida grew beside a different plant, the bacterial community around her roots slowly changed. Her bacteria began to resemble those living on her neighbor's roots. This happened most strongly when the soil already carried the microbial legacy of that neighboring plant. It was as though the neighboring plants were quietly introducing their own helpful bacterial friends to Leida, allowing the two plants to share a healthier underground community instead of simply fighting for resources.

Still, Martijn wanted proof that these bacteria were truly responsible. So he carefully collected the natural bacterial communities from the roots of plants that had grown under different conditions. He grew these bacteria separately and then added them to new seedlings growing alone in clean, sterile soil. If the bacteria really mattered, the young plants should behave just like the original ones. Once again, the results amazed the researchers. Plants that received bacteria from healthy neighbor relationships grew much better than those receiving bacteria from less favorable conditions. The bacteria themselves had changed how well the plants grew. Leida finally understood that her neighbors were not helping her directly. Instead, they were changing the invisible bacterial community living around her roots. These tiny microorganisms helped plants absorb nutrients more efficiently, protected them from harmful microbes, and created a healthier underground environment. The strongest friendships between plants were not happening above the soil where leaves touched, but below the ground where billions of invisible bacteria quietly connected one root system to another.

As the seasons passed, Leida looked across the colorful meadow with new appreciation. She realized that a healthy grassland is not simply a collection of plants competing with one another. Instead, it is a living underground network where plants, bacteria, and soil history work together. The soil remembers which plants grew there before, neighbors reshape each other's bacterial communities, and those bacteria help determine whether plants struggle or thrive. Martijn smiled as he recorded the final results of the study. "For many years," he said, "people believed plants only competed for sunlight, water, and nutrients. Now we know there is another hidden partnership beneath our feet." This discovery from Leiden University revealed that tiny bacteria form an invisible bridge between neighboring plants, helping explain how different species can live together in healthy grasslands. It also offers new ideas for sustainable farming, where choosing the right neighboring crops could naturally encourage beneficial soil bacteria, improve plant growth, reduce the need for fertilizers and pesticides, and protect biodiversity for future generations. Sometimes, the smallest unseen helpers create the greatest changes in nature.



REFERENCE

Kuerban, M., Gomes, S.I.F. & Bezemer, T.M. Neighbours rewire plant–soil feedback patterns via reshaping root microbiomes. Nat. Plants 12, 1344–1356 (2026). https://doi.org/10.1038/s41477-026-02338-0

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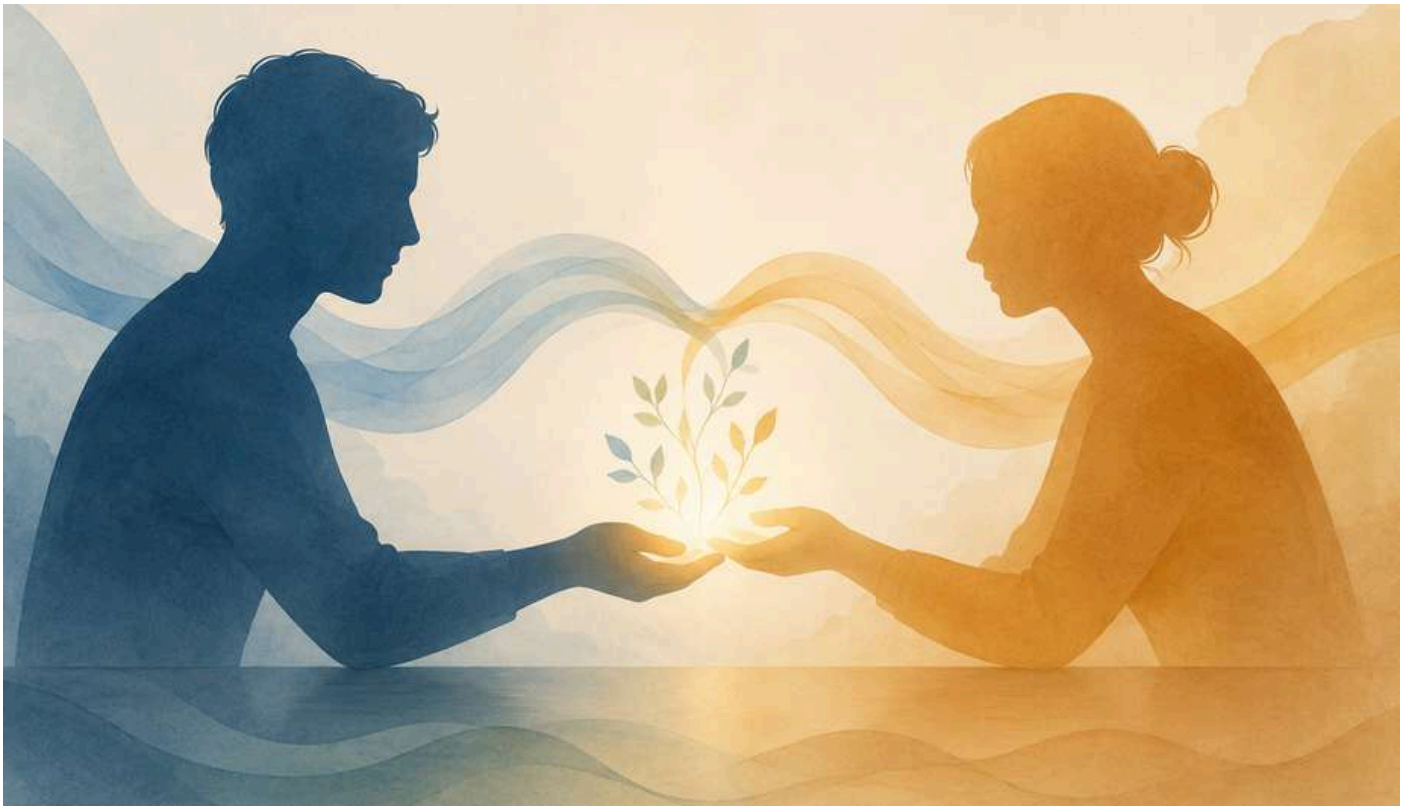
| By Dr. Sivan Friedman

INDIVIDUALISTIC AND COLLECTIVISTIC CULTURES: DIFFERENT WAYS OF COMFORTING OTHERS

In the lively city of Jerusalem, where researchers at the Hebrew University of Jerusalem welcomed scientists from around the world, a young psychology student named Shira often wondered why people comforted one another so differently. One afternoon, while walking through the university gardens, she received two phone calls. Her friend Anna from Germany had failed an important exam and was deeply upset. Shira immediately wanted to reassure her, reminding her that mistakes happen and she would succeed next time. A few minutes later, her friend Min, who lived in South Korea, called after having a difficult day at work. Instead of asking to be cheered up, Min quietly explained how the experience might help her become stronger. "Why do my friends react so differently to sadness?" Shira wondered. Curious to find the answer, she visited Professor Maya, who smiled andsaid, "Perhaps the answer is not about emotions themselves, but about the cultures people grow up in." Together they began exploring how people around the world think about helping others feel better. They hoped that by understanding these differences, people from different countries could communicate more kindly and avoid misunderstandings when offering emotional support.

The research team invited thousands of volunteers from countries including Germany, the United States, Brazil, India, China, Japan, South Korea, and Israel. They asked everyone the same simple question: When someone close to you is feeling sad or worried, how much do you want to help them feel better? As the answers arrived, Shira noticed a clear pattern. People from individualistic cultures, which value personal achievement and independence, were much more likely to reduce another person's unpleasant emotions as quickly as possible. In contrast, people from collectivistic cultures, which emphasize family and social harmony, believed that sadness, disappointment, or worry could sometimes teach valuable lessons, strengthen relationships, and encourage personal growth. Shira realized that people from different cultures were not caring more or less, they simply understood emotions in different ways. The researchers also found that these differences appeared most clearly when people were trying to manage other people's emotions, rather than their own feelings.



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Shira's curiosity grew even stronger. She wanted to know how people actually supported others when they were upset. The researchers found that people from individualistic cultures often listened carefully, expressed kindness, encouraged emotional acceptance, and helped others see hope in difficult situations. Their goal was to ease emotional pain. People from collectivistic cultures sometimes chose different approaches. They were more likely to encourage emotional restraint or thoughtful reflection instead of immediately removing unpleasant feelings. At first, Shira thought these responses sounded less comforting, but Professor Maya explained, "For many people, reflecting on difficult experiences helps them learn, become stronger, and make better decisions." Shira finally understood that both approaches came from kindness, even though they reflected different cultural beliefs. Neither approach was right or wrong; each had developed over generations to fit the values and traditions of the society in which people lived.

To see whether these differences mattered in everyday life, the researchers followed couples living in Germany and South Korea. Every day, the couples recorded how they supported one another and how close they felt in their relationships. In Germany, partners who regularly tried to make each other feel better usually reported stronger emotional bonds. In South Korea, however, simply reducing a partner's unpleasant emotions did not always lead to greater closeness because difficult emotions were often seen as meaningful rather than something that should disappear immediately. Shira realized that the same caring action could have different meanings depending on a person's cultural background. She also understood that offering emotional support requires not only kindness but also sensitivity to another person's beliefs and expectations.

As the study came to an end, Shira stood once again in the peaceful gardens of the Hebrew University of Jerusalem, thinking about everything she had learned. She understood that there was no single "correct" way to comfort another person. Some cultures teach that helping someone feel better immediately is the greatest act of kindness, while others believe difficult emotions can help people become wiser, stronger, and more connected to those around them. Professor Maya smiled and said, "Real kindness is not treating everyone the same, it is understanding what another person truly needs." Shira knew this lesson would stay with her forever. In a world where people from many cultures live, study, and work together, respecting different emotional traditions can build stronger friendships, healthier families, and greater understanding. Whether in schools, hospitals, workplaces, or homes, taking a moment to understand another person's cultural perspective can make emotional support far more meaningful. Sometimes the greatest way to help another person is not simply making them feel happier, but first understanding how they believe healing begins.

REFERENCE

Ginosar Yaari S, Chentsova-Dutton Y, Riediger M, Rauers A, Kim MY, Miyamoto Y, et al. People in more individualist cultures are more motivated to make others feel better. Proc Natl Acad Sci U S A. 2026;123(27):e2533994123. https://doi.org/10.1073/pnas.2533994123

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| By Dr. Sudha Shankar

WHY TROPICAL FOREST MAMMALS FACE EXTINCTION

Deep within the endless green rainforests of the tropics lived a young wildlife explorer named Canopy. Every morning, Canopy walked beneath towering trees where sunlight filtered through emerald leaves. Giant elephants pushed through thick vegetation, jaguars silently followed hidden trails, monkeys swung from branch to branch, and tapirs wandered beside winding rivers. To Canopy, every mammal played an important role. Elephants scattered seeds that grew into towering trees, monkeys spread fruits across the forest, and predators kept animal populations balanced. But over time, Canopy noticed the forest growing quieter. Animals that older rangers often spoke about had become rare or disappeared altogether. Empty footprints replaced fresh tracks, and camera traps that once captured magnificent wildlife often recorded nothing. Canopy wondered, "Why do some tropical forest mammals disappear while others survive? Can we predict which species are most at risk before they vanish forever?"

Determined to solve this mystery, Canopy gathered scientists from tropical forests across South America, Africa, and Asia. Together they launched one of the largest investigations ever conducted to understand why tropical forest mammals become extinct and how they can be protected.

The expedition covered 64 tropical forests across the Neotropics, Afrotropics, and Indomalaya. Instead of disturbing wildlife, the team installed hundreds of motion-sensitive camera traps that photographed animals whenever they passed. Over many years, these cameras recorded 210 different mammal species, including elephants, gorillas, pangolins, deer, tapirs, wild pigs, monkeys, and big cats. The researchers carefully studied each species. Was it large or small? Did it reproduce quickly or slowly? Did it mainly eat plants or hunt other animals? Did it spend most of its time on the ground or climbing trees? Did it have a relatively large brain that might help it adapt to changing environments? They also measured forest cover, nearby human populations, and whether the land was protected. Finally, they compared these traits at global, regional, and local scales to discover

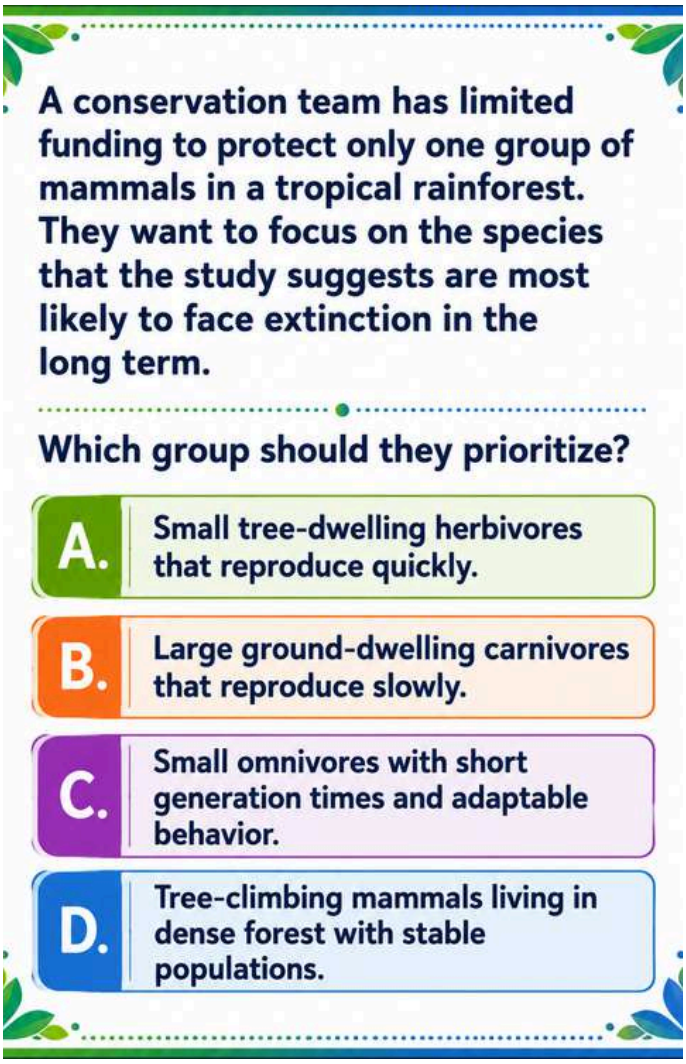
| By Dr. Sudha Shankar

whether the same characteristics predicted extinction everywhere.

After analyzing the data, Canopy and the team uncovered a remarkable pattern. Looking back over the past 130,000 years, they found that the same characteristics repeatedly increased a mammal's risk of extinction across all three scales. Large-bodied mammals faced greater danger because they needed enormous amounts of food, reproduced slowly, and were often hunted. Animals with long generation times recovered slowly after population losses. Species with smaller brains appeared less able to adapt to changing environments, while mammals that depended mainly on meat faced greater risks because their prey also declined. Mammals living mostly on the ground were usually more vulnerable than species able to climb trees, where they could escape many dangers. The researchers also found that forests with dense tree cover consistently supported healthier mammal populations. These results showed that the same biological traits have influenced extinction risk for thousands of years.

However, the mystery deepened when Canopy analyzed only animals that are still alive today, excluding species that disappeared thousands of years ago. Surprisingly, the results changed. In some protected forests, large mammals appeared to survive better than smaller ones. The team discovered why. Most modern wildlife surveys are conducted inside protected areas, where conservation programs focus on safeguarding endangered animals such as elephants, gorillas, and big cats. Because these species receive special protection from hunting and habitat loss, they often survive better than expected. Meanwhile, many of the largest and most vulnerable mammals had already disappeared long ago and were no longer included in today's surveys. This created what scientists call a shifting baseline. Each generation studies only the animals that remain, making it easy to overlook species that vanished in the distant past. As a result, studies focusing only on living species may miss the long-term causes of extinction.

Standing beneath the towering rainforest canopy one final evening, Canopy realized that the greatest lesson was not simply which animals were disappearing, but how extinction should be studied. Long-term studies reveal the traits that have made species vulnerable for thousands of years, while modern studies show how today's conservation efforts are changing those risks. Neither approach alone tells the whole story. By combining evidence from both the past and the present, conservationists can better identify species needing urgent protection. The study also showed that healthy forests remain the strongest defense against extinction, providing food, shelter, and safe breeding grounds for countless mammals. As the sun disappeared behind the trees, monkeys called through the canopy while elephants and jaguars continued their ancient journeys. Canopy smiled, knowing that understanding the past gives humanity the best chance to protect tropical forest mammals for generations to come.



REFERENCE

Simon D. Schowanek et al. ,Predictors of extinction risk in large tropical forest mammals: From global to local.Sci. Adv.12,eaeb7543(2026).DOI:10.1126/sciadv.aeb7543

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SCIENCE DESK

Rethinking Global Health: Polysectionality as an alternative policy-framework to navigate polycrisis

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Q *What inspired you to propose the concept of "polysectionality," and what problem in global health were you trying to solve?*

A Health is the most pressing human need with massive scientific developments taking place in the field of medicine and disease, globally. Yet the Covid 19 pandemic jolted the world badly. Most countries were unprepared to cope up with the emergency situation arising due to the contagion spreading at a fast speed and mutating at every stage. The large-scale casualties of pandemic brought back the debate on policy failures inspiring leading scholars to debate on the entanglement of 'polycrisis'.

The loss of precious lives and state's helplessness impacted me deeply and made me think what could be done which led me conceptualize the framework of 'polysectionality'. It is an innovative policy approach to public health providing a multidimensional policy framework which can be applied in diverse contexts.

Q *Many readers may be familiar with "intersectionality." In simple terms, what is polysectionality, and how is it different?*

A Intersectionality, as coined by Kimberley Crenshaw and further developed by Patricia Hill Collins, is a theoretical lens and social theory locating where power interlocks and intersects and its impact on Blacks and women. Polysectionality is a step towards understanding and accepting the complex, multilayered matrix of global health (or any issue) dependent on an array of factors that are viewed mainly as non-health related yet affects health deeply. Intersectionality has been interpreted in diverse ways across the world as critical theory, a method, paradigm etc. which remains significant given the stubbornness of structural inequalities yet its applicability in welfare policy remains fuzzy. Polysectionality is a conceptual policy framework addressing the issues and gaps which often leads to health policy failures. Given the genesis of intersectionality, it is rooted on a 'matrix of oppression'. On the other hand, Polysectionality is aimed towards building global solidarities among groups, communities and countries to face health crises collectively, based on a 'matrix of opportunities.'.

Q Polysectionality takes intersectionality forward in health policy research. Polysectionality is

A an advancement to the intersectional theories as it involves intra-sectional, inter-sectional and multi-sectional dimensions to various concerns such as health and climate change. Whereas intersectionality connotes the relatedness to two or more identities, polysectionality brings out the heterogeneities within the variables, focusing on intragroup/ community differences, inter-group and multisectoral diversities unravelling the often-hidden prejudices and biases missed by policymakers.

Why do you believe many global health policies fail to meet the needs of different communities, especially in the Global South?

Often global health policies take the Western framework as a blueprint and apply it by simply tweaking it to Global South countries without in-depth analysis of the issues affecting health. This is

the first major cause of policy failure. Yet even a very good policy may not succeed due to piecemeal approach focusing solely on disease-management rather than a holistic understanding of factors affecting health. Given the pressure of multiple health crisis on policymakers, they focus on immediate management rather than long-term resolution. Many a times, community engagement is kept peripheral as the communities are not treated as equals by the policy experts. A nuanced understanding of ground realities which the community's face and are much better aware of, is often forgotten once the crisis is over.

Q *Your framework highlights factors such as location, culture, economy, politics, and identity. Why is it important to consider all of these together when designing health policies?*

A Health is polycentric meaning there are multiple factors affecting it. My framework of polysectionality considers factors like location, culture, economy, identity and political will all together to fill the gaps in policy-design. Health is affected by climate-change leading to disasters like forest fires, avalanches, cloud bursts which are aggravated due to one's location and lead to differential health risks. Political will is paramount as health is a political-economy issue not merely medical. Individuals belonging to different communities and identities face health crisis differently. During my fieldwork with migrant workers during the Covid-19 pandemic, I found out how language used to disseminate health information played a decisive role in understanding the intensity of the contagion.

Q *Can you share a real-world example where a polysectional approach could have improved healthcare outcomes or reduced health inequalities?*

A There are numerous examples, but I will give you two- women and young girls suffer greater risk of communicable diseases due to socio-cultural taboos related to menstruation. They are kept outside their homes with no or limited sanitation as some communities follow practices of chhaupadi and even though the Supreme Court of Nepal made it a violation of human rights, it is still practiced. The application of political will and cultural practices as emphasized in polysectional approach, may help change mindsets. Second, vaccine hesitancy among the indigenous and tribal communities became a major issue during the pandemic. Adopting the polysectionality approach could have saved many precious lives.

Q *Looking ahead, how do you hope the concept of polysectionality will influence future global health research and policymaking?*

A I am working towards greater dissemination of polysectionality and making it more empirically evident through collaborative research and seeking global funding. As I have begun working on polysectionality only recently, I hope to develop it through rigorous comparative studies among diverse communities investigating how this approach can deliver better healthcare policy designing, implementation and training to personnels. This may attract policymakers and political leaders to take cognizance of polysectionality and adopt it in health governance.

The underlining objective of polysectionality is respecting diversities cultures and knowledge systems without compromising scientific findings affecting health. Towards this, polysectionality is to keep an open mind trying to limit our biases. It rests on the six prerequisites-acceptance by global health scholars and institutional projects worldwide that ‘decolonial’ is not only about reiterating the Global South as a field of study and experiments; Inclusion of communities as equals not mere involvement they do not have any say; respecting indigenous/local knowledge and not just to hold Eurocentric-Western know-how as scientific and superior; multidirectional knowledge exchange for open conversations, changing the mindset that knowledge emanates in Global North and flows to Global South; differential yardsticks of measurement; and contextualising health as a whole.

Reference

Dr. Papia Sengupta's contributions to the field are highlighted in her publications, (https://doi.org/10.1177/17579759261446310) and (https://doi.org/10.1080/14790718.2021.2021918).

These studies show that improving global health is not only about medicine, but also about understanding people's languages, cultures, and everyday experiences. They highlight the need for health policies that are more inclusive, fair, and better suited to the diverse communities they serve.

SCIENCE DESK

Pressure From Within or Pressure from Outside: The Role of Chemical Pressure and Externally Applied Pressure in Chemical Synthesis

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Q *Many advanced materials can only be created under extremely high pressures. What inspired your team to find an alternative approach to this long-standing challenge?*

A The evolution of logic throughout human history has taught humanity a timeless lesson: every problem appears complex until it is approached through a simple, correct approach. Another important realization is that almost everything we observe has its roots in philosophy and human behavior. Therefore, viewing chemicals as isolated and distinct entities is a fundamental mistake. Like humans, chemicals exhibit behavior, and in many ways, this behavior complements and mirrors the patterns observed in human behavior. Similarly, chemistry can be approached through behavioral analogies, where asking simple, well-posed questions often leads to profound insights.

New needs demand new materials, and in the pursuit of this goal, advances in materials science, particularly the application of high pressure, have accessed new dimensions in both the synthesis and property space of materials. Classic examples, such as the transformation of graphite into diamond, illustrate how high pressure can unlock otherwise inaccessible crystal structures, unusual oxidation states, and remarkable functionalities. Recently developed static and dynamic high-pressure- techniques have enabled the synthesis of numerous functional materials with exceptional performance, including superconductors, superhard phases, and high-energy-density- materials

However, this success naturally leads to a simple but important question: Is it possible to synthesize high-pressure phases under ambient conditions?
This question marks the beginning of our story. In searching for an answer, another thought emerges: what if the crystal lattice could experience pressure from within itself rather than from an external source? This motivates the concept of generating “internal pressure” within materials.

Q *Your study introduces the concept of "chemical pressure." What does this mean, and how can chemistry mimic the effects of extreme physical pressure?*

A The key idea is that substituting existing ions with smaller ions of the same chemical nature or with units that form stronger bonds can act like internal clamps that pull the surrounding atoms inwards, effectively simulating the compression imposed by a high-pressure apparatus-. In scientific terms, this

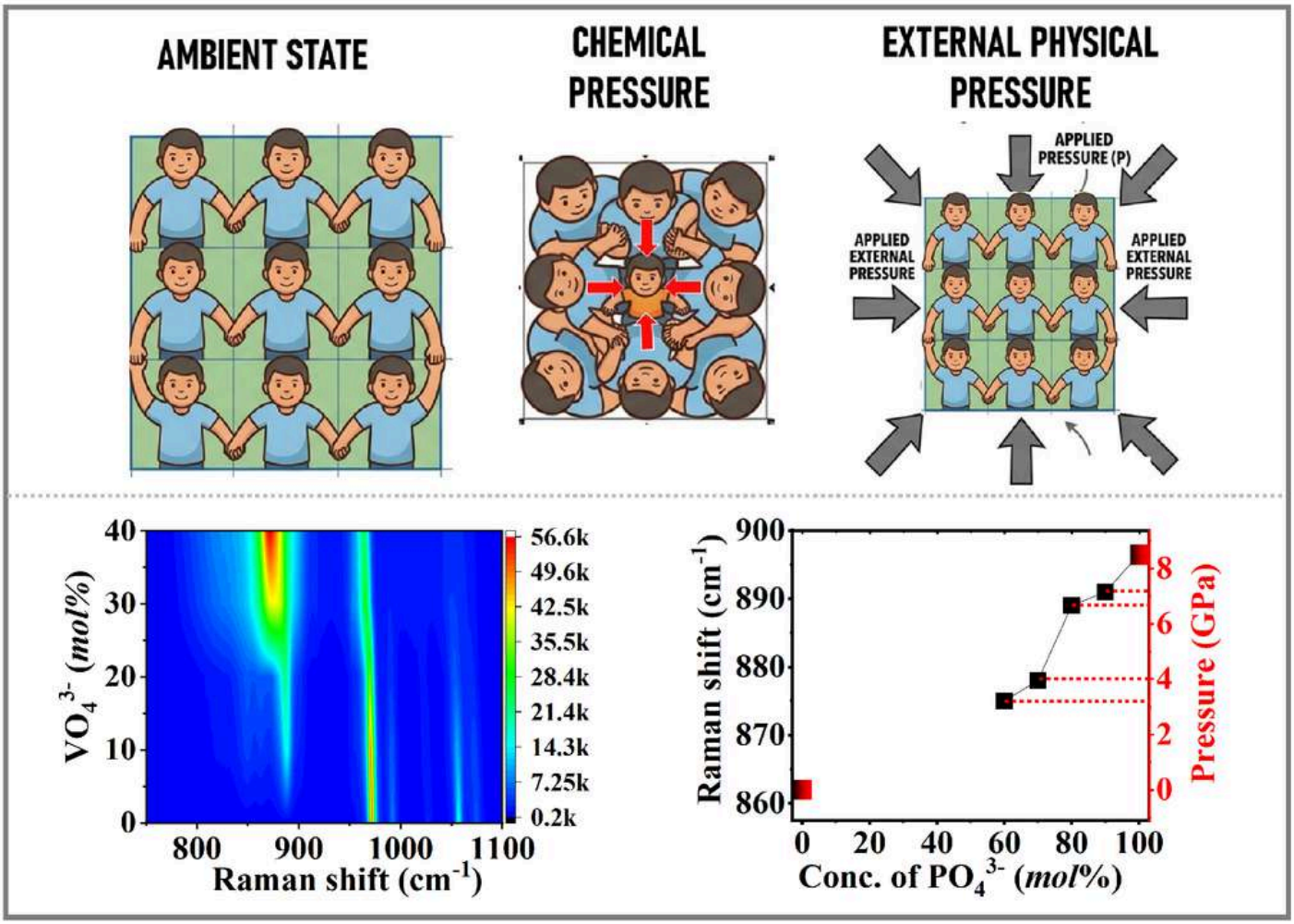

Figure 1. A pictorial representation of the scenario of chemical pressure and external physical pressure, together with qualitative and quantitative analysis of Raman mode hardening, demonstrates that chemical pressure produces effects analogous to externally applied pressure.

internally generated lattice force arising from chemically induced strain is referred to as chemical pressure. A pictorial representation of the chemical and externally applied pressures is shown in Figure 1.

Q *Why is being able to stabilize high-pressure crystal structures under normal laboratory conditions such an important breakthrough for materials science?*

A Developing ambient-pressure synthetic routes to phases previously accessible only under extreme pressures is very important, as it fundamentally expands the accessible materials genome, bringing high-pressure materials chemistry into mainstream solid-state synthesis. By eliminating the need for diamond anvils and multi-anvil techniques, this approach bridges the gap between fundamental discoveries and practical material synthesis.

Q *Your research uses phosphate substitution to achieve this transformation. Could you explain, in simple terms, how this chemical modification changes the structure of the material?*

A Selecting an appropriate host lattice to implement our hypothesis was a critical first step. Drawing on our previous work on ABO4 compounds and insights from the literature, we focused on a class of materials that are well known for their polymorphism. Many rare-earth ABO4 compounds (A = rare earth; B = tetrahedral oxyanions such as PO43- or VO43-) can crystallize in multiple structures, most notably zircon and monazite structures. High-pressure studies have shown that PrVO4 undergoes an irreversible zircon-to-monazite transformation under an external pressure of 6 GPa, and importantly, PrVO4 lies close to the zircon-monazite phase boundary. This makes it an ideal model system to test our hypothesis: can externally applied pressure be mimicked through internally generated chemical pressure by substituting

smaller PO43- tetrahedra for VO43- ?. In our PrBO4 (B = Cr, V, P) systems, the key “chemical piston” is the PO43- tetrahedron, which is significantly smaller in volume than VO43- or CrO43- in comparable coordination environments. This substitution imposes a negative chemical pressure that contracts the lattice and causes it to adopt the dense monazite structure rather than the more open zircon structure.

After extensive synthetic trials, we successfully stabilized single-phase PrV0.40P0.60O4 and PrCrO4 with monazite structures under ambient conditions. Our hypothesis of mimicking externally applied pressure through chemical pressure was validated by a systematic study of the hardening of the VO43- Raman modes with increasing PO43- substitution. A quantitative estimate of the induced chemical pressure was obtained based on certain assumptions. Although the resulting values should not be interpreted as exact equivalents of hydrostatic pressure, they provide a reasonable measure of its effect. This interpretation is further supported by the corresponding evolution of the lattice strain, which exhibits a consistent trend with the estimated chemical pressure (Figure 1).

Q *Beyond creating a new crystal structure, your materials also exhibit interesting optical and oxygen-storage properties. Why are these properties important, and where could they be applied in the real world?*

A Beyond structural transformation, these materials exhibit intriguing optical and thermochemical properties arising from the unique electronic configuration of Cr5+ (3d1), its highly asymmetric crystal-field environment, and the inherited metastability of the Cr5+ oxidation state within the monazite lattice. In PrCr1-xPxO4, Cr5+ occupies a highly asymmetric C1 crystallographic site. The combined effects of the low-symmetry crystal field and intrinsic Jahn–Teller activity of the 3d1 configuration completely lift the degeneracy of the 2E and 2T states for an ideal tetrahedral (Td) environment, resulting in five non-degenerate d orbitals. This symmetry lowering also relaxes the Laporte selection rules, giving rise to intense visible-light absorption and a vibrant green color comparable to that of conventional chromium oxide pigments, despite containing substantially less chromium. The metastability of Cr5+, coupled with the lattice defect tolerance capacity of the monazite lattice, enables low-temperature, thermochemically reversible oxygen sorption and desorption. In this process, metastable Cr5+ can reversibly cycle between Cr5+ and Cr4+ as oxygen is absorbed and released at relatively low temperatures, which is relevant for catalytic converters, solid oxide fuel cells, and chemical looping schemes for clean energy. These findings highlight a new and relatively unexplored functional dimension of the Cr5+ oxidation state.

Q *Do you believe this chemical pressure strategy can be extended to other classes of materials? What opportunities could this create for future discoveries?*

A After testing PrVO4 as a model system to validate our approach, we sought further confirmation of the strategy by extending it to the monazite polymorph of CeVO4. Moreover, Ce precedes Pr in the periodic table and exhibits only a minimal difference in ionic radius (Ce3+ vs. Pr3+), making it a suitable candidate for this investigation. We successfully stabilized the targeted phase monazite CeVO4, thereby supporting the effectiveness of our strategy. However, we believe that this approach requires further exploration, at least for systems in which high-pressure phases are separated by narrow thermodynamic stability boundaries, to achieve more robust and generalizable outcomes.

Q *Looking ahead, how might this approach influence the development of next-generation materials for clean energy, electronics, environmental technologies, or other emerging applications?*

A The ability to “dial in” high-pressure structures using chemistry alone reshapes the approach to material discovery. Rather than viewing metastable phases as mere curiosities of limited accessibility, this strategy enables the deliberate design of synthetic routes that stabilize them in macroscopic quantities and allows for the evaluation of their real-world potential.

Reference

Prof. Nagarajan and Mr. Indra Singh's contributions to this field are highlighted in their publication, in Inorganic Chemistry, (2026) (https://doi.org/10.1021/acs.inorgchem.6c00984).

SCIENCE DESK

When MRI Is Not Enough: How Genetics Is Reshaping the Diagnosis of Epilepsy

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Q *Epilepsy affects millions of people around the world. What inspired your team to investigate this genetic form of epilepsy, and why is understanding its causes so important?*

A Epilepsy is one of the most common neurological disorders, affecting nearly 50 million people worldwide. Seizure control has improved enormously, yet approximately one third of patients have drug-resistant epilepsy, a reality that can quietly reshape a person's education, work, independence and safety. For decades, the diagnostic pathway has rested on three pillars: clinical history, electroencephalography (EEG), and magnetic resonance imaging (MRI). In many patients, MRI identifies the structural substrate, such as hippocampal sclerosis, focal cortical dysplasia, tumours, vascular malformations, or developmental anomalies, which guides medical and surgical decisions.

But one question kept returning to us in the reading room: what do we tell the patient whose seizures are severe and disabling, yet whose MRI looks entirely normal? Such patients were once labelled "MRI-negative" or "cryptogenic," as though the brain held no answer. That assumption is what inspired our work. A normal scan, we came to believe, does not mean there is nothing wrong. It often means the cause lies below the resolution of our images, in the biology of the brain itself. Establishing the cause matters, because a named diagnosis carries prognostic information, permits counselling and family screening, and increasingly opens the door to treatment directed at the underlying mechanism.

Q *For readers without a scientific background, could you explain how certain genes help the brain develop normally, and what happens when these genes do not function as they should?*

A Cortical development is an exquisitely choreographed process. Before birth, neurons are generated, migrate to their destined layers, and assemble into functional networks under tight genetic control. Some of these genes act as regulators of cellular growth and proliferation, instructing cells when to divide and, equally importantly, when to stop.

Our recent study, published in Neuroradiology, examined one such regulatory system: GATOR1-related epilepsies, caused by pathogenic variants in the DEPDC5, NPRL2 and NPRL3 genes. Together these genes encode the GATOR1 complex, a key negative regulator of the mTOR signalling pathway, which governs neuronal growth, migration and cortical organisation during development. When this molecular brake fails, mTOR signalling runs unchecked, resulting in malformations of cortical development. GATOR1 variants are now recognised as one of the commonest genetic causes of focal epilepsy, in which seizures arise from a circumscribed region of the brain.

Q *Your research revealed that changes in these genes can lead to a wide variety of brain changes. What were the most important discoveries, and how do they improve our understanding of epilepsy?*

A The most striking observation from our study was the extraordinary heterogeneity of neuroimaging findings. While focal cortical dysplasia, a localised disorganisation of cortical architecture, remains the classical hallmark, our patients also demonstrated diffuse cortical malformations, generalised cerebral atrophy, and, importantly, completely normal MRI examinations despite harbouring pathogenic mutations.

This concept extends beyond GATOR1-related disorders. Many genetic epilepsies, including ion channelopathies, synaptopathies, chromatin remodelling disorders, and metabolic epilepsies, may present with normal or nonspecific neuroimaging findings. Conversely, identical genetic mutations can produce markedly different imaging phenotypes, even among members of the same family.

Q *Brain MRI is an important tool in diagnosing neurological disorders. How does your study help doctors better recognize and interpret brain changes associated with genetic epilepsy?*

A The role of the neuroradiologist has expanded accordingly. Rather than searching only for an overt lesion, we now look for subtle imaging biomarkers that may point toward an underlying molecular diagnosis. Lesion detection has improved markedly with volumetric acquisitions at high spatial resolution, dedicated epilepsy protocols, susceptibility-weighted imaging, diffusion tensor imaging, quantitative volumetry, functional MRI and advanced postprocessing. Artificial intelligence and machine learning are further enhancing detection of subtle dysplasia that may escape even experienced observers. By cataloguing the imaging spectrum associated with a defined genetic pathway, studies such as ours give radiologists a framework for recognising when a scan, including a normal one, should prompt genetic evaluation.

Q *Some people with epilepsy have normal-looking brain scans despite experiencing severe seizures. How does your research help explain this, and why is it an important finding?*

A This directly addresses a longstanding paradox: how a patient may experience frequent, disabling seizures while the scan appears reassuringly normal. The abnormality was never absent. It lay beyond the resolution of conventional imaging, residing in molecular and microstructural organisation rather than in macroscopic anatomy. Recognising this reframes MRI-negative epilepsy from a diagnostic dead end into a diagnosis awaiting the right tools, and it changes the counselling such patients receive.

Q *How can combining genetic testing with advanced brain imaging improve diagnosis, treatment decisions, and personalized care for people living with epilepsy?*

A Comprehensive genetic testing is now embedded in modern epilepsy evaluation. Targeted gene panels rapidly screen hundreds of genes associated with epilepsy; whole exome sequencing has become a cornerstone in unexplained drug-resistant epilepsy; and whole genome sequencing extends detection to structural variants, noncoding mutations and repeat expansions. Sequencing at very high depth can identify somatic mosaicism, in which mutations are confined to a small population of brain cells, an important mechanism underlying focal cortical dysplasia and many epilepsies driven by mTOR dysregulation.

The greatest value lies not in the diagnostic label alone, but in how it alters management. A pathogenic variant carries prognostic weight, enables genetic counselling and family screening, and increasingly directs targeted therapy. Inhibition of the mTOR pat-

hway in selected disorders is the clearest example of a shift from symptom suppression toward mechanism-based treatment. Genetics has likewise reshaped epilepsy surgery. Resection remains highly effective in carefully selected patients, yet seizure freedom is not guaranteed even after apparently complete lesionectomy, because the epileptogenic process may extend beyond the visible lesion as microscopic dysplasia, multifocal abnormality or widespread network alteration. Surgical planning is therefore best undertaken in a multidisciplinary setting integrating imaging, electrophysiology, genetics and neuropathology.

Q *Looking ahead, what are the next major challenges in this field, and how do you hope your research will contribute to better diagnosis, treatment, or quality of life for people affected by epilepsy?*

A Significant challenges remain, and they are of three distinct kinds. A large proportion of the variants identified on sequencing are of uncertain significance, leaving families without a definitive answer. Genotype–phenotype correlation is still imperfect: we cannot reliably predict which imaging pattern a given variant will produce, nor explain why the same variant yields different appearances in different individuals. And access to advanced imaging and sequencing remains uneven, scarcest in precisely those settings that carry the greatest epilepsy burden.

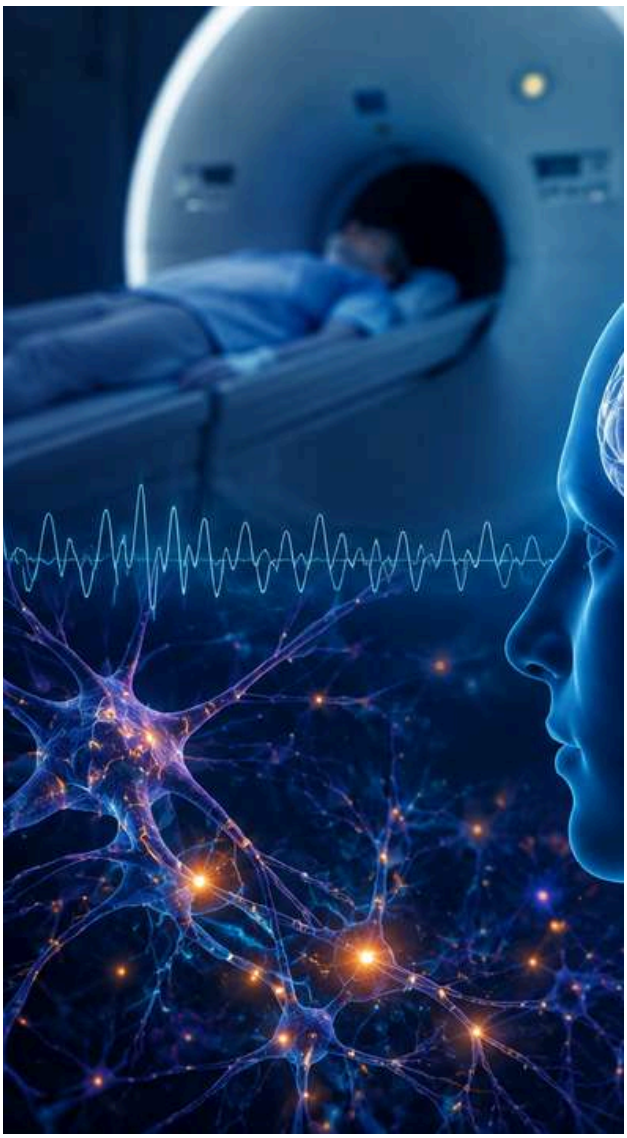
The second of these is where the clearest opportunity lies. Radiogenomics, the systematic correlation of imaging phenotypes with genetic data, seeks to make that relationship predictable in both directions: inferring a likely molecular diagnosis from the scan, and anticipating the imaging appearance of a known variant. The other two will require different remedies, namely functional validation of uncertain variants and equitable access to technology.

Looking ahead, we expect the boundary between imaging and sequencing to keep blurring. Advances in sequencing technology, transcriptomics, spatial genomics, digital pathology and computational image analysis are expected to uncover mechanisms currently beyond recognition and to enable genuinely personalised therapeutic strategies. The goal is a future in which every patient, including those with an apparently normal scan, receives an accurate diagnosis and a therapy chosen for the biology of their own brain.

For any reader drawn to this field, the central lesson is a hopeful one. A normal MRI is no longer the end of the search; it is often the beginning. By learning to read every scan, even the normal ones, as a clue to the molecular architecture beneath, we are moving epilepsy care from managing seizures to understanding the mechanism of the disease and ultimately treating them.

Reference

The authors' contributions to this field are reflected in their publication in Neuroradiology: Rb R, Ajith A, Nayak A, Radhakrishnan A, Thomas B, Kesavadas C. Neuroimaging spectrum of GATOR1-related epilepsy (GATORopathies). Neuroradiology. 2026 May 18:1–10.



SCIENCE DESK

Can Genetic Testing Predict Who Will Respond to Leukemia Treatment? New Insights into Chronic Myeloid Leukemia

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Q *What inspired you to study why some patients with chronic myeloid leukemia respond well to treatment while others develop drug resistance?*

A The There are two unanswered questions in Chronic Myeloid Leukemia (CML):

1. Why do some patients develop TKI (Tyrosine Kinase Inhibitor) resistance?
2. Why do half of the patients with Deep Molecular Response relapse during Treatment-free periods?

These two burning questions have intrigued scientists and clinicians for the last few years. TKIs block the activated tyrosine kinase produced by the BCR::ABL1 translocation, or Philadelphia chromosome, that gives rise to CML. Some patients develop resistance even to the latest-generation agents. Half of them are found to have Tyrosine Kinase Domain (TKD) mutations, mostly at the sites where these drugs attach to ABL1.

However, we still do not know the reason for resistance or treatment failure in the majority of our patients. Major CML working groups worldwide are pursuing this. India has a lot of CML patients, and unlike the western population, where CML is mostly the disease of the elderly, ours are mostly young and middle-aged adults. We need to explore more to find the answers, especially in our population.

Q *For readers who may not be familiar with the disease, what is chronic myeloid leukemia, and how has modern treatment improved patients' lives?*

A Let us break down each term of Chronic Myeloid Leukemia to understand it better.

Chronic means long-standing or slow-growing.

Myeloid refers to the myeloid lineage of cells, which gives rise to Granulocytes (neutrophils, eosinophils, and Basophils), as well as Monocytes, erythrocytes, and Megakaryocytes.

Leukemia is derived from Greek terms Leukos, meaning "white," and Haima, meaning "blood". In the mid-1800s, German pathologist Rudolf Virchow coined the term "Leukemia" to denote an increase in immature white blood cell precursors in the peripheral blood.

Now, CML arises from reciprocal translocation of the long arms of chromosomes 9 and 22, fusing BCR with ABL. The resulting BCR::ABL fusion gene sits on a shortened chromosome 22, also called the Philadelphia Chromosome, and encodes a constitutively active tyrosine kinase — an enzyme that promotes continuous cell division and prevents apoptosis, or programmed cell death. As per the late-

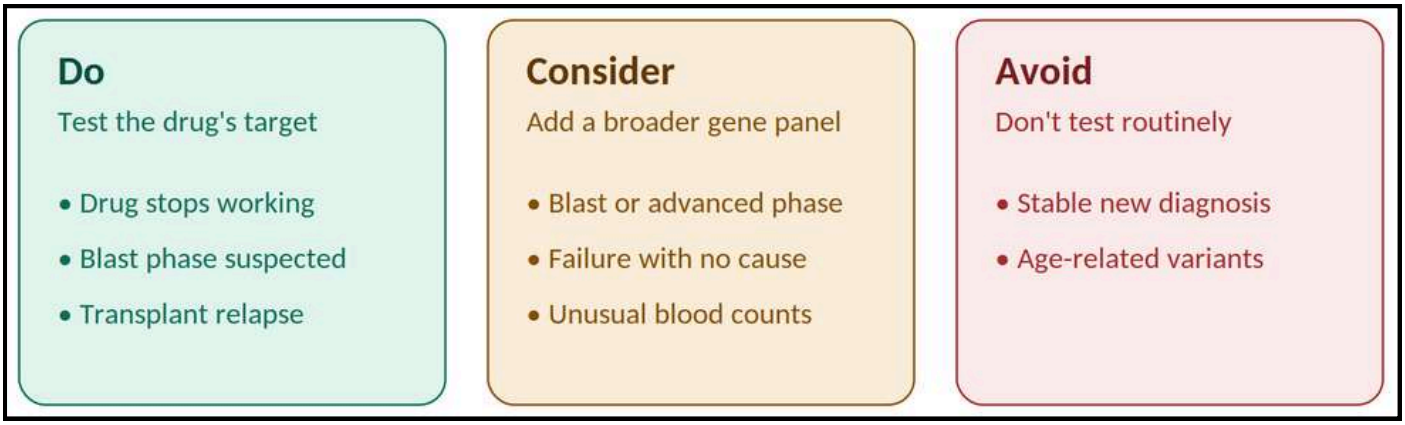

Figure 1. When genetic testing helps in chronic myeloid leukemia — and when it does not. Not every patient with CML needs broad genetic testing. Testing the drug's target is the established step when a drug stops working, when the disease may be advancing, or after a relapse following transplant — though simpler explanations, such as missed doses, drug interactions or assay quality, should be excluded first. A broader gene panel can add information in advanced disease, in unexplained treatment failure, or when blood counts behave oddly. Routine testing at a stable new diagnosis is not recommended, and age-related variants alone should not trigger a change of drug. Based on the framework proposed by the authors in reference 2.

st WHO guideline, CML has two phases: chronic, and blast crisis, where increased blasts give acute leukemia-like features.

CML has been the prototype for all malignancies. Not only was it the first malignancy to have a disease-defining mutation, but it also became the first malignancy to have a targeted therapy. That drug was featured on the cover of TIME magazine. From extended chemotherapy, CML patients began getting their disease controlled — though not cured — by a single oral tablet, which was revolutionary at the turn of the millennium. The quality of life improved drastically and with minimal expenses.

Q *Why does treatment sometimes stop working even when patients initially respond well to therapy?*

A It has been observed 20%–30% of CML patients develop resistance or treatment failure. TKD (tyrosine kinase domain) mutations are mainly discovered as causes of secondary resistance. The search for mutations that could lead to primary resistance to TKIs is ongoing. CML working groups from the US and Australia have found promising results in the form of somatic mutations that could answer all the questions. We still do not have clear answers for all our patients as to why they develop resistance or go on to develop blast crisis even while on treatment.

Q *Your study focuses on genetic testing. In simple terms, how can changes in a patient's leukemia cells help doctors predict treatment response?*

A Today, we have three generations of TKIs and some new lineage drugs, like Asciminib, which is a "STAMP" inhibitor. STAMP means specifically targeting the ABL Myristoyl Pocket, which works by binding to a specific Myristoyl pocket, effectively overcoming resistance to traditional therapies. However, we need to know the type of TKD mutation present so that an appropriate drug can be provided to the patient.

For example, T315I is the most common TKD mutation encountered in our country and across Southeast Asia. These patients have historically responded only to the third-line TKI, i.e., Ponatinib, though Asciminib now offers another option. Similarly, we have mutations that guide which second-generation TKIs, such as Bosutinib, Dasatinib, or Nilotinib, would be effective in them.

Q *How could next-generation sequencing (NGS) improve the way doctors choose treatments for patients with chronic myeloid leukemia?*

A As stated earlier, we are still searching for the reason for TKI resistance. Next-generation sequencing has opened up a vast avenue for us to investigate this gap. Somatic mutations, particularly in genes involved in epigenetic regulation, myeloid transcription, and signaling, have been found to influence disease behavior, such as blast crisis, and to occur in high-risk or TKI-resistant disease.

In the past, sequencing was a limiting factor in diseas-

e monitoring, but nowadays it is doable. We can run broad targeted myeloid panels ours covered 135 genes, detecting Single Nucleotide Variants (SNVs), Insertions and Deletions (Indels), and Copy Number Variants (CNVs). This will help us better understand the disease biology. It has been observed that Myeloid Neoplasms share a substantial repertoire of these somatic mutations, which have a long-term effect on disease progression, patients' response to treatment, and overall survival.

Q *What are the biggest challenges in using genetic testing routinely in clinical practice, especially in countries with limited healthcare resources?*

A The biggest challenge would be the cost and availability. These assays are available in metropolitan centers and larger tertiary hospitals, but the number of labs offering these services remains limited. Centers like ours struggle with the financial aspect, but in the near future, the panels will be available at a lower cost. Technology is advancing rapidly, and the main cost typically lies in library preparation and bioinformatics management.

Another challenge is the difficult decision of what to do with the result. A panel that reports a variant of uncertain significance, or a clonal hematopoiesis variant misread as a driver, can cause more harm than no test at all if it triggers an unnecessary change of therapy. So, caution is warranted in interpreting these results and modifying the further treatment of the patients.

Since the overall utility is restricted up front, a stratified approach is both good practice and cost-effective. We have described this in one of our articles, where we suggested when NGS should be done, when clinicians can consider it, and when we should avoid it altogether.

Q *Looking ahead, how do you think genetic testing and personalized medicine will change the future of leukemia treatment?*

A Data on somatic mutations in CML are increasing worldwide, and the European LeukemiaNet (ELN) has addressed this in its latest update. We would make three predictions.

First, cost will stop being the main limit. Once panels are cheap and available beyond metro cities, the real constraint becomes interpretation, which needs reporting standards and trained clinicians. This is why we have argued for a minimum reporting checklist flagging variants that may reflect clonal hematopoiesis.

Second, we expect baseline profiling to be reserved for a defined high-risk subgroup, once prospective data show who benefits. We do not know that yet, and should not test first and rationalize afterward.

Third, and most importantly, genomics may help answer the treatment-free remission question — identifying in advance who can safely stop therapy. For young and middle-aged adults facing decades of daily medication, that would be a major change.

More extensive, multicentric studies are needed, and within the next decade we might find CML paving the way in cancer management and follow-up yet again.

Reference

Dr. Shruti Mishra and Prof. Kailash Kumar's contributions to this field are highlighted in their publications in the International Journal of Laboratory Hematology (https://doi.org/10.1111/ijlh.70165) and Leukemia & Lymphoma (https://doi.org/10.1080/10428194.2026.2639051).
Their research explores how genetic changes beyond the well-known BCR::ABL1 mutation influence treatment response and drug resistance in chronic myeloid leukemia (CML). They have also developed practical guidance on when next-generation sequencing (NGS) should be used to support more accurate diagnosis, treatment decisions, and personalized patient care.

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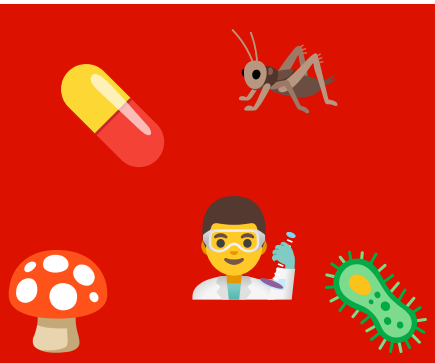


Q1

Scientists find that a field is releasing greenhouse gases. Why is it important to know exactly where these gases come from?

A. To choose the right way to reduce emissions
B. To make plants grow taller
C. To change the soil color
D. To increase rainfall

Q2

Scientists are engineering easy-to-grow yeast to produce important drug molecules. What could be a major benefit?

A. More efficient and sustainable medicine production
B. Replacing all medicines with food
C. Stopping yeast from growing
D. Eliminating all bacteria

Q3

Our muscles use glucose from the bloodstream for energy. Why can regular physical activity help control blood sugar?

A. Active muscles use more glucose
B. Exercise stops digestion
C. Muscles produce all our insulin
D. Exercise removes sugar from food

Q4

Environmental conditions can change how active some plant genes are without changing the DNA sequence. What is this called?

A. Epigenetic change
B. Photosynthesis
C. Mutation
D. Pollination

Q5

People often pause more when speaking if they are prevented from using their hands. What does this suggest?

A. Gestures can help us organize thoughts and communicate
B. Gestures prevent memory
C. Hands control our hearing
D. Speaking does not involve the brain

Q6

Some new medical treatments use controlled electrical signals instead of relying only on drugs. What is the basic idea?

A. Electricity can influence certain body functions
B. Electricity replaces all medicines
C. Patients need to be electrically charged
D. Electricity provides nutrients

Q7

We can recognize thousands of smells even though we have a limited number of odor receptors. How is this possible?

A. Different smells activate different combinations of receptors
B. Every smell creates a new receptor
C. Our ears detect smells
D. Our tongue detects all odors

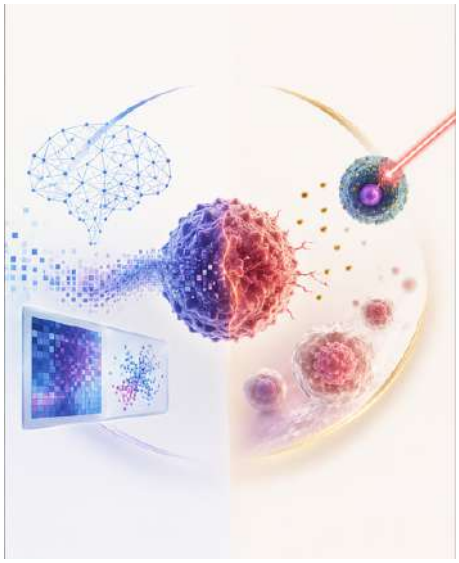
Q8

Diabetes can affect how immune cells respond to infections such as tuberculosis. What does this tell us?

A. Metabolic health can influence our ability to fight infection
B. Diabetes prevents all infections
C. Sugar kills all bacteria
D. Immunity is unrelated to metabolism

DISCOVERY HIGHLIGHTS

AI, CANCER & ADVANCED THERAPEUTICS



AI MAPS THE HIDDEN STEM-LIKE CELLS THAT HELP CANCER SURVIVE

Cancer stem-like cells can help tumors grow, resist treatment, and return after therapy, but identifying these cells across different cancers has been challenging. A new study has developed ACSCeND, a deep-learning tool that can identify different states of cancer stem-like cells using both single-cell and bulk RNA sequencing data. The researchers applied the approach to more than 25,000 tumor profiles from multiple cancer datasets. They found that tumors with higher levels of cancer stem-like cells were associated with poorer disease-free survival and reduced response to immunotherapy. The tool also revealed different molecular programs associated with distinct stem-like cell states, providing new insights into how tumors change and evolve. The findings suggest that artificial intelligence could help researchers better understand cancer stem-cell behavior and potentially identify patients who may respond differently to treatment. ACSCeND may ultimately support the development of more personalized therapies targeting cancer stemness.

Chowdhury D. et al., NAR Cancer, 2026.

LIGHT-DRIVEN NANOBOTS SHOW PROMISE FOR TARGETED BREAST CANCER THERAPY

Delivering cancer treatment precisely to tumors while limiting damage to healthy tissues remains a major challenge. A new study has developed smart light-powered nanobots designed to move toward and act on breast cancer cells. The researchers created tiny particles coated with dopamine and equipped them with folic acid for tumor targeting. When exposed to near-infrared (NIR) light, the nanobots moved directionally and responded to changes in their surrounding environment, including pH and glutathione levels. In mice with breast tumors, treatment with the nanobots combined with a 980-nm laser significantly inhibited tumor growth and reduced relative tumor volume. Because their activity can be controlled by light, these nanobots could potentially deliver therapeutic effects at a specific place and time. The findings highlight how nanorobotics and light-based technologies could contribute to more precise and minimally invasive approaches to breast cancer treatment. This approach may offer a way to concentrate treatment more selectively at tumor sites, potentially improving therapeutic efficiency while reducing unwanted effects on surrounding healthy tissues.

Srivastava S. et al., ACS Applied Materials & Interfaces, 2026.

ATMOSPHERIC SCIENCE & CLIMATE

AN UNUSUAL OZONE LAYER APPEARS OVER THE BAY OF BENGAL

The ozone layer plays a vital role in protecting life on Earth from harmful ultraviolet radiation, but its distribution in the atmosphere can change with weather and air movement. A new study has reported an unusual enhancement of stratospheric ozone over the North Bay of Bengal during winter. Researchers detected an elevated ozone layer between 21 and 23 km above Earth, with ozone levels around 50 nbar higher than typical profiles observed over the eastern Indian subtropical region. The unusual layer was approximately 2.1–2.4 km thick and persisted for more than 24 hours. Radar observations, atmospheric reanalysis and satellite measurements provided additional evidence for the event. The researchers suggest that compression of air masses and the movement of mid-latitude air into the region may have contributed to the ozone enhan-

DISCOVERY HIGHLIGHTS

cement. The findings provide new experimental evidence of how atmospheric circulation can redistribute stratospheric ozone over the Indian subtropical region.
Das S. S. et al., Earth and Space Science, 2026.

DIFFERENT TYPES OF AIR POLLUTION HEAT THE ATMOSPHERE IN DIFFERENT WAYS

Tiny particles suspended in the atmosphere, known as aerosols, can influence air quality, clouds and Earth's climate by interacting with sunlight. A global study has classified aerosols from 171 monitoring sites across six continents into seven major types and examined how each affects atmospheric heating.

The researchers found clear geographical patterns: pure dust dominated Northern Africa, mixtures of dust and pollution were common across South Asia, while urban and industrial regions in Europe and North America showed different pollution-related aerosol types. Strongly absorbing aerosols, often associated with biomass burning and black carbon, were particularly common in parts of South America, Southeast Asia and southern Africa. Importantly, these strongly absorbing aerosols produced the greatest atmospheric heating, reaching about 0.85 K per day, compared with only 0.22 K per day for very weakly absorbing aerosols. The findings provide a clearer global picture of how different airborne particles influence atmospheric energy and climate.
Mukhopadhyay S. et al., Atmospheric Environment, 2025.

SPACE, SOLAR & IONOSPHERIC SCIENCE

THE SUN'S UPPER ATMOSPHERE ROTATES FASTER THAN ITS SURFACE

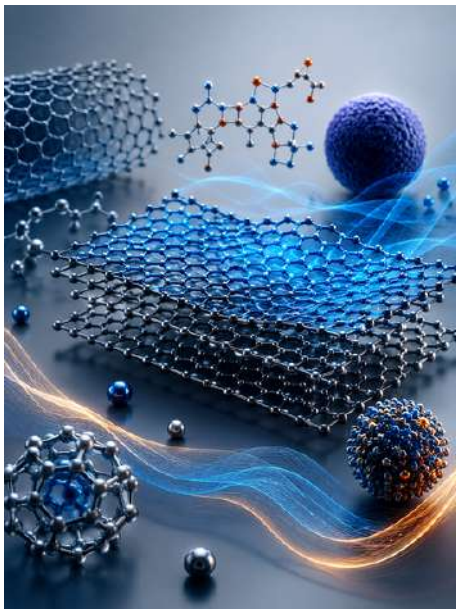
The Sun does not rotate like a solid object different regions and latitudes rotate at different speeds. A new study has used nearly three decades of radio observations, from 1992 to 2020, to investigate how the Sun's upper chromosphere rotates. Researchers analysed full-disc solar images collected at 17 GHz by the Nobeyama Radioheliograph, covering more than two solar cycles. They found that the upper chromosphere rotates significantly faster than the visible solar surface, or photosphere, across all latitudes. Its rotation pattern also showed less variation between different latitudes. Interestingly, the equatorial rotation rate showed only a weak relationship with changes in solar activity. The results demonstrate how radio observations can provide a clearer view of motions within specific layers of the solar atmosphere and support evidence that solar rotation rates may increase with height above the photosphere. Understanding these differences could help scientists better explore the complex dynamics of the Sun's atmosphere.
Routh S. et al., Astronomy & Astrophysics, 2025.

A NEW WAY TO MAP THE UPPER IONOSPHERE MORE ACCURATELY

The ionosphere, a region of Earth's upper atmosphere filled with electrically charged particles, plays an important role in radio communication, navigation and satellite systems. However, accurately measuring electron density in its upper regions remains difficult because direct observations are limited. A new study has developed an improved method for reconstructing the topside ionosphere over India using ground-based ionosonde measurements combined with satellite observations. Researchers analysed data from Tirunelveli during 2014 and 2020, representing periods of high and low solar activity, and incorporated information from COSMIC satellites to improve estimates of how electron density changes with altitude. The reconstructed profiles were independently compared with measurements from Swarm satellites. The results showed that incorporating realistic changes in atmospheric scale height significantly improved reconstruction accuracy, particularly during periods of high solar activity. The approach could provide scientists with a more reliable picture of the upper ionosphere where direct measurements are unavailable. This improved reconstruction method could strengthen space-weather monitoring over India, supporting more accurate modelling of ionospheric conditions and potentially improving the reliability of satellite navigation, communication and other technologies affected by atmospheric disturbances.
Guru K. S. K. et al., Radio Science, 2025.

DISCOVERY HIGHLIGHTS

ADVANCED MATERIALS & NANOTECHNOLOGY



A MOLECULAR REDESIGN COULD HELP LITHIUM-ION BATTERIES CHARGE FASTER

Developing batteries that can charge rapidly while remaining stable over many cycles is an important goal for next-generation energy storage. A new study has designed organic electrode materials called covalent organic frameworks (COFs) and shown that small changes to their molecular structure can significantly improve battery performance. Researchers modified the side chains of pyrene-linked diketopyrrolopyrrole-based COFs to improve how lithium ions are stored and transported. The best-performing material, Py-DKPOMe COF, reached 80% state of charge in just 61.7 seconds and retained useful capacity even at very high charging rates. Computer simulations showed that its ether-containing side chains improve lithium-ion binding while reducing barriers to ion movement, helping lithium travel rapidly through the material. The electrode also demonstrated long-term cycling stability and promising sodium-ion storage. The findings show how precise molecular engineering of organic materials could contribute to faster, durable and potentially more versatile rechargeable batteries.

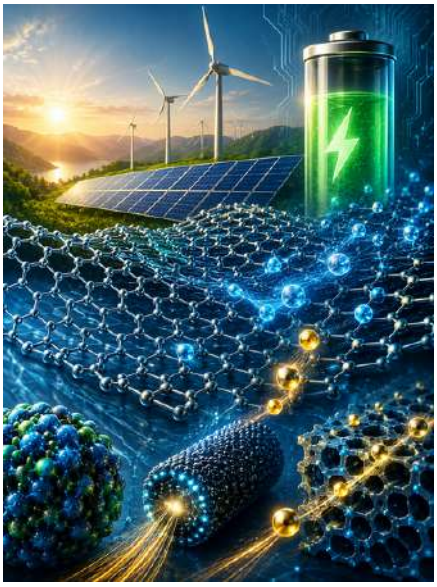
Mishra B., Ghoshal A. et al., Advanced Materials, 2026.

BOROPHENE COULD TURN PLANT-BASED OIL INTO A HIGH-PERFORMANCE LUBRICANT

Reducing friction between moving machine parts can save energy, limit wear and extend the lifetime of industrial equipment. A new study has explored borophene, an ultrathin two-dimensional nanomaterial, as an additive for improving the lubricating properties of castor oil. Researchers found that adding just 0.1% borophene by weight reduced the average coefficient of friction from 0.059 to 0.034, a reduction of about 42%. The treated lubricant also produced much smoother steel surfaces, indicating substantially reduced wear. Further analysis showed that borophene helps create a thin protective layer, or tribofilm, between moving surfaces. This layer reduces resistance during sliding while improving the material's ability to withstand mechanical loads. The findings suggest that combining borophene with renewable plant-based oils could provide a promising route toward high-performance, energy-efficient and more sustainable lubricants for machinery and engineering applications. This approach could support cleaner industrial technologies on petroleum-based lubricants.

Boruah U. et al., ACS Applied Engineering Materials, 2026.

ENERGY MATERIALS & FUNCTIONAL NANOMATERIALS



BENDING ULTRATHIN METALS COULD CHANGE HOW THEY INTERACT WITH LIGHT

Metals are widely used in technologies that control light at extremely small scales, but their optical properties have generally been considered difficult to change. A new study shows that mechanical strain can be used to tune plasmon resonances in ultrathin metals, providing a new way to control how these materials interact with light. Researchers studied ultrathin films of titanium nitride (TiN) and found that applying tensile strain produced a clear shift in their plasmon resonances compared with unstrained films of the same thickness. The magnitude of this change closely followed the amount of strain within the material. Computer calculations further suggested that strain changes the local defects and electronic structure of the metal, which in turn alters its plasmonic behaviour. The findings

DISCOVERY HIGHLIGHTS

challenge the traditional view that plasmonic properties of metals are largely fixed and could open new possibilities for mechanically tunable nanophotonic and plasmonic devices. *Dadhich D. et al., Nano Letters, 2026.*

A NEW NANOSENSOR CAN DETECT TINY AMOUNTS OF AMMONIA AT ROOM TEMPERATURE

Detecting harmful gases quickly and accurately is important for environmental monitoring, industrial safety and wearable technologies. A new study has developed an advanced nanosensor capable of detecting extremely low levels of ammonia (NH_3) at room temperature. Researchers created a hybrid material by combining vanadium oxide with flower-like vanadium disulfide (VS_2) structures. This combination improves how ammonia molecules interact with the sensor and how electrical charges move through the material. The optimized sensor could detect ammonia concentrations as low as 280 parts per billion, while maintaining strong selectivity and stable performance for more than 10 weeks. The researchers also demonstrated three potential applications: an automatic gas-triggered switch, a self-powered gas detector driven by a piezoelectric nanogenerator, and a flexible wearable sensor. The findings show how engineered nanomaterials could enable sensitive, low-power and portable gas-monitoring technologies for real-world applications. Such sensors could make continuous ammonia monitoring.
Nath V. G. et al., ACS Sensors, 2026.

ASTRONOMY AND ASTROPHYSICS

A RARE STAR SYSTEM REVEALS HOW BLUE STRAGGLERS ARE BORN

Blue stragglers are unusual stars that appear younger, hotter and brighter than other stars of the same age, leaving astronomers with questions about how they form. A new study has discovered an extremely rare X-ray-active blue straggler in the star cluster Collinder 261 that appears to be caught while it is still forming. The star is part of a binary system in which a smaller companion is actively transferring material to the blue straggler. The two stars orbit each other approximately every 2.1 days, while observations of X-rays, stellar rotation and light variations provide evidence of ongoing mass transfer. Computer modelling suggests that this process began billions of years ago and continues today at a relatively stable rate. The system provides rare direct observational evidence supporting the idea that some blue stragglers form when one star in a binary system gains material from its companion, effectively rejuvenating its appearance.
Sheikh A. H. et al., The Astrophysical Journal Letters, 2026.

A NEW APPROACH COULD MAKE LONG-DISTANCE QUANTUM COMMUNICATION EASIER

Quantum networks use entangled quantum states to transmit information, but maintaining strong entanglement across large distances remains a major challenge. In real experiments, quantum systems often produce nonmaximally entangled states, which are less effective for long-distance communication. A new study has introduced a method called General Concurrence Percolation (GCP) that uses the structure of a quantum network to establish stronger connections between distant points. Researchers tested the approach on two-dimensional lattice networks and found that GCP can create a connected network of maximally entangled states at a lower percolation threshold than existing protocols. A lower threshold means that long-range quantum connectivity could potentially be achieved with fewer or weaker initial quantum connections. The researchers also developed a mathematical model explaining why this improvement occurs. The findings provide a new theoretical strategy for building more efficient and robust quantum networks, an important step toward future large-scale quantum communication. This approach could also reduce the resources needed to maintain quantum entanglement across complex networks. By improving connectivity even when the initial entanglement is imperfect, GCP may help researchers design quantum networks that perform more reliably under realistic conditions. In the future, such advances could contribute to secure quantum communication, distributed quantum computing and interconnected quantum devices.
Nath D. & Roy S., Physical Review A, 2026.

DISCOVERY HIGHLIGHTS

EARTH HISTORY & PALEOENVIRONMENTS

ANCIENT POLLEN REVEALS 5,200 YEARS OF MONSOON CHANGE IN THE HIMALAYAS

The Indian Summer Monsoon has shaped Himalayan ecosystems for thousands of years, but its strength has varied considerably over time. A new study has reconstructed 5,200 years of vegetation and monsoon history using pollen preserved in sediments from Deoria Tal in the Garhwal Himalaya, Uttarakhand. Researchers analysed changes in pine, oak and other plant communities to identify periods of wetter and drier climate. The record revealed major hydroclimatic changes around 4,200, 3,100 and 2,000 years ago. Between about 4,000 and 3,200 years ago, warmer and wetter conditions supported denser forests, while a prolonged period of stronger monsoon rainfall occurred between roughly 2,600 and 1,000 years ago. The researchers also detected a weakening monsoon during later centuries, including conditions associated with the Little Ice Age. Interestingly, increasing agriculture around 800 years ago began to complicate the relationship between vegetation and climate. The findings show how lake sediments can preserve a remarkable natural archive of long-term monsoon variability.

Porinchu D. F., Quamar M. F. et al., Palaeogeography, Palaeoclimatology, Palaeoecology, 2026.

FOSSIL LEAVES REVEAL AN ANCIENT HISTORY OF SCREW-PINES IN INDIA

Fossil plants can reveal how today's tropical vegetation developed over millions of years. A new study has reported well-preserved fossil leaves belonging to the screw-pine family, Pandanaceae, from the Makum Coalfield in Assam, India. The fossils, identified as Pandanites trinervis, come from the late Oligocene, providing important evidence that this plant family was present in India during the Paleogene. Their distinctive leaf structure, including parallel veins and characteristic marginal prickles, helped researchers establish their relationship with Pandanaceae. Evidence from the surrounding sediments and fossil pollen suggests that these plants lived in a warm, humid landscape of freshwater swamps, river corridors and evergreen forests, similar to environments occupied by their modern relatives. The discovery fills an important gap in the fossil history of Pandanaceae and suggests that the Indian subcontinent may have served as an important region for the long-term survival and evolution of these tropical plants before their later diversification across Asia.

Bhatia H. & Srivastava G., Geobios, 2026.

ENGINEERING & SMART MATERIALS

A NEW DEVICE COULD MAKE SMART FLUIDS EASIER TO MEASURE

Magnetorheological (MR) fluids are smart materials that can rapidly change their flow properties when exposed to a magnetic field, making them useful in adaptive shock absorbers, brakes and clutches. However, accurately measuring these changing properties can be difficult. A new study has developed a modified concentric cylindrical magnetorheometer designed to provide more precise and reliable measurements of MR fluids. The instrument uses an enclosed design to prevent fluid loss, maintains consistent shear conditions and provides a more uniform magnetic field during testing. Experiments showed that the device could reliably measure how the yield stress of MR fluids changes with magnetic-field strength, iron-particle concentration, material configuration and measurement gap size. Higher concentrations of carbonyl iron particles produced greater yield stress, while larger measurement gaps

DISCOVERY HIGHLIGHTS

reduced performance. The new system could provide researchers and engineers with a more accurate platform for developing and testing magnetically controlled smart materials for advanced mechanical applications. *Singh B. K. & Sarkar C., Rheologica Acta, 2026.*

SMART FLUIDS COULD MAKE FUTURE MACHINES MORE ADAPTABLE

Magnetorheological (MR) fluids are smart fluids whose flow can be controlled using a magnetic field, making them useful in adaptive dampers, lubrication systems, valves and microfluidic devices. A new study has developed a mathematical model to better understand how these fluids move through porous channels under different magnetic and flow conditions.

The model combines the effects of magnetic forces, porous resistance, non-Newtonian fluid behaviour and interactions between the fluid and channel walls. The researchers found that stronger magnetic fields slowed the fluid, while increasing resistance within the porous material further reduced its movement. Changes in the fluid's rheological properties also increased shear stress, demonstrating how several physical factors work together to control MR fluid behaviour. By predicting these interactions more accurately, the model could help engineers optimize smart flow-control systems, adaptive damping technologies and magnetically controlled devices without relying entirely on extensive experimental testing.
Netravati B. et al., Discover Applied Sciences, 2026.

PLANT SCIENCE & AGRICULTURAL INNOVATION

RICE CAN REPAIR DAMAGED PROTEINS TO HELP FIGHT A MAJOR FUNGAL DISEASE

Sheath blight is a damaging rice disease caused by the fungus Rhizoctonia solani, but plants have their own molecular mechanisms for limiting infection. A new study has discovered that protein repair plays an important role in rice disease resistance. Researchers found that enzymes called Protein L-isoaspartyl methyltransferases (PIMTs) help rice tolerate sheath blight by repairing proteins damaged during fungal infection. Using gene overexpression, suppression and genome editing, the team showed that PIMT activity restricts fungal penetration and colonization of rice tissues. Importantly, infection damaged proteins including aldehyde dehydrogenase (ALDH) and the pathogenesis-related protein PBZ1, reducing their natural antifungal activity. PIMT repaired these proteins and helped restore their protective functions. ALDH also contributed to controlling oxidative damage and maintaining reactive oxygen species balance during infection. The findings reveal an intriguing defence strategy in which rice can repair damaged components of its own immune machinery, helping the plant withstand fungal attack.
Gautam S. et al., Nature Communications, 2026.

A NEW DATA TOOL COULD HELP BREEDERS FIND BETTER MAIZE HYBRIDS FASTER

Selecting the best maize hybrids requires breeders to compare yield, maturity and performance across many locations, making large field trials difficult and time-consuming to interpret. A new study has evaluated REMATTOOL-R, a decision-support tool designed to make this process faster, more objective and reproducible. Researchers analysed data from India's All India Coordinated Research Project (AICRP) on Maize, covering 45 entries tested across five locations. The tool simultaneously considered grain yield, flowering time, grain moisture and plant stand to identify promising hybrids. It selected five experimental hybrids that produced at least 5% higher grain yield than the standard check while maintaining comparable maturity and agronomic performance. Importantly, all five matched the hybrids independently selected for advancement through the official AICRP evaluation process, and three progressed to further advanced trials. The findings show how data-driven decision tools can complement traditional field testing, helping breeders evaluate large datasets more efficiently and accelerate the development of improved crop varieties. Such tools could make crop breeding more efficient by improving consistency across trials, reducing selection time and helping breeders identify promising hybrids earlier. This could accelerate their advancement through testing programs of high-performing maize varieties for farmers.
Neelam S. et al., Frontiers in Plant Science, 2026.

DISCOVERY HIGHLIGHTS

BIODIVERSITY, ECOLOGY & CONSERVATION

LOCAL KNOWLEDGE CAN HELP SCIENTISTS TRACK INDIA'S ELUSIVE WILD DOGS

Dholes, or Asiatic wild dogs, are elusive carnivores that can be difficult and expensive to study using conventional wildlife surveys. A new study from India's Western Ghats shows that knowledge held by people living and working alongside wildlife could provide an important additional tool for conservation. Researchers interviewed 476 forest department staff and local residents across Wayanad in Kerala and Valparai in Tamil Nadu to gather information about dhole sightings, pack sizes and interactions with other animals and people. Local observations of pack sizes closely matched findings from conventional ecological studies. Interestingly, encounters with domestic dogs were reported more frequently than interactions with other large predators, raising concerns about competition and possible disease transmission. Livestock attacks were reported to be extremely rare, suggesting relatively low levels of conflict with people. The study demonstrates that Local Ecological Knowledge can complement traditional field surveys, particularly for monitoring difficult-to-detect wildlife living beyond protected areas.

Saravanan P. et al., Scientific Reports, 2026.

CLIMATE CHANGE COULD PUSH SOUTH ASIA'S THREATENED PLANTS BEYOND PROTECTED AREAS

South Asia supports extraordinary plant diversity, but climate change and habitat fragmentation could shift many threatened species away from the places currently designed to protect them. A new study assessed the present and future habitats of 127 threatened plant species across South Asia using more than 8,500 occurrence records, climate projections and spatial conservation modelling. The researchers found that the Himalayas and Western Ghats currently contain some of the most important suitable habitats. However, future climate scenarios predict substantial habitat loss, increasing fragmentation and declining connectivity, with some scenarios suggesting that more than 80% of assessed species could lose suitable habitat by 2070. Most strikingly, researchers identified about 912,000 km² of high-priority conservation landscape, of which 85% lies outside existing protected-area networks. The findings suggest that conservation strategies may need to move beyond today's protected boundaries and incorporate climate-adaptive corridors and newly emerging habitats to safeguard South Asia's threatened flora.

Ali M. et al., Geography and Sustainability, 2026.

PROTECTING NINE SPECIES COULD SAFEGUARD INDIA'S BIODIVERSITY AND CARBON

Could protecting a few key animals help conserve much more of India's wildlife? A new study assessed 160 threatened and legally protected vertebrates and identified nine potential "anchor species," including sambar, leopard, dhole, tiger, king cobra, gaur, Indian pangolin, sloth bear and great hornbill. Researchers found that protecting the habitat of any one of these species could potentially benefit more than 700 vertebrate species while safeguarding around 1.1 gigatons of above-ground carbon. Sambar, leopard and dhole showed particularly large combined biodiversity and carbon benefits.

The findings suggest that expanding conservation beyond traditional flagship species such as the tiger could help India protect biodiversity and natural carbon together, while identifying valuable landscapes for future conservation. By prioritizing these species and their habitats, conservation programs could use limited resources more effectively while protecting wider ecological communities. The approach may also support India's future protected-area expansion and strengthen efforts to address biodiversity loss and climate change together.

Lamba A. et al., Conservation Letters, 2026.

SCIENCE IN FOCUS

INDIA-AUSTRALIA PARTNERSHIP

India and Australia Join Hands to Protect Traditional Knowledge

India and Australia have taken a significant step toward protecting traditional knowledge from inappropriate patent claims. On 9 July 2026, the Council of Scientific and Industrial Research (CSIR) and IP Australia signed an agreement giving Australian patent examiners access to India's Traditional Knowledge Digital Library (TKDL).

The TKDL is a pioneering database created to prevent traditional Indian knowledge from being mistakenly patented as a new invention. Through the agreement, IP Australia can use the database as prior art while examining patent applications, helping determine whether claimed innovations are genuinely new or already part of documented traditional practices.

Established in 2001, the TKDL contains information on more than 5.2 lakh formulations and practices from Ayurveda, Unani, Siddha, Sowa Rigpa, and Yoga. The information is available in five international languages to support patent examination worldwide.

Australia becomes the 18th patent office to gain access to the database under a non-disclosure agreement. TKDL evidence has already contributed to more than 375 patent applications worldwide being revoked, rejected, amended, withdrawn, or abandoned.

The partnership demonstrates how digital technology and international cooperation can help protect centuries-old knowledge while strengthening modern intellectual-property systems. This collaboration could become a valuable model for safeguarding traditional knowledge globally.

MULTILINGUAL AI-BOOST

AI Speaks Konkani: BHASHINI Brings Multilingual Digital Governance to Goa

India's push toward inclusive digital governance is getting a multilingual AI boost. The Digital India BHASHINI Division, in collaboration with the Government of Goa, organised the "BHASHINI Rajyam: State Engagement Workshop" in Panaji, with a special focus on expanding AI-powered digital services in Konkani.

The initiative aims to remove language barriers by allowing citizens to access government information and digital services in their preferred language. BHASHINI technologies include AI-powered translation, speech recognition, text-to-speech, transcription and transliteration, opening possibilities for voice-based public services across governance, tourism, healthcare, education and banking.

A major focus in Goa will be strengthening Konkani language datasets and improving AI models through collaboration among government agencies, researchers, language experts, academia and technology partners.

BHASHINI is already operating at considerable scale. According to the Digital India BHASHINI Division, its technologies power more than 800 government websites, have enabled over 8 billion AI inferences, and currently process more than 20 million AI inferences each day. The platform supports 36 Indian text languages and 23 Indian voice languages.

The Goa initiative demonstrates how multilingual AI could make digital public services more accessible while ensuring that regional languages remain central to India's digital transformation.

SCIENCE IN FOCUS

SCIENTIFIC INNOVATIONS BEYOND LAB

From Lab to Market: CSIR Transfers Four Indigenous Technologies to Industry

India's push to translate homegrown research into real-world technologies gained momentum as the Council of Scientific and Industrial Research (CSIR) transferred four indigenous technologies to industry and commercially launched a smart rural water-monitoring system at an event in New Delhi on 23 July 2026. Developed by CSIR-Central Scientific Instruments Organisation (CSIR-CSIO), the transferred technologies include an Induction Motor Stethoscope, a portable motor-and-pump performance monitor, and an i-Power Quality Analyser. An optical module and beam-combiner assembly for the Head-Up Display of SU-30 aircraft was also transferred to Bharat Electronics Limited. A key highlight was the commercial launch of an affordable IoT-enabled water monitoring system for rural areas. The technology is designed to monitor water quality, quantity and service delivery, potentially supporting more reliable and efficient rural water management. CSIR-CSIO also reported receiving ₹1.67 crore in royalties from Bharat Electronics Limited during FY 2025–26 for licensed indigenous military avionics technologies. The developments highlight CSIR's growing emphasis on moving scientific innovations beyond laboratories and into industry, public services and indigenous manufacturing supporting India's broader Atmanirbhar Bharat vision. Such technology transfers could strengthen collaboration between research institutions and industry, accelerate commercialization of indigenous innovations, and help locally developed technologies reach communities.

SUSTAINABLE AI

BRICS Science Academies Unite to Harness AI for Sustainable Development

Scientists and science leaders from across the Global South gathered at IIT Hyderabad for the two-day BRICS Science Academies Forum Meeting 2026, centered on the theme "Harnessing Artificial Intelligence for Sustainable Development and Strengthening Global South Cooperation." Representatives from eight BRICS member countries and five partner countries explored how collaborative, inclusive and context-sensitive AI could address some of the world's most pressing challenges.

Five areas emerged as priorities for cooperation: advanced materials and manufacturing, healthcare, climate and environmental sustainability, agriculture and food security, and disaster prediction and management. Discussions also emphasized ethical and transparent AI, data sharing, cybersecurity, linguistic diversity, capacity building and reducing the digital divide.

The forum highlighted applications ranging from AI-assisted healthcare and materials discovery to climate forecasting, smart agriculture and green hydrogen technologies. A major outcome was progress toward a Joint Statement reflecting the participating science academies' shared vision for responsible and sustainable AI. The statement is expected to be endorsed shortly and presented at the BRICS Science, Technology and Innovation Ministerial Meeting in August 2026. The meeting underscored a central message: AI can become a powerful tool for sustainable development, but its benefits must remain human-centered, inclusive and accessible across the Global South.

SCIENCE IN FOCUS

INDIGENOUS AI ECOSYSTEM

IndiaAI Mission Maps 762 AI Opportunities Across Government

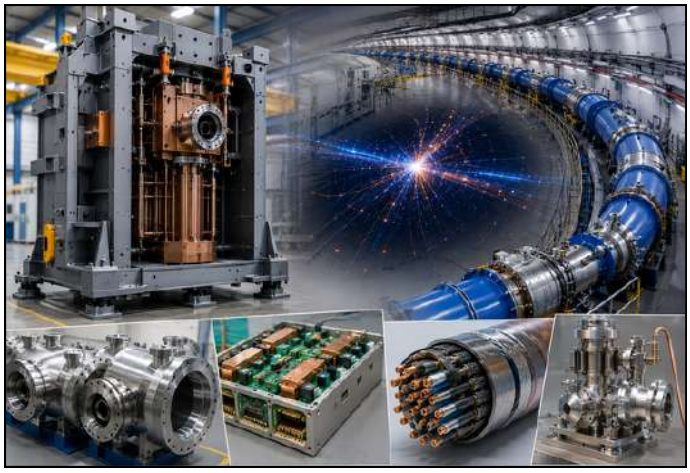
India is accelerating the use of artificial intelligence in governance and public services through the IndiaAI Mission, with 762 AI-related problem statements identified across 62 government ministries and departments. The initiative aims to apply AI to improve service delivery, operational efficiency and decision-making across sectors.

The Mission is building a broader national AI ecosystem through indigenous foundation models, computing infrastructure, AI datasets, startup financing, skills development and responsible AI frameworks. It has also launched 11 national-level AI hackathons and innovation challenges covering healthcare, agriculture, climate, cybersecurity, governance, financial regulation and other areas.

To strengthen AI capacity nationwide, the government has approved 58 AI Centres of Excellence and 543 Data & AI Labs in ITIs and polytechnics, particularly in Tier-2 and Tier-3 cities. In addition, 686 IndiaAI fellowships have been awarded across 178 institutions.

Alongside rapid adoption, the Mission is emphasizing safe and responsible AI, including privacy, algorithmic fairness, explainability, bias mitigation and independent auditing.

Together, these initiatives signal India's effort to move AI from experimentation toward large-scale, citizen-focused public services. This expansion could help make AI-driven solutions more accessible, practical and responsive, while strengthening innovation, digital capacity and citizen-focused public services across communities throughout India.



MAKE IN INDIA

India Builds Critical Beam Technology for International FAIR Mega-Science Project

India has achieved an important milestone in its contribution to the Facility for Antiproton and Ion Research (FAIR), one of the world's major particle-accelerator projects being built in Darmstadt, Germany. The first of three Indian-developed beam catcher units has reached the FAIR site and is awaiting installation.

Designed by CSIR-Central Mechanical Engineering Research Institute (CSIR-CMERI), Durgapur, under the supervision of Bose Institute, the beam catcher is a critical component of FAIR's Super Fragment Separator. It is engineered to absorb the intense remnants of high-energy heavy-ion beams used to produce radioactive beams for advanced nuclear-physics experiments.

The technology presents an exceptional engineering challenge. Each unit weighs around 40 tonnes and combines precision mechanics, ultra-high vacuum technology, graphite and high-purity copper absorbers, water cooling and radiation shielding.

India is also supplying 58 ultra-high-vacuum chambers, 932 km of specialised cables and 524 ultra-stable power converters for FAIR. Indian researchers are additionally contributing advanced detector systems for nuclear-structure, astrophysics and compressed-baryonic-matter experiments.

The achievement highlights how India's participation in international mega-science projects is strengthening domestic capabilities in precision engineering, accelerator technology and advanced manufacturing, while advancing the country's Make in India initiative.

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 SMARTER STICK FOR SAFER, MORE INDEPENDENT MOBILITY

For people who are blind or visually impaired, something as simple as walking through an unfamiliar place can present unexpected challenges. A conventional white cane is an essential mobility aid, but it generally detects an obstacle only when the cane physically reaches it. It also cannot automatically provide information about location or contact someone during an emergency. A new invention, titled "Smart Assist Stick for Physically Challenged Peoples," aims to add a layer of technology to the traditional walking stick to improve safety and independence.

The idea is straightforward: what if a walking stick could sense an obstacle before the user reaches it, warn them, and also help them call for assistance when needed?

At the heart of the smart stick is a small Arduino Nano microcontroller that coordinates several sensors and communication components. Ultrasonic sensors are positioned at different heights on the stick to detect obstacles ahead, including both low-level and mid-level objects. When an obstacle comes within a set distance, the system can warn the user through a buzzer and spoken voice prompts.

This advance warning could be particularly useful for hazards that may be difficult to detect with a conventional cane before contact. Instead of relying entirely on physical touch, the user receives information about an approaching obstacle and can respond earlier.

Another important feature is the integration of GPS and mobile communication. The stick can track the user's current or last known location. If the user becomes lost, injured, or needs urgent assistance, an easily accessible SOS button can trigger an emergency message or voice call to predefined contacts. When location information is available, it can also be transmitted to help caregivers or emergency responders locate the user.

The invention brings these capabilities together in a single portable device powered by a rechargeable battery. The design also allows possibilities such as voice prompts in different regional languages, vibration-based warnings, and periodic location updates to caregivers.

The broader importance of the invention lies in independence. Assistive technology is most valuable when it helps people navigate everyday life with greater confidence while providing additional support when something goes wrong. By combining obstacle detection, voice guidance, GPS location tracking, and emergency communication, this smart stick seeks to transform a familiar mobility aid into a more connected safety tool.

Ultimately, the technology demonstrates how relatively accessible electronic components can be combined around a very human goal: helping visually impaired people move through the world more safely and independently. Beyond its immediate functions, the smart stick could also serve as a flexible platform for future assistive technologies. Additional sensors, improved navigation systems, smartphone connectivity, or artificial intelligence could further enhance its ability to recognize surroundings and guide users. Importantly, keeping such devices affordable, lightweight, reliable, and easy to operate will determine their practical impact. Innovations like this show how thoughtful engineering can make everyday technologies more inclusive and responsive to individual needs.

INNOVATION

Jain SK, Shrivastava A, Jain H, Shrivastav P, Sharma K, Dohre H, Panchal M. Smart Assist Stick for Physically Challenged People. Indian Patent Application No. 202521132034.

📄 Shri G.S. Institute of Technology and Science, Indore, India. Published 6 February 2026.

| By Dr. Priyanka

SECURING THE QUANTUM FUTURE: A SELF-HEALING APPROACH TO DIGITAL COMMUNICATION

Every day, enormous amounts of sensitive information from personal conversations and financial transactions to government and healthcare communications travel across digital networks. Today, much of this information is protected by encryption. But the rise of quantum computing could create a new challenge: sufficiently powerful quantum computers may eventually weaken or break some of the cryptographic methods widely used today. This creates concern that encrypted information collected now could potentially be decrypted in the future.

The invention "Quantum-Resistant Group Communication with Self-Healing Key Distribution, System and Method thereof" proposes a new approach for protecting group communications against both conventional and future quantum-computing attacks.

At its core, the system combines traditional cryptography with post-quantum cryptography. Instead of relying on a single method to establish secure communication, it generates shared secrets using both a classical key-exchange system and a lattice-based post-quantum mechanism. These are combined to create a secure group key. This hybrid approach is intended to maintain protection even if classical cryptographic methods become vulnerable to quantum computers.

Managing security becomes more complicated when many people communicate within the same group. Whenever someone joins or leaves, security keys may need to change. The invention addresses this using a tree-like key-management structure. Rather than updating everything for every participant, the system updates only the affected part of the tree. This is designed to make secure communication more efficient as groups become larger.

One of the most interesting features is its "self-healing" security mechanism. Imagine that an encryption key is temporarily exposed to an attacker. Instead of leaving future conversations permanently vulnerable, the system periodically creates new keys and can also update them when security-related events occur. Compromised or outdated keys are replaced, allowing secure communication to be restored automatically without requiring users to leave and rejoin the group.

Messages themselves receive several layers of protection. They are encrypted, authenticated, and digitally signed using post-quantum techniques. The system is designed to protect message confidentiality while also helping recipients verify that messages are genuine and have not been secretly modified.

The potential importance of such technology extends beyond everyday messaging. The patent describes possible relevance to defense, finance, critical communications, mobile systems, and other security-sensitive environments.

As quantum computing develops, digital security may need to evolve with it. This invention presents one possible direction: communication systems that are not only designed to resist future quantum attacks, but can also recover their security after a key is compromised making digital communication more resilient for the quantum era.

INNOVATION

Rudra B, Renisha PS. Quantum-Resistant Group Communication with Self-Healing Key Distribution, System and Method thereof. Indian Patent Application No. 202541118182.

📄 By National Institute of Technology Karnataka, Surathkal, Mangaluru, India.

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

Dr. Amandeep Singh Oberoi
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Scientific Profile | Organization Link | Research Lab Page | Factors Press

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

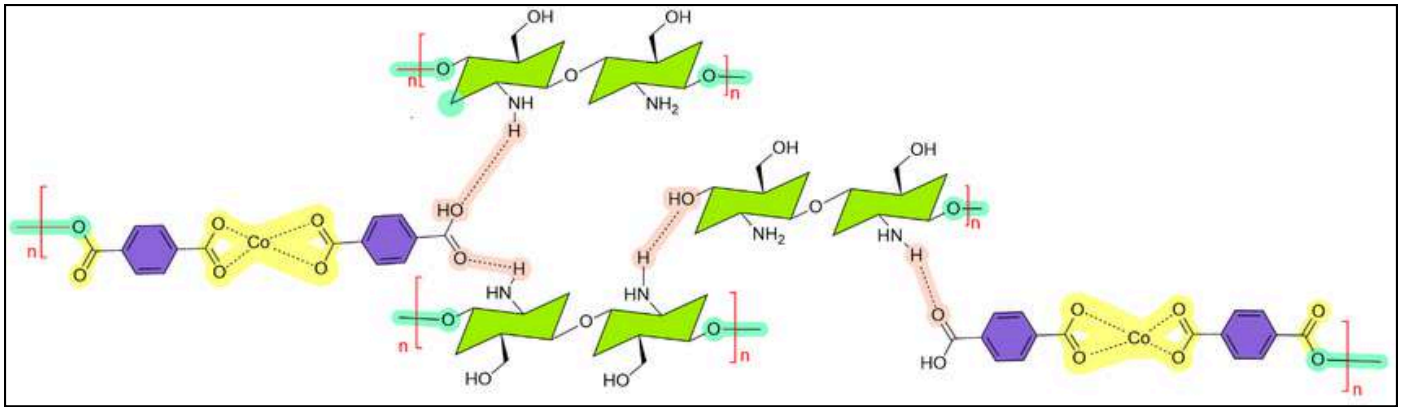
The rapid growth of transportation networks has increased the demand for road infrastructure that is durable, cost-effective, and environmentally sustainable. Conventional pavement systems often experience deterioration due to traffic loading, temperature variations, moisture intrusion, and environmental 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).

Fundamental Research to Frontline Therapy

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

AREAS OF EXPERTISE
Cell Biology | Microscopy and Image Analysis | Immunoengineering

Q *Could you briefly introduce yourself and share what inspired you to pursue a career in science and biomedical research?*

A I am Mitali Shah, and I currently work as a Senior Scientist in the Research & Development division of Immuneel Therapeutics Pvt. Ltd. based out of Bengaluru, India. As a child, I was inclined towards science and mathematics (among other interests) – I would partly attribute that to having family that, despite the lack of a formal background, was also generally interested in these fields, and a great high school biology teacher who sparked my interest in Biology. Consequently, this led me to enroll for a B. Tech in Biotechnology from Vellore Institute of Technology. It is during this period that I undertook multiple research projects and diverse internships (in both industrial and academic settings) that were instrumental in my decision to take on a career in scientific research. These experiences not only exposed me to the broader academic research ecosystem that existed in India, but I also discovered that I liked working in a laboratory, learning cell biology, thinking about experiments and making sense of data and observations. So, I would say that these experiences had the greatest impact on my decision to pursue a PhD to further train those muscles and get trained for a career in science.

Q *Your journey spans VIT, IISc, the University of Chicago, and now the biotechnology industry. What were the key experiences that shaped your scientific career and research interests?*

A I learnt my fundamentals during my undergrad at VIT, where I particularly enjoyed reading cell biology textbooks, and was also introduced to advances in cell and gene therapy through some excellent elective courses. On the practical side of things, I laid my foundation for working in a professional, academic laboratory via an IAS-NASI-INSA undergraduate research fellowship at the University of Hyderabad with Prof. Sharmistha Banerjee. At her lab, not only did I get to 'wet' my feet (rather, hands) with molecular biology experiments, but I also learnt to look at fundamental research as a sine qua non in solving real-world problems such as infectious diseases – a primary focus of her lab. Predominantly, though, it was my capstone project at the Tata Institute of Fundamental Research in Mumbai that further nurtured my fascination with fundamental cell biology, taught me how to work independently and introduced me to the power of being able to quantify biological data. Thus, for a PhD, I was keen on pursuing an inter-disciplinary research project that would allow me to delve deeper into cell biology and also train myself in advanced experimental and analytical methods for the same. I was fortunate to find myself in a laboratory working at precisely that intersection at the Department of Bioengineering at the Indian Institute of Science for a PhD right after my undergrad, which was a major turning point and the start of a transformative period of my life. The other turning point of major significance, that has shaped my research interests today, came in the third year of my time at IISc, when I joined Prof. Siddharth Jhunjhunwala's Immunoengineering laboratory and started working on an entirely new research topic for my thesis, due to a career move my previous advisor had to make. I found myself immersed in immunology research that colleagues in the lab were doing, and saw first-hand how curiosity-driven, rigorous interrogation of immune-system phenomena can lead to a more

precise understanding of their working and therefore help inform potential clinical interventions or applications. Now, in the industry, I'm furthering this research interest by exploring how the same happens at a commercial level where translation to a real-world solution is significantly faster, which makes pursuing this kind of research extremely gratifying as well. Additionally, towards the end of my PhD I worked on developing a live-cell imaging assay at Prof. Yamuna Krishnan's laboratory of chemical biology at the University of Chicago. This experience reinforced, once again, how much inter-disciplinary exchanges and perspectives have to offer to biological research – particularly given how so many of the toolkits we use to probe biology, and even our fundamental understanding of biomolecules, have all emerged from pathbreaking work in chemistry. Combined, these experiences have taught me to be open and keen about my research interests, and inspired me to continue exploring newer ways of looking at problems.

Q *During your PhD, you studied how immune cells process and respond to foreign particles. Why is understanding these fundamental biological processes important for developing future medical treatments?*

A My PhD research focussed on understanding a cellular process called 'phagosome maturation', which is a term denoting the events that take place inside a certain kind of immune cell after it engulfs foreign matter - like harmful pathogens, as part of the body's immune response. While my work does not directly lead to a therapy or any other application, it adds to our understanding of how immune cells decide the fate of the material they engulf – and this process represents one of the central defence and housekeeping mechanisms of our bodies. By understanding how it is governed at a molecular level, we can now design interventions that precisely regulate immune cell functions via those mechanisms. The development of new and effective medical treatments often depends on knowing how healthy cells work, before we can safely modify them, and fundamental research is essential to get us to that point. Historically, new developments in medicine have often traced their origins either to sheer serendipity or on the back of years, if not decades, of careful experimentation – however, in each case, progress has also depended on astute observations and systematic, curiosity-driven exploration rooted in fundamental science.

Q *Many students wonder whether basic research has real-world value. How has your own journey demonstrated the connection between laboratory discoveries and healthcare innovation?*

A The value of fundamental research is easy to underestimate until one looks closely at where some of the biggest medical breakthroughs in recent times have actually come from. mRNA vaccines, deployed at unprecedented speed during the COVID-19 pandemic, were built on decades of basic research into RNA biology. CRISPR-Cas9 technology, a gamechanger in the field of gene editing, emerged from scientists trying to understand how bacteria defend themselves against viruses. Sometimes, the discoveries made through basic research can kickstart entire fields by themselves, which can then go on to bring about varied clinical applications – which is what the discovery of induced pluripotent stem cells did for regenerative medicine. In each of these cases, the clinical application arrived because of years of curiosity-driven work that wasn't necessarily chasing an application at the start. My own journey so far has only reiterated this general principle, applicable far beyond landmark discoveries alone. For example, even in the industry or early-stage research setting, where the questions being asked are usually more focussed, they are still thoroughly rooted in fundamental scientific principles. And, answering them still requires standing on the shoulders of giants – drawing directly from the basic research that came before. Development is dependent on the same systematic exploration, statistical rigour and reproducibility that fundamental science demands.

While the goals might be different in both the settings, there is no escaping basic biology – eg, one cannot design a drug against a target without first understanding the target's biology. I have been fortunate to have laid my scientific career's foundations with fundamental research.

It has instilled in me the joy of asking questions and doing science for its own sake, and not only does this give me a perspective that I value immensely in my day-to-day work, it also continues to inform the choices I make in my scientific career.

Q *You currently work on developing advanced cell therapies for cancer. For readers hearing the term for the first time, what is CAR-T therapy, and why is it considered one of the most exciting advances in modern medicine?*

A CAR-T therapy has been one of the biggest recent advances in the management of certain types of blood cancers. It is an exciting innovation because it represents an entirely new category of cancer therapy viz. adoptive cell therapy. CAR stands for Chimeric Antigen Receptor, and essentially this therapy helps convert a patient's own immune cells (T cells) to highly specific and efficient destroyers of cancer cells. This is achieved by drawing T cells from the patient's blood, and then modifying their DNA so that they express a synthetic receptor – the 'CAR' on their surface. This receptor is designed in the lab to recognize a specific protein found on the surface of the patient's cancer cells and trigger the destruction of that cancer cell. Once re-infused into the patient, these genetically engineered T-cells circulate through the body as they expand, seek out cells bearing that target protein, and destroy them directly. Unlike conventional modes of therapy such as chemotherapy or radiation - which attack rapidly dividing cells and healthy tissue indiscriminately, CAR-T therapy is highly specific and works as a "living drug" - the therapeutic agent is a genetically modified cell that can multiply, adapt, and persist in the body. This August marks nine years to the approval of the first therapy of this kind for use in cancer patients, and while we still await substantial long-term data, CAR-T therapy has been successful in producing long-term remissions in certain cancers where previous lines of treatment had proven to be ineffective. Given these promising results, current research worldwide is pushing CAR-T in several directions at once - expanding it to more cancer types, improving how the engineered cells function once inside the body, engineering CAR-T cells directly inside the patient's body, and developing off-the-shelf versions that don't require using the patient's own cells, to name a few. Together, these efforts at innovation make CAR-T cell therapy one of the most active and exciting frontiers in cancer medicine today.

Q *One of the major goals in the field is making advanced therapies more accessible. What are the scientific and practical challenges involved in making CAR-T therapy affordable and available to more patients, what is the role of startups for the same?*

A Like I mentioned earlier, CAR-T therapy is personalised, precision cancer therapy, and therefore scaling the therapy remains one of the biggest practical challenges in this field. The nature of the therapy makes it notoriously expensive and logistically complex everywhere it exists and thus inventive approaches are needed to make it available to more patients in a resource-constrained healthcare ecosystem such as ours. Startups are uniquely poised to bridge the gap between the innovation that can bring about these changes and their translation, by being close enough to the science to translate it faithfully, while working with the urgency and focus needed to develop an approved product that meets strict quality standards. In India, specifically, public sector bodies such as BIRAC have also provided support, and such public-private partnership that shares risk across entrepreneurial teams, government funding bodies, and academic and medical institutions are key to bringing these cutting-edge technologies closer to patients. Thus, beyond innovation in the science and deep-tech alone, institutional readiness with respect to quality, manufacturing, regulatory navigation, and cost-engineering go a long way in ensuring that the science translates to the bedside, accessible to patients who need it the most.

Q *For students interested in following a similar path, what academic choices, laboratory experiences, or technical skills would you recommend they develop during their undergraduate and postgraduate studies?*

A I think everyone embarks on their own unique journey, no two paths look alike. And so, before I list specifics, I'd be remiss not to mention that there is no single blueprint one has to follow – mine or anyone else's, to get to wherever one is going. That said, for undergraduate and postgraduate students interested in working in research, be it academic or in the industry, I would highly recommend reaching out to people working in areas of your interest to intern with such laboratories/companies.

Especially during your undergrad, it can be worthwhile to take up a variety of internships by working in different labs or roles, and to try and explore the breadth of what biotech has to offer – not only

does this increase your skill set as a student, it will also provide you with experiences that will help you understand the kind of work you would enjoy doing (or not doing) after your studies. Additionally, willingness to learn and a curious mindset will often take you places where your skillset alone would not, so always nurture that. As for during your postgraduate studies, the same advice applies with the scope likely being constrained by your research interests and roles that you are curious about.

Q *The future of healthcare increasingly relies on collaboration among biologists, engineers, clinicians, and data scientists. How important is interdisciplinary thinking in today's biomedical research environment?*

A We are certainly well into the era of interdisciplinary collaboration – to the point where I believe that it is now indispensable for the progress of modern biomedical research. In fact, I would say that the roles you mention are beginning to blur too, as the depth of interdisciplinary collaboration continues to increase in both academic and industrial research settings – when people across various roles and disciplines collaborate in a manner that they are not just a part of the pipeline pushing a project forward to the next team of experts, but engaging and building effective studies or programs together, the distance between an insight and actionable steps that ultimately make research move faster is compressed significantly. Fortunately, this is also something modern interdisciplinary departments at academic institutions have been well aware of for a while now and thus have been actively training their students for it, and thus interdisciplinary thinking is here to be the mainstay of contemporary biomedical research. This most certainly does not take away from the value of being proficient in your chosen field of interest – but that alone should never be the whole story. The most interesting areas in research in general today are at the interfaces between specialties, and when one is able to understand enough of the adjacent fields complementary to their own expertise, is when genuine collaboration and breakthroughs precipitate.

Q *Looking ahead, what emerging developments in immunology, biotechnology, and cell therapy excite you the most, and what message would you like to share with students who aspire to contribute to the next generation.*

A I am really excited about the current cell therapy space – there is so much active research happening in the area and the space is fertile for some impactful therapies to emerge. We are already beginning to see other immunoengineering approaches for cancer come up such as TCR-T cell therapy, natural killer cell-based therapies and cancer vaccines, but more importantly, we are also seeing the immunoengineering toolkit developed for CAR-T cells being applied to autoimmune diseases, fibrosis and persistent infectious diseases. This is indicative of its potential of expanding from a narrow oncology tool to a multi-purpose platform for engineering biology to solve otherwise intractable problems.

As for a message to students, I would like to share something that I know has been my cornerstone in my very brief career so far - keep the original excitement and sense of wonder alive in you without letting the scale of these difficult, stubborn problems intimidate you as you begin to dent the frontiers of human knowledge. It is the former that likely inspired you to get to this place and it is also what will make you ask curiosity-driven questions and stay persistent long enough to follow wherever those questions lead you.

| OBITUARY |

M. P. Parameswaran

THE SCIENTIST WHO TOOK SCIENCE TO THE PEOPLE

(Jan 1935 – Aug 2026)

India has lost a remarkable figure in science, education and public engagement. Dr. M. P. Parameswaran, nuclear engineer, educator, author and one of the leading figures of India's people's science movement, passed away on 11 August 2026 in Thrissur, Kerala, at the age of 91. His life represented an important philosophy of science, the belief that scientific knowledge should not remain confined to laboratories, universities and research institutions, but should reach ordinary people and contribute meaningfully to society.

Born on 18 January 1935 in Kiralur, Kerala, Dr. Parameswaran developed an early interest in science and engineering. He studied engineering at the College of Engineering, Trivandrum, before joining the Bhabha Atomic Research Centre (BARC) in Bombay. He later pursued advanced studies at the Moscow Power Engineering Institute, where he earned his PhD in Nuclear Engineering in 1965. His early career coincided with an important period in the development of India's nuclear science and technology programme, and he remained associated with BARC until 1975. Between 1969 and 1973, while on deputation from BARC, he also served as Assistant Director of the State Institute of Languages in Kerala.

Although nuclear engineering formed the foundation of his scientific career, Dr. Parameswaran would become especially known for something that extended far beyond the laboratory. He strongly believed that science should be understandable and accessible to everyone, regardless of educational or social background. This conviction eventually transformed the direction of his career. In 1975, he left his professional position to devote himself full-time to the Kerala Sasthra Sahithya Parishad (KSSP), which developed into one of India's most influential people's science movements.

For Dr. Parameswaran, science communication was not simply about explaining scientific facts. He believed that scientific thinking could encourage people to ask questions, examine evidence, challenge misconceptions and make better-informed decisions. Through KSSP, scientific ideas were taken directly to communities through books, educational programmes, public campaigns and grassroots activities. Teachers, students, scientists, writers and members of the public became participants in a broader effort to strengthen scientific awareness. The success of the movement in Kerala subsequently inspired science communication initiatives in other parts of India.

Dr. Parameswaran also played an important role in taking the people's science movement to the national level. In 1987, he served as Convener of the National Organising Committee of the Bharat Jan Vigyan Jatha, a major science communication initiative designed to bring scientific awareness directly to communities across the country. He was also instrumental in the establishment of the All India People's Science Network (AIPSN), which provided a common platform for organizations engaged in public science communication and scientific awareness.

His commitment to public education extended naturally to literacy. Dr. Parameswaran recognized that literacy and scientific awareness were deeply connected, because access to knowledge becomes truly empowering only when people have the ability to understand, question and use it. In 1990, he played an important role in organizing the Bharat Gyan Vigyan Jatha in support of India's National Literacy Mission. This initiative contributed to the broader literacy movement and the development of the Bharat Gyan Vigyan Samiti. His involvement demonstrated his belief that literacy, education and scientific thinking were interconnected elements of social progress.

One of Dr. Parameswaran's greatest strengths was his ability to communicate difficult scientific ideas in language accessible to general readers. He wrote 29 popular science books in Malayalam and two in English, in addition to more than 300 articles in various periodicals. His intellectual interests were remarkably broad, covering subjects such as radioactivity, nuclear science, astronomy, mathematics, ecology, science, technology and society.

OBITUARY

Through these writings, he helped bring subjects that might otherwise have seemed highly technical or inaccessible closer to ordinary readers. For generations of Malayalam readers, his books provided an opportunity to encounter and appreciate science beyond the formal classroom. His contributions to science writing and education received considerable recognition. He received Government of India awards for Books for Neoliterates in 1962 and Basic and Cultural Literature in 1964, as well as recognition for his contribution to children's literature. In 2022, he was honoured with the Kerala Sree Award, one of the major civilian honours presented by the Government of Kerala, recognizing a lifetime of contribution to society.

Dr. Parameswaran's interests also extended to the relationship between language and technology. During his association with the Kerala Institute of Languages, he contributed to efforts to develop a Malayalam keyboard layout for typewriters, work that became increasingly relevant as Indian languages entered the digital era. This reflected another defining feature of his career: his willingness to connect science and technology with practical social needs. Whether he was dealing with nuclear engineering, literacy, language, ecology or public education, his central concern remained remarkably consistent, how knowledge could be made useful, understandable and accessible to people.

The life of Dr. M. P. Parameswaran also reminds us that the impact of a scientist cannot always be measured only through research papers, patents or technological discoveries. Some scientists expand the boundaries of knowledge, while others create technologies that transform society. There are also scientists who perform another essential role: building a bridge between science and the people it is ultimately intended to serve. Dr. Parameswaran devoted much of his life to building that bridge.

His journey from nuclear engineering to grassroots science communication demonstrated the extraordinary breadth of what a scientific career can accomplish. He showed that scientists can contribute not only by generating new knowledge, but also by helping society understand, question and use that knowledge.

For young scientists, teachers and science communicators, his life carries an enduring message: scientific knowledge becomes more powerful when it is communicated clearly, shared widely and connected with people's everyday lives.

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.

7 August 1925 — M. S. Swaminathan

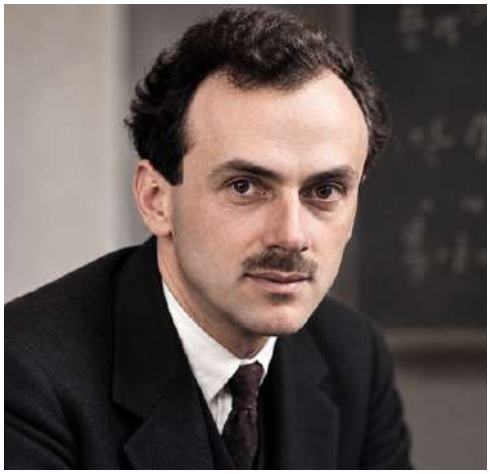
01

M. S. Swaminathan was an Indian geneticist, plant breeder and agricultural scientist who played a major role in India's Green Revolution. Working with Indian and international scientists, including Norman Borlaug, he helped introduce and develop high-yielding wheat varieties suited to Indian conditions. These advances, together with improved agricultural practices, contributed greatly to increasing food production and strengthening India's food security. Swaminathan later championed the idea of an "Evergreen Revolution," emphasizing that increases in agricultural productivity should be environmentally sustainable. His work influenced crop improvement, biodiversity conservation, sustainable agriculture and food security in India and around the world. He was awarded the first World Food Prize in 1987.

8 August 1902 — Paul Dirac

02

Paul Dirac was a British theoretical physicist and one of the founders of modern quantum mechanics. His most famous achievement was developing the Dirac equation, which brought together quantum mechanics and Einstein's special theory of relativity to describe electrons. Remarkably, his equation also predicted the existence of a particle identical to the electron but carrying a positive charge, the positron, later experimentally discovered as the first known example of antimatter. Dirac's mathematical ideas became fundamental to quantum field theory and modern particle physics. He shared the 1933 Nobel Prize in Physics with Erwin Schrödinger for discoveries that advanced atomic theory. His work continues to influence our understanding of matter, antimatter and the quantum world.



8 August 1931 — Roger Penrose

03

Roger Penrose is a British mathematical physicist whose work transformed our understanding of black holes, gravity and the structure of the universe. Using powerful mathematical methods, Penrose demonstrated that black-hole formation is a natural consequence of Einstein's general theory of relativity under realistic conditions. His work on gravitational collapse and singularities became fundamental to modern astrophysics and cosmology. Penrose has also contributed widely to geometry, mathematics and fundamental physics. In 2020, he received half of the Nobel Prize in Physics for showing that black-hole formation is a robust prediction of general relativity. His research provided an important theoretical foundation for understanding some of the most extreme objects in the universe.

12 August 1887 — Erwin Schrödinger

04 Erwin Schrödinger was an Austrian physicist and one of the central architects of quantum mechanics. In 1926, he developed the famous Schrödinger equation, which describes how the quantum state of a physical system changes and made it possible to calculate the behaviour and energy levels of electrons in atoms. The equation remains one of the foundations of quantum physics and is essential to fields ranging from chemistry and materials science to modern electronics. Schrödinger also became widely known for his famous “Schrödinger’s cat” thought experiment, created to illustrate the unusual implications of quantum theory. He shared the 1933 Nobel Prize in Physics with Paul Dirac for their contributions to atomic theory.

12 August 1919 — Vikram Sarabhai

05 Vikram Sarabhai was an Indian physicist, institution-builder and visionary who laid the foundations of India’s space programme. Born in Ahmedabad, he conducted important research in cosmic rays but is remembered especially for recognizing how space technology could support India's development. Sarabhai promoted the use of satellites for communication, education, meteorology and natural-resource management at a time when space exploration was largely associated with major global powers. His vision helped shape the programme that eventually developed into ISRO and led India toward indigenous satellite and launch capabilities. He also strongly supported science education and established institutions including the Community Science Centre in Ahmedabad. Sarabhai’s vision continues to resonate through India's modern achievements in satellites, planetary exploration and space technology.

15 August 1892 — Louis de Broglie

06 Louis de Broglie was a French physicist whose revolutionary idea changed scientists’ understanding of matter. In 1924, he proposed that particles such as electrons could also behave like waves. Until then, wave–particle duality had largely been associated with light. De Broglie suggested that the same principle should apply to matter, an idea subsequently confirmed experimentally through electron diffraction. His concept of matter waves became one of the fundamental principles of quantum mechanics and helped provide the intellectual foundation for the development of wave mechanics. The idea also underlies technologies such as electron microscopy. For this groundbreaking discovery of the wave nature of electrons, de Broglie received the 1929 Nobel Prize in Physics.

23 August 1918 — Anna Mani

07

Anna Mani was a pioneering Indian physicist and meteorologist who helped modernize weather measurement in India. After beginning her scientific career at the Indian Institute of Science under C. V. Raman, she later joined the India Meteorological Department (IMD), where she played an important role in developing and standardizing meteorological instruments. Her work improved measurements of solar radiation, atmospheric ozone, wind and other weather parameters. She also contributed to the development of instruments that could be manufactured in India, strengthening the country's ability to collect reliable weather data independently. Mani eventually became Deputy Director-General of the IMD. Her contributions laid important foundations for modern meteorological observation, renewable-energy assessment and atmospheric research in India.

23 August 2023 — India Makes History on the Moon

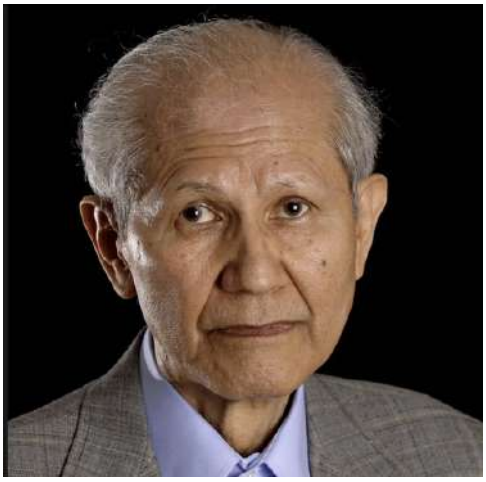
08

On 23 August 2023, India achieved a historic milestone when Chandrayaan-3 successfully soft-landed on the Moon. The Vikram lander touched down in the Moon's southern high-latitude region, making India the fourth country to achieve a successful lunar soft landing and the first to reach this region. After landing, the Pragyan rover explored the lunar surface and carried out scientific measurements, including analysis of its chemical composition. The mission demonstrated India's growing capabilities in space engineering, navigation and planetary exploration. To honour this achievement, the Government of India designated 23 August as National Space Day, celebrating India's progress in space science and inspiring future generations.

27 August 1928 — Osamu Shimomura

09

Osamu Shimomura was a Japanese biochemist whose work gave modern biology one of its most powerful research tools: green fluorescent protein (GFP). While studying the jellyfish Aequorea victoria in the 1960s, Shimomura isolated GFP and investigated how it produces its characteristic green fluorescence. Scientists later discovered that the gene encoding GFP could be introduced into other organisms and attached to genes or proteins of interest. This allowed researchers to watch biological processes inside living cells, track protein movement and visualize gene activity. GFP subsequently transformed cell biology, developmental biology, neuroscience and biomedical research. Shimomura shared the 2008 Nobel Prize in Chemistry for the discovery and development of GFP.



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

Power From Your Shirt? The Magic of Piezoelectricity

Envisage this: you're walking down the street, and with every step, your shirt is quietly generating electricity. Sounds futuristic?

Not anymore. Welcome to the world of piezoelectric energy harvesting, where simple movements can be transformed into electricity.

What Is Piezoelectricity?

The word might sound intimidating, but the idea is simple: certain materials create an electric charge when you press, bend, or stretch them. Discovered back in 1880 by the Curie brothers, this effect is like squeezing a crystal and watching it spark. These materials don't just produce electricity, they also change shape when exposed to an electric field. That's why they're used in everything from sensors and speakers to cutting-edge energy devices.

Piezoelectric materials are of two types: Natural substances: Quartz, topaz, tourmaline, and even everyday substances like bone, wood, silk, and enamel.
Engineered materials: Ceramics: Strong output but brittle. Polymers: Flexible and wearable, though less effective.

Composites: The best of both worlds, combining strength and flexibility.

Meet the Nanogenerator

The real game-changer is the nanogenerator a tiny device that converts mechanical/thermal energy as produced by small-scale physical change into electricity. Think of it as a microscopic power plant that can keep your smartwatch or fitness tracker running without charging, power medical implants like pacemakers using your heartbeat, and supply electricity to IoT sensors monitoring bridges, cars, or even your home. Rising energy demand has intensified reliance on fossil fuels, yet their continued use results in significant carbon dioxide emissions and environmental degradation. To address this challenge, innovative energy harvesting techniques are being developed, particularly within urban infrastructure such as roads, where vast amounts of kinetic energy are wasted annually. Key market trends include the integration of solar panels, piezoelectric devices, and thermoelectric and electromagnetic harvesters to capture this untapped energy (Table 1).

Among these, piezoelectric nanogenerators (PENGs) stand out at the intersection of materials science, nanotechnology, and energy engineering. Their importance lies in enabling self-powered electronics, reducing dependence on conventional batteries, and paving the way for sustainable, autonomous technologies in healthcare, IoT, and wearable devices.

The global energy harvesting system market was valued at $511.6 million in 2020 and is projected to reach $1,057.7 million by 2030.

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Metallurgical and Materials Engineering, National Institute of Technology Karnataka Surathkal, Srinivasnagar (P.O.), Mangaluru, India.

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

AREAS OF EXPERTISE
Nanogenerators • Advanced Functional Nanofibers • Energy Materials • Multiphase polymeric systems • Waste Management

(source: https://www.alliedmarketresearch.com/energy-harvesting-system-market-A13686)

Key Discoveries and Advances in Piezoelectric Energy Harvesting

High-performance materials: Development of PVDF (poly(vinylidene fluoride)) and copolymers and lead-free ceramics with strong piezoelectric coefficients. Nanostructuring breakthroughs: Electrospinning and thin-film deposition techniques that maximize electroactive phase content in PVDF. Hybrid energy harvesters: Combining piezoelectricity with triboelectric or photovoltaic effects for higher efficiency. Bio-integrated devices: Demonstrations of nanogenerators powering pacemakers, sensors, and smart

Technology	Typical output	Best use cases	Pros	Cons
Solar panels (roadside/embedded)	mW–kW	Rooftops, road shoulders, parking lots	High maturity; predictable daytime output	Reduced output in shade/rain; maintenance needs
Piezoelectric (including nanogenerators)	**µW–mW per device**	**Road vibration, footpaths, wearables, sensors**	**Works in low-light; ideal for vibration sources; battery-free sensors**	**Low per-unit power; material durability/cost issues**
Thermoelectric	µW–mW from small ΔT	Waste heat from pavements, vehicles, Heating, Ventilation, and Air Conditioning	Harvests heat continuously where ΔT exists	Requires temperature gradient; modest efficiency
Electromagnetic (captures ambient energy, such as vibrations, movement, or stray radio waves, and converts it into usable electrical power using Faraday's law of induction)	mW–W (mechanical motion)	Road speed bumps, vehicle suspensions	Higher instantaneous power for large motion	Mechanical complexity; wear and maintenance

Table 1. Key Energy Harvesting Technologies Compared

textiles. Scalable fabrication: Progress in large-area printing and flexible substrates for wearable applications.

PVDF and its copolymers exhibit outstanding piezoelectric and ferroelectric properties, enabling the efficient conversion of ambient mechanical stimuli, such as vibrations, pressure variations, and biomechanical motions into usable electrical energy. The inherent polymorphism of fluoropolymers, particularly the tuneable transitions between nonpolar and electroactive crystalline phases, offers a powerful framework for tailoring structure–property relationships through processing strategies including electrospinning, mechanical stretching, and electrical poling. This synergy of intrinsic electroactivity, structural adaptability, and broad device compatibility firmly establishes fluoropolymers as a cornerstone material platform for next-generation self-powered systems.

Current State of the Field

The field has moved beyond proof-of-concept and is entering early commercialization. PENGs are already being tested in wearables, biomedical implants, and IoT sensors, but widespread adoption requires breakthroughs in power density, durability, and scalable manufacturing. The overarching vision is a future where devices are energy autonomous, continuously harvesting ambient mechanical energy without batteries.

In short: Piezoelectric nanogenerators are evolving from niche prototypes into real-world sustainable energy solutions, with the potential to revolutionize how we

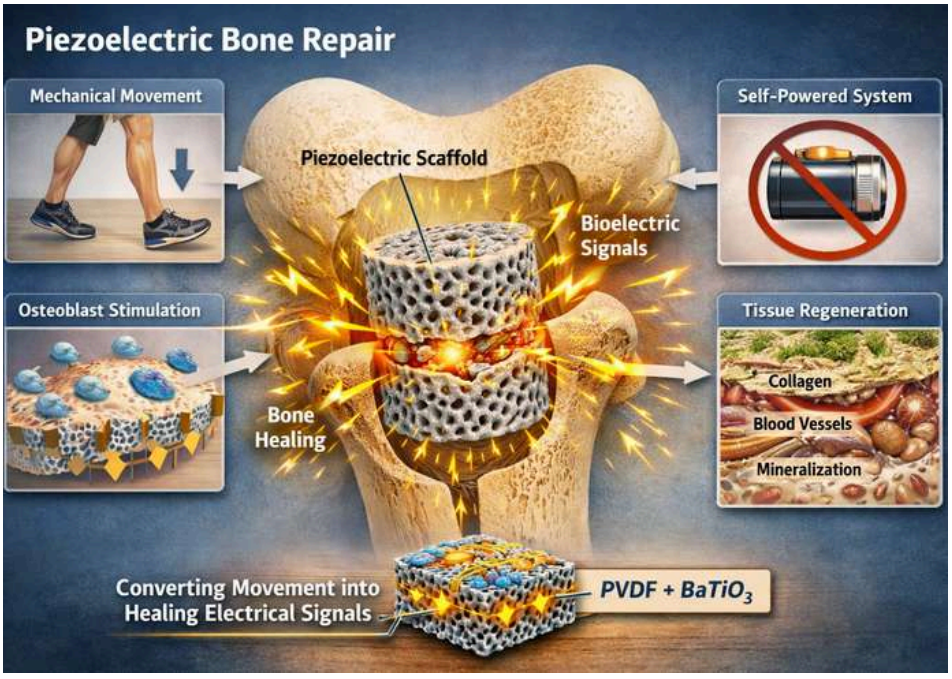


Figure 1: Schematic representation of piezoelectric nanogenerator-assisted bone repair. Mechanical movement induces electrical signals in the piezoelectric scaffold (PVDF + $BaTiO_3$), stimulating osteoblast activity and promoting tissue regeneration.

power small-scale electronics.

Why This Matters

Convenience: Imagine never charging your smartwatch again it powers itself from your daily movements. Sustainability: Reduces reliance on disposable batteries, cutting electronic waste.

Healthcare impact: Safer, longer-lasting implants powered by the human body itself. Smart cities: Maintenance-free sensors for infrastructure monitoring.

Power-Generating Shoes: Walking or running charges tiny electronics — imagine sneakers that juice up your fitness tracker as you move.

Smart Jackets: Fabrics woven with piezoelectric fibers can harvest energy from stretching and bending, turning clothing into wearable power stations. Heartbeat-Powered, Pacemakers: Implantable devices that draw energy directly from the rhythm of your heart, reducing the need for surgical battery replacements. Self-Healing Rubber Sensors: Flexible composites that repair themselves after damage, while continuously monitoring health signals like blood pressure or motion.

Bridge Vibration Monitors: Piezoelectric sensors embedded in infrastructure harvest vibration energy to power themselves, keeping tabs on structural health without ever needing a battery swap.

Scientists are already weaving piezoelectric fibers into fabrics, opening the door to self-powered clothing. Imagine jackets that charge your phone or shoes that power GPS trackers. Add eco-friendly materials and hybrid systems that combine piezoelectricity with solar or triboelectric effects, and the possibilities multiply.

PENGs are emerging as a powerful tool for bone tissue repair, enabling self-powered scaffolds that stimulate bone regeneration by converting mechanical stress (like walking or muscle movement) into bioelectric signals.

Major Challenges and Knowledge Gaps

Low power density: Current devices often produce microwatt-level outputs, insufficient for larger electronics. Durability: Mechanical fatigue and microcracks may reduce long-term reliability. Scalability: Transitioning from lab-scale prototypes to industrial-scale production remains difficult. Standardization: Lack of unified testing protocols for benchmarking performance. Biocompatibility: Ensuring materials are safe for long-term implantation in humans.

Future Outlook

The field of PENGs is poised at a transformative stage, moving from proof-of-concept prototypes toward practical, scalable applications. Several converging trends will shape its trajectory (Figure 2).

The transition to lead-free, eco-friendly piezoelectric materials is essential for sustainable and biocompatible devices.

Advances in polymer–nanoparticle composites and self-healing polymers promise improved durability and performance.

Integrating PENGs with triboelectric, thermoelectric, or photovoltaic harvesters will enable multi-modal energy capture, significantly boosting output power density.

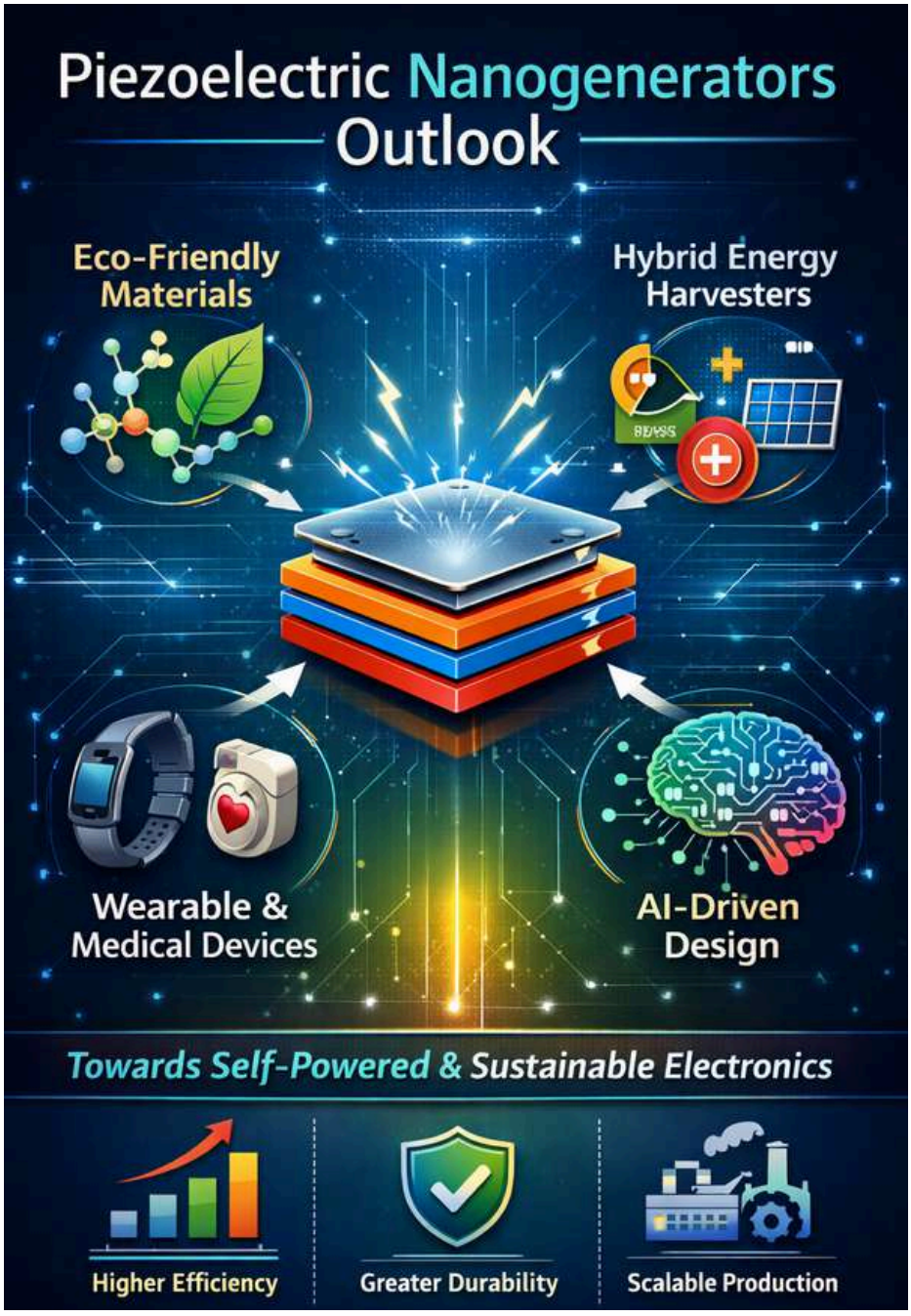
Seamless incorporation into wearables, biomedical implants, and IoT sensors will drive adoption. Flexible substrates and large-area printing techniques are expected to make commercialization more feasible.

Establishing unified testing protocols and performance metrics will be critical to compare devices across labs and accelerate industrial uptake.

Machine learning and computational modelling will optimize nanostructures, predict material behavior, and shorten development cycles.

From quartz crystals to futuristic nanogenerators, piezoelectricity is reshaping how we think about energy. The next time you take a step, stretch, or even breathe, remember: your body's motion could be the battery of tomorrow.

In summary, PENGs are evolving into a cornerstone technology for self-powered electronics. While challenges in power density, durability, and scalability remain, the combination of material breakthroughs, hybrid architectures, and intelligent design strategies suggests a future where ambient mechanical energy can reliably sustain the next generation of autonomous devices. Together, these advances could bring self-powered technologies closer to everyday life, making future electronics more sustainable, autonomous, reliable, and accessible.



Prof. Srinivasan Anandhan's significant contributions to the fields of nanomaterials, piezoelectric materials, and energy harvesting are reflected in several of his representative publications. Readers interested in exploring his research in greater detail may refer to the following works:

Selected Publications

- ACS Applied Nano Materials 2019, 2, 7328–7339. https://doi.org/10.1021/acsanm.9b01812
- Nanotechnology 2026, 37, Article 242004. https://iopscience.iop.org/article/10.1088/1361-6528/ae7425
- Soft Matter 2020, 16, 5679–5688. https://doi.org/10.1039/D0SM00341G

Figure 2: Future Outlook of Piezoelectric Nanogenerators: Advancing toward self-powered and sustainable electronics through eco-friendly materials, hybrid energy systems, biomedical integration, and AI-driven design.

EMERGING INSIGHT

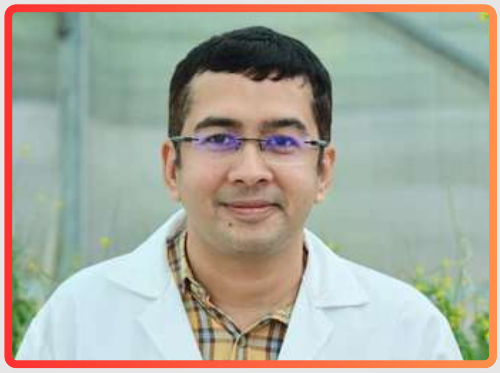
Could novel imaging tools decode the secrets of plants?

Looking Beyond What We Can See

Plants are foundational to life on Earth, yet many aspects of their biology remain hidden. Over decades of research, we have revealed much about plant form and function, but understanding how plants survive changing and stressful environments still requires probing their processes at finer spatial and temporal scales. Imaging morphological and anatomical features with advanced microscopes has helped, but important limitations persist: rigid cell walls, densely light scattering tissues, and strong autofluorescence often obscure signals. Equally limiting is our chemical toolbox, we still lack many probes and sensors that can reliably detect the right molecules in the right place at the right time within living plant tissues. Progress in instrumentation has been steady, but the next major advances will likely come from chemistry. Next generation fluorescent probes, genetically encoded sensors, and small molecule reporters tailored for plant biology will let us track metabolites, ions, signaling molecules, and enzymatic activities with high spatial and temporal resolution. Coupling such probes with improved optical clearing methods, adaptive optics, and deeper penetration imaging modalities will overcome physical barriers and reveal dynamic processes in intact tissues. Together, better chemical tools and complementary imaging technologies will open new windows into plant development, stress responses, and adaptation mechanisms, and help us understand not just structure, but the molecular choreography that keeps plants alive.

The Biggest Unanswered Questions

Plant anatomy and biology have been advanced using fluorescent dyes, small-molecule probes, genetically encoded indicators, and self-labeling systems, although certain drawbacks leave unanswered questions and hinder further breakthroughs. As the field progresses, major challenges remain in visualizing the real-time dynamics of reactive oxygen species (ROS), ions, hormones, and metabolites; tracking the movement of signaling molecules; and monitoring cell wall and plasma membrane remodeling during development and stress responses. Further, physiological questions like tracing the assembly and dissolution of transient receptor ligand interactions, identification of in vivo ubiquitination, proteostasis, turnover mechanisms, apoplastic vs. cytoplasmic signaling dynamics, and hormonal crosstalk, among others, remain unanswered. A central challenge is bridging the gap between static structural and molecular predictions and the dynamic, real-time behavior of biomolecules in living plant cells. Achieving this goal will require next-generation probes that operate reliably in the chemically complex, highly autofluorescent environment of plant tissues while maintaining exceptional sensitivity, specificity, and spatiotemporal



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| Factors Press |

AREAS OF EXPERTISE
Plant Developmental Biology • Cell Biology • Agricultural Biotechnology • Molecular Biology

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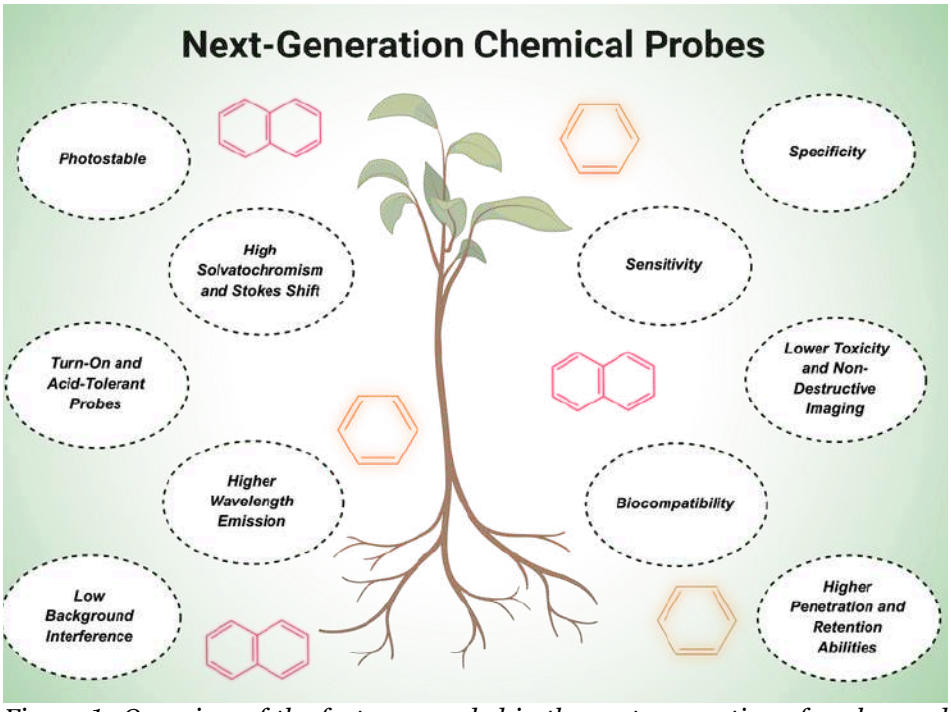

Figure 1: Overview of the features needed in the next generation of probes and dyes to overcome the limitations and drawbacks of conventional stains.

resolution.

Scientific and Technological Breakthroughs Needed

One of the major challenges in deciphering the structural and molecular complexity of plants lies in the design and synthesis of highly targeted probes and dyes. Although numerous fluorescent dyes and probes have been developed since the advent of modern plant biology, several limitations continue to hinder their broader application. These include insufficient cell- and tissue-specific selectivity, cytotoxicity, limited biocompatibility for long-term live-cell imaging, inadequate tissue penetration and retention, and suboptimal emission wavelengths. The development of probes with longer emission wavelengths, particularly near-infrared (NIR) fluorophores and two-photon probes, would minimize background interference and substantially enhance imaging performance in plant tissues.

Another major challenge is overcoming the inherent autofluorescence of plant tissues, which arises primarily from chlorophyll, lignin, and other cell wall-associated components that emit strongly within the visible spectrum. This issue could be addressed by developing NIR probes that operate in the infrared region or fluorophores with large Stokes shifts and pronounced solvatochromic properties, thereby enabling efficient spectral separation between endogenous autofluorescence and probe emission.

Another drawback is the widespread use of constitutively fluorescent probes, which emit continuously irrespective of biological activity, resulting in elevated background fluorescence until excess probe is removed. This limitation underscores the need for activatable, or "turn-on," probes that fluoresce only in response to specific molecular interactions, biochemical reactions, or signaling events, thereby enabling higher imaging contrast and real-time visualization of dynamic cellular processes.

Next, the development of acid-tolerant probes for compartments such as the apoplast and vacuoles with low pH values remains an open avenue, given that dyes such as standard GFPs and pHluorins denature or quench their quantum yields at low pH. Also, GFP tags are too bulky to bind to small signaling peptides, phytohormones, lipids, and cell-wall glycans, underscoring the need for non-disruptive bio-orthogonal labeling via click chemistry, which enables their imaging without hindering natural binding affinities. A systematic transition from simple promoter-reporter constructs to genetically encoded biosensors and degron systems could pave the way for measuring real-time dynamic fluxes by quantifying fluorescence gain/loss. Further, measuring protein dynamics as an absolute measure of complete protein abundance can be advanced through the use of activity-based probes that chemically tag themselves at catalytic sites via targeted chemistries and trace specific localization patterns. Also, the use of genetically targetable chemical probes, as well as probes for phytohormones, enzymes, metabolites, and cell wall components, remains limited in terms of specificity. Expanding the repertoire of these probes, together with advances in fluorophore engineering, bioorthogonal chemistry, and biosensor design, will be essential for bridging the gap between static molecular observatio-

ns and the dynamic, real-time visualization of plant physiology at cellular and subcellular resolution.

Emerging Trends Shaping the Future

Recent technological advances have transformed the way plant scientists investigate cellular chemistry, physiology, and tissue architecture. Among these developments, small-molecule fluorescent probes have enabled the sensitive detection of reactive oxygen species (ROS), ions, pH, and stress-associated biomarkers while facilitating live, non-destructive imaging.

Likewise, genetically encoded indicators, self-labeling and hybrid-labeling strategies, and near-infrared (NIR) and two-photon fluorescent probes have emerged as powerful tools that address the increasing demand for high-resolution, real-time visualization of dynamic biological processes. Nevertheless, there remains a growing need for probes capable of monitoring cell wall composition, membrane chemistry and dynamics, and stress-responsive molecular events with greater specificity and spatiotemporal resolution.

One particularly promising innovation is the development of plant tissue-clearing reagents such as ClearSee and ClearSeeAlpha, which efficiently reduce chlorophyll-mediated autofluorescence while preserving compatibility with a wide range of fluorescent dyes, proteins, and probes. These clearing agents overcome many of the limitations associated with conventional staining and clearing techniques, thereby improving imaging depth, signal quality, and tissue transparency.

Another significant advancement is the development of highly photostable fluorophores that minimize photobleaching, a long-standing limitation of conventional fluorescent dyes. An excellent example is MitoPB Yellow, a photostable fluorescent probe specifically designed to visualize the mitochondrial inner membrane. Its high selectivity, sensitivity, and resistance to photobleaching enable prolonged imaging with reduced background interference, making it particularly valuable for studying mitochondrial dynamics in living cells.

Similarly, the recently developed photostable fluorophore PhoxBright 430 (PB430) utilizes an intramolecular charge-transfer mechanism to achieve high solvatochromism, excellent quantum yields, and remarkable photostability. Its successful conjugation to antibodies has enabled stable fluorescence signals for long-term visualization of cytoskeletal dynamics, demonstrating the potential of this class of fluorophores for advanced live-cell imaging applications.

In concert with the development of these probes and stains, modern-day advanced microscopic techniques, such as but not limited to Super-Resolution microscopy, including SIM (Structured Illumination Microscopy) and STORM (Stochastic Optical Reconstruction Microscopy), Expansion microscopy (ExM), and Light Sheet Fluorescence microscopy (LSFM), have significantly provided a concerted enhancement in the imaging applications. These techniques have enhanced the optical resolution to the ~20-60 nm scale, reduced photobleaching, while maintaining high zoom and magnification capabilities, providing impetus for visualizing single-cell modules. These efforts on both the equipment and interface sides offer promising capabilities for scientific advancement.

How Will the Field Evolve?

The future of plant studies and innovations lies in the transition from general-purpose fluorescent staining molecules to highly tailored, synthetic molecular designs. The field seems to evolve along two paths: more specialized techniques that address the needs of specific probe compartmentalization, and towards specific signals and biological questions. In short, plant imaging must move from simply making things visible towards making the invisible biochemical dynamics measurable in living plants. This transformation will require probes capable of reporting real-time changes in molecular interactions, enzyme activities, signaling pathways, and metabolite dynamics rather than merely providing static localization information. Another avenue is to move from single static maps to multiplexed live biosensing, and from in vitro binding assays to in vivo quantitative approaches, including fluorescence resonance energy transfer (FRET), fluorescence lifetime imaging microscopy (FLIM), and other advanced fluorescence-based techniques coupled with next-generation chemical probes and genetically encoded biosensors. The move from the simple, general to the specific and complex would pave the way for an integral understanding of these systems and their development.

What Lies Ahead?

The major developments foreseen in this rapidly advancing field include the development of NIR and two-

photon probes specialized for out-of-reach signaling molecules, including, but not limited to, phytohormones, ligand-receptor interactions, enzymes, and metal ions. The field would greatly benefit from organelle-targeted and protein-targeted dyes, as well as probes with biocompatibility, low toxicity, and background interference. In the coming years, the establishment of comprehensive probe libraries tailored for stress biology, cell wall dynamics, metabolite mapping, and cellular signaling will significantly expand our understanding of plant physiology and development. Such resources will facilitate the simultaneous investigation of multiple molecular processes, providing a more comprehensive view of plant responses to developmental and environmental cues. The major outlook for plant scientists would be a shift from traditional probes to more specific, targeted entities, requiring optimizations in well-studied plant systems, but would enhance the overall outlook and provide us with more information about their workings and dynamics.

Dr. Subramanian Sankaranarayanan and Hemal Bhalla's contribution to the development of novel tools for plant anatomy research is reflected in the recent publication in Plant and Cell Physiology (2026) (DOI: https://doi.org/10.1093/pcp/pcag084).
Their work focuses on the development of targeted synthesis of intramolecular charge-transfer-based pyridinium probes for xylem staining in plant tissues. These molecules harbor high specificity and sensitivity compared to the existing pool of traditional dyes tested across diverse monocot and dicot species, including xylem mutants. The molecules are favored not only for specificity and sensitivity but also for low background interference and photobleaching, higher synthetic and quantum yields, high solvatochromism, and Stokes shift in the NIR region, aided through the ICT mechanism.

These molecules have paved the way for next-generation targeted synthesis and their exploitation to understand diverse biological mechanisms.

EMERGING INSIGHT

Nanozymes as Next-Generation Antimicrobials in Combating Antimicrobial Resistance

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

AREAS OF EXPERTISE
Antioxidant/pro-oxidant nanomaterials • nanomaterial delivery • antibiotic resistance • wound healing

The Growing Challenge of Antimicrobial Resistance

Antimicrobial resistance (AMR) is rapidly becoming one of the greatest threats to the global healthcare including humans and animals. As conventional antibiotics continue to lose their effectiveness, global researchers endeavor to explore novel therapeutic approaches that are less likely to cause resistance in the pathogens. Among the most promising innovations of recent times, nanozymes (engineered nanomaterials exhibiting the catalytic functions of natural enzymes) have emerged as an excellent alternative to the conventional antibiotics. Being nanomaterial, nanozymes too display unusual intrinsic properties due to the extremely tiny size, high surface to volume ratio and high surface area that makes the basis of extremely high catalytic activity. Pro-oxidant nanozymes have demonstrated remarkable potential for producing reactive oxygen species rendering them suitable for eliminating antibiotic-sensitive as well as resistant bacterial species, and disrupt biofilms. Although a lot has been reported in this context, the field remains in its infancy and therefore, several exciting questions are yet to be answered. One of the biggest concerns is the behavior (stability and activity) of nanozymes within the complex biological systems. It also remains to be studied that what are the possible effects of the interaction of nanozymes with multiple components of complex biological milieu. It is also discovering that how soon these nanozymes are recognized by the reticuloendothelial system and levels of opsonization. Although nanozymes are found accumulated in spleen and

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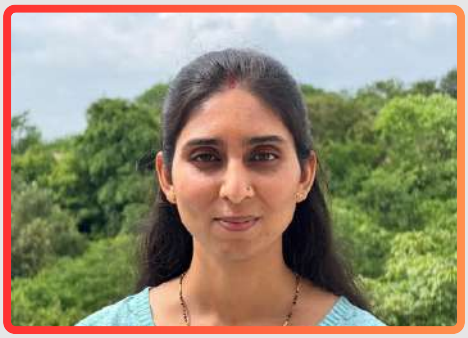
AREAS OF EXPERTISE
Anti-oxidant nanozymes • animal nutrition



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AREAS OF EXPERTISE
Pro-oxidant nanozymes • antibiotic resistance • Molecular Biology • nanomedicine

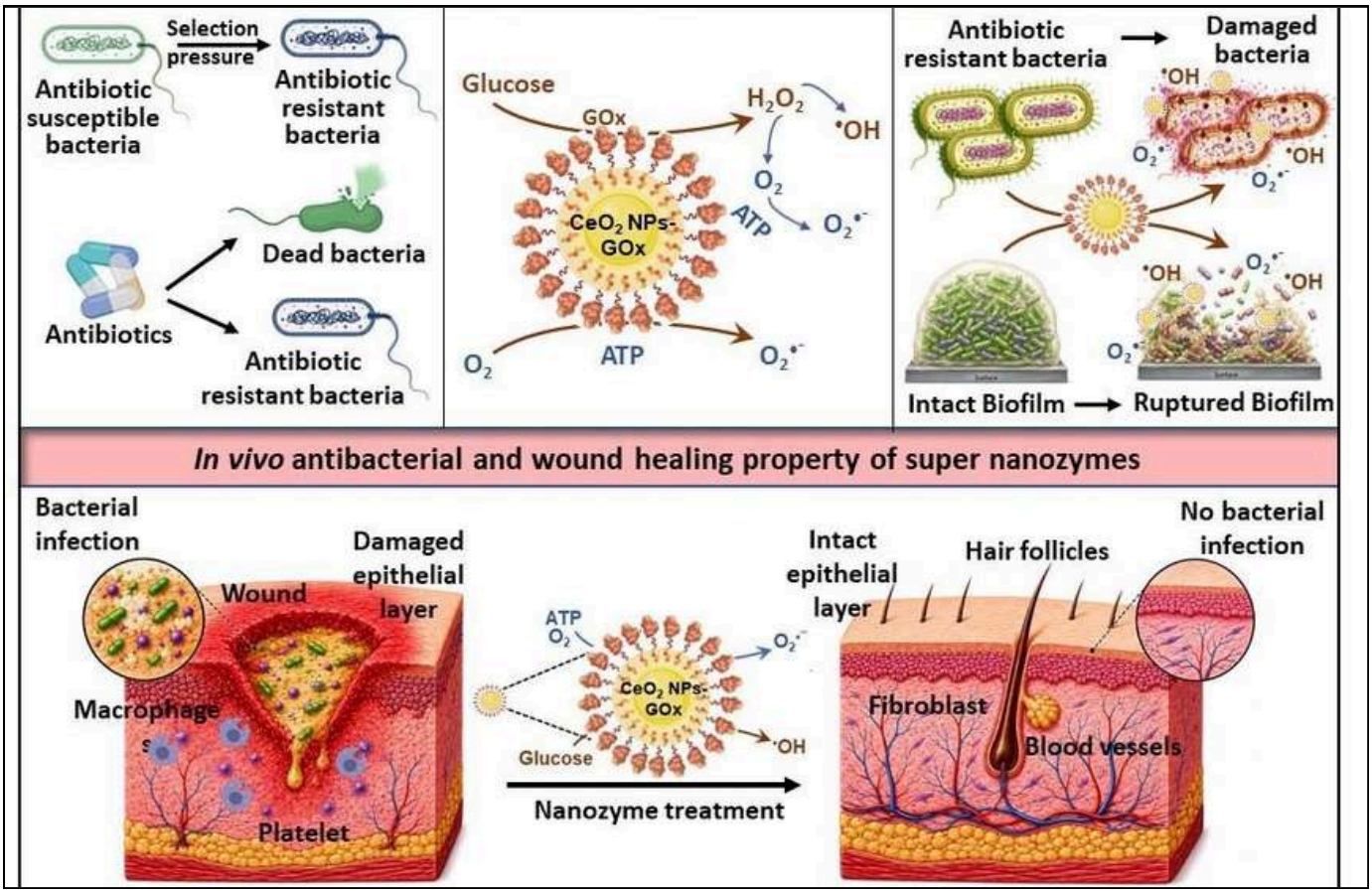

Figure 1: Schematic representation of antibiotic resistance development in bacteria and CeO2 NPs-GOx mediated ATP-enhanced radical generation disrupting bacterial membrane, inhibiting biofilm formation, and accelerated infected wound healing

liver that indicates that swift clearance by macrophages, presents a major bottleneck for targeted drug delivery and long circulation in blood. These questions are some of the forefront concerns of translational limitations of nanozyme-based technologies from the laboratory to clinical practice. Another major unanswered and challenging area is understanding the precise molecular mechanisms underlying nanozyme-mediated antibacterial activity. Although reactive oxygen species generation is widely recognized as a primary mechanism, growing evidence suggests that nanozymes may also influence bacterial metabolism, gene expression, quorum sensing, and host immune response. Deciphering these complex interactions could enable researchers to design more effective and selective therapeutic platforms.

Scientific and Technological Breakthroughs Needed

Several scientific and technological breakthroughs will be required to unlock the full potential of nanozyme-based medicine. The next generation of nanozymes should include the development of theranostic nanozymes, exhibiting both diagnostic and therapeutic capabilities within a single platform. Such systems would enable real-time monitoring of disease progression along with treatment efficacy leading to personalized medicine. Equally important is the development of selective or target-dependent nanozymes that can specifically recognize and eliminate pathogenic microorganisms while sparing beneficial microbiota and healthy host tissues. Achieving this level of selectivity would significantly improve treatment safety and efficacy. These advances will pave the way for intelligent, precision nanozyme therapeutics with broad clinical applications. Further, the development of advanced analytical and imaging technologies for real-time monitoring of nanozyme behaviourur in complex biological environments is required. High-resolution in vivo imaging, multimodal molecular imaging, single-particle tracking, and real-time spectroscopic techniques will enable researchers to monitor nanozyme biodistribution, catalytic

activity, degradation, and therapeutic responses within living systems. Emergence of such discoveries and technologies are required to deepen our understanding of nanozyme–biological interactions, and support the rational design of next-generation nanozyme therapeutics.

Among the most promising emerging trends is the development of microenvironment-responsive nanozymes. Our own research on ATP-enhanced glucose-oxidase conjugated cerium-oxide nanozyme (CeO2 NPs-GOx) system highlights the potential of exploiting biochemical signals naturally present within infected tissues. ATP, glucose, and local physiological changes such as pH can serve as endogenous triggers capable of activating catalytic therapy precisely at the site of infection. Such self-regulated therapeutic systems represent an important step toward personalized and precision medicine by maximizing antibacterial efficacy while minimizing damage to healthy tissues. Another rapidly emerging area is the application of artificial intelligence (AI) and machine learning (ML) in nanozyme research. Rather than relying solely on human intelligence-based time-consuming experimental screening, AI and ML can predict the optimal composition, morphology, surface chemistry, crystal structure, catalytic activity, and biosafety of nanozymes. These computational approaches can reveal structure–activity relationships, accelerate the rational design of highly efficient, disease-specific nanozymes, and substantially reduce both development time and cost. The integration of nanozymes with advanced biomaterials is another exciting innovation that are being discovered currently. Incorporating nanozymes into hydrogels, wound dressings, tissue-engineered scaffolds, microneedle patches, and implant coatings can provide sustained localized therapy while promoting tissue regeneration, reducing inflammation, and preventing bacterial colonization. Such multifunctional platforms hold great promise for treating chronic wounds, diabetic ulcers, burn injuries, and implant-associated infections.

The Next Five to Ten Years

Over the next five to ten years, the field is likely to evolve from proof-of-concept demonstrations toward clinically relevant applications. We anticipate the emergence of highly specialized nanozyme systems tailored for specific diseases and patient populations. Standardized protocols for evaluating catalytic activity, therapeutic performance, and long-term safety will become increasingly important. Regulatory frameworks governing nanozyme-based therapeutics are also expected to mature, facilitating eventual clinical translation. In near future, the nanozyme field is expected to significantly evolve by developing stimuli-responsive nanozymes, AI-assisted nanomaterial design, bioinspired catalytic systems, and multifunctional theranostic platforms, etc. Equally important will be advances in large-scale manufacturing and reproducibility, which are essential prerequisites for commercialization. Nanozyme-based start-ups are also expected to emerge rapidly as the field transitions from laboratory research to commercial translation. These companies are likely to focus on developing clinically validated nanozyme therapeutics, rapid point-of-care diagnostics, precision livestock health products, biosensors, and environmentally sustainable catalytic technologies.

What Lies Ahead?

In future, readers are expected to witness the transformation of the field from first-generation single-enzyme mimics toward next-generation intelligent catalytic nanomedicines that integrate multiple catalytic functions with targeted delivery, disease-responsive catalytic actions, and real-time diagnostics.

The multifunctional nanozyme platforms are also expected to transform human and veterinary medicine, environmental remediation, biosensing, AMR eradication, and industrial bio-catalysis. The emergence of clinically validated and commercially available nanozyme-based products is anticipated to be one of the most significant milestones in nanomedicines over the coming decade. These advances could make nanozymes increasingly precise, adaptable, and accessible, helping bridge laboratory innovation with practical applications while opening new possibilities for personalized treatment, sustainable technologies, and rapid disease detection.

Dr. Singh and his team's contributions to this field are highlighted in their recent publication in Advanced Materials (2026) https://doi.org/10.1002/adma.202520966 which shows how a novel cascade catalytic nanozyme can rapidly eliminate MRSA bacteria and accelerate infected wound healing.

EMERGING INSIGHT

Could Lithium Hold the Missing Link to Insulin Resistance?

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AREAS OF EXPERTISE
Clinical Biochemistry • Protein Biochemistry • Trace metals • Infectious Diseases

Insulin resistance (IR) is the fundamental metabolic defect underlying type 2 diabetes mellitus (T2DM) and precedes overt hyperglycemia by many years. Although considerable progress has been made in understanding insulin signaling, current therapeutic approaches largely focus on improving glycemic control rather than correcting the molecular defects that initiate insulin resistance. Increasing evidence suggests that trace elements are integral regulators of insulin synthesis, signaling, oxidative stress, and glucose metabolism, yet their precise physiological roles remain incompletely understood.

Our recent cross-sectional study demonstrated that lower physiological serum lithium concentrations are independently associated with increased insulin resistance, an elevated insulin-to-C-peptide ratio (ICPR), and a higher triglyceride-glucose (TyG) index, suggesting a potential role for lithium in regulating insulin sensitivity, hepatic insulin clearance, and glucose homeostasis. Rather than viewing lithium solely as a therapeutic drug for bipolar disorder, these findings suggest that physiological or dietary lithium may be an overlooked modulator of glucose homeostasis. However, the critical unanswered question remains whether reduced lithium concentrations contribute directly to the development of insulin resistance or merely reflect a consequence of, or a compensatory response to, the underlying metabolic dysfunction. Little is known about the optimal physiological lithium concentration for metabolic health, the effects of dietary and environmental lithium exposure, or lithium's interactions with other essential trace elements such as magnesium, chromium, and zinc. Equally important, the molecular mechanisms through which physiological lithium regulates insulin action remain poorly understood. It remains uncertain whether restoring physiological lithium levels can reverse insulin resistance by activating the PI3K/Akt/GSK3β pathway, thereby promoting GLUT4 translocation, improving proinsulin processing, and boosting hepatic insulin clearance.

The relationship between lithium and pancreatic β-cell biology also warrants greater attention. Emerging evidence suggests that lithium-mediated regulation of GSK3β and autophagy may preserve β-cell survival under metabolic stress, but direct human evidence remains limited. Likewise, the observation that individuals with lower lithium concentrations exhibit higher insulin-to-C-peptide ratios raises intriguing questions about hepatic insulin clearance. Determining whether lithium influences insulin secretion, hepatic insulin extraction, peripheral insulin sensitivity, or all three processes will be essential for defining its physiological role. Unlike therapeutic lithium monitoring, which targets concentrations between 0.6 and 1.2 mmol/L, little is known about optimal endogenous lithium concentrations or the dietary, environmental, and genetic factors that determine them.

Addressing these questions will require a shift from observational associations to mechanistic and translational research. Well-designed randomized controlled trials are needed to determine whether restoring physiological lithium concentrations can improve insulin sensitivity and metabolic function, rather than merely correlating with them. Advances in analytical technologies will also be critical. Unlike ion-selective electro-

de methods, which were developed primarily for therapeutic lithium monitoring and lack the sensitivity to accurately measure ultra-trace physiological lithium concentrations, high-resolution analytical platforms such as inductively coupled plasma mass spectrometry (ICP-MS) will enable precise quantification of endogenous lithium and facilitate the establishment of population-specific physiological reference ranges. Future investigations should also incorporate phosphoproteomics, metabolomics, and transcriptomics to map lithium-responsive signaling networks. Equally important will be the application of advanced metabolic phenotyping, including hyperinsulinemic-euglycemic clamp studies, isotope-based assessment of hepatic insulin clearance, continuous glucose monitoring, and tissue-specific imaging, to elucidate how physiological lithium regulates insulin signaling and glucose metabolism in vivo.

One of the most promising developments is the shift from glucose-centred diabetes management towards mechanism-based precision medicine. Rather than relying solely on HbA1c or fasting glucose, future metabolic assessment is likely to incorporate molecular biomarkers that reflect insulin signalling, β-cell function, hepatic insulin clearance, inflammation, and micronutrient status. Another emerging innovation is the concept of nutritional pharmacology, in which the physiological restoration of essential micronutrients is used to optimize intracellular signalling pathways rather than to achieve pharmacological drug concentrations.

In this context, lithium may represent an entirely new class of metabolic modulator that acts via endogenous signalling mechanisms rather than conventional glucose-lowering pathways. Equally exciting is the growing use of integrated biomarkers. Combining HOMA-IR, TyG index, proinsulin-to-insulin ratio, insulin-to-C-peptide ratio, and phosphorylation of PI3K/Akt/GSK3β provides a multidimensional assessment of insulin resistance across clinical, biochemical, and molecular domains. Such integrated phenotyping may substantially improve patient stratification and therapeutic monitoring. Artificial intelligence will further accelerate this transformation by integrating biochemical, molecular, genomic, dietary, and lifestyle data into predictive algorithms that identify individuals at greatest risk of insulin resistance before irreversible β-cell dysfunction occurs.

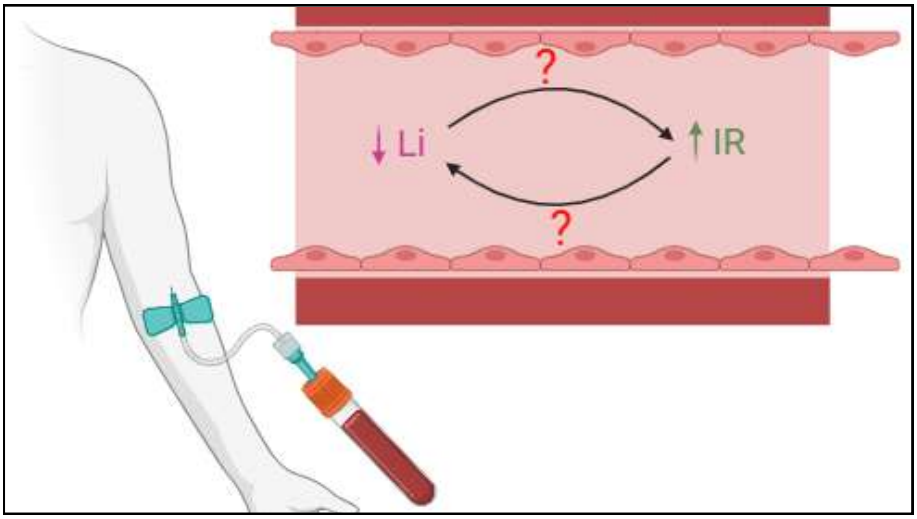

Figure 1: Lower circulating lithium levels are associated with increased insulin resistance; however, it remains unclear whether lithium deficiency contributes to the development of insulin resistance or whether insulin resistance itself alters lithium homeostasis.

Over the coming decade, diabetes research is expected to move beyond symptom control towards correcting the molecular mechanisms responsible for insulin resistance. Nutritional trace elements are likely to attract increasing attention as regulators of intracellular signalling rather than merely dietary cofactors. Large multicenter longitudinal studies across diverse populations will determine whether physiological lithium deficiency precedes the onset of insulin resistance or simply accompanies established disease. If these observations are confirmed, randomized dose-ranging clinical trials will define the optimal lithium concentration required to restore metabolic homeostasis while maintaining long-term safety.
Concurrently, mechanistic studies will increasingly focus on validating lithium-responsive signalling pathways in human tissues, particularly the PI3K/Akt/GSK3β axis, GLUT4 trafficking, mitochondrial metabolism, autophagy, and hepatic insulin clearance. These investigations may identify novel therapeutic targets that extend well beyond lithium itself. Clinical practice is also likely to evolve toward individualized metabolic profiling. Future diabetes risk assessment may integrate trace-

element measurements, insulin-processing indices, molecular signaling biomarkers, and genetic susceptibility to enable earlier diagnosis and personalized interventions. If proven effective, low-dose lithium supplementation could become a safe, inexpensive adjunct to existing glucose-lowering therapies, shifting the focus from disease management to mechanism-based precision diabetes care.

Several developments are likely to shape this field in the near future. Prospective multicenter studies will determine whether serum lithium levels consistently predict incident insulin resistance and diabetes across geographic regions and dietary environments. Improved analytical technologies such as ICP-MS will establish reliable physiological reference ranges for lithium and clarify inter-individual variability. Researchers should also watch for mechanistic studies examining lithium's effects on insulin signaling, hepatic insulin clearance, mitochondrial metabolism, and pancreatic β-cell preservation. Integration of trace element biology with multi-omics analyses, artificial intelligence, and precision nutrition is expected to yield a more comprehensive understanding of metabolic regulation than has been possible before. These developments are expected to transform our understanding of insulin resistance, shifting it from a disorder of impaired glucose metabolism to a condition of disrupted intracellular signalling influenced by genetics, nutrition, and trace-element biology. Perhaps the most transformative possibility is that physiological lithium may ultimately emerge not only as a biomarker but also as a modifiable determinant of metabolic health. Although considerable work remains before clinical translation, the convergence of nutritional science, molecular endocrinology, and precision medicine offers a compelling opportunity to redefine our understanding and management of insulin resistance. The coming decade is likely to determine whether this overlooked trace element becomes an integral component of next-generation strategies for diabetes prediction, prevention, and personalized treatment.

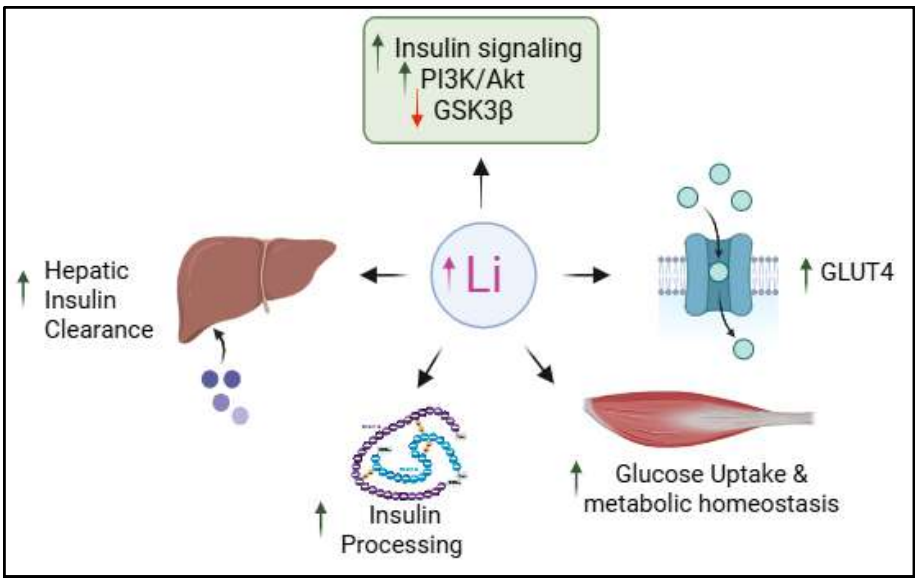

Figure 2: Physiological lithium may enhance PI3K/Akt signaling, inhibit GSK3β, promote GLUT4 translocation, improve insulin processing and hepatic insulin clearance, and ultimately increase glucose uptake and metabolic homeostasis. These mechanisms remain to be validated at physiological lithium concentrations in humans.

Dr. Gupta's research are reflected in the team's publication in Biological Trace Element Research,https://doi.org/10.1007/s12011-026-05203-5. Their research showed that lithium levels in the blood are linked to how well the body responds to insulin in people with type 2 diabetes. Building on these findings, their future research aims to understand how lithium affects insulin function and to explore whether low-dose lithium could become a safe and effective treatment to help improve insulin resistance and manage diabetes.

EMERGING INSIGHT

The Future of the Battle Against Visceral Leishmaniasis

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| Factors Press |

AREAS OF EXPERTISE
Host-pathogen interaction • *Leishmania donovani* • Macrophage signalling pathways

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AREAS OF EXPERTISE
Host-pathogen interaction • *Leishmania donovani* • Macrophage signalling pathways

A Silent Killer That Still Threatens Millions

Every year, the deadly parasitic disease visceral leishmaniasis (VL), commonly known as kala-azar, claims thousands of lives, yet it remains one of the world's most neglected tropical diseases. Once transmitted by its vector sandflies, the parasite Leishmania donovani causes persistent fever, fatigue, weight loss, severe anemia, and swelling of the abdomen due to enlarged liver and spleen, making untreated visceral leishmaniasis almost invariably fatal. While existing medicines have saved many patients, they have not even nearly ended our battle against this deadly parasite. One of the greatest concerns facing scientists today is the rapid emergence of drug-resistant Leishmania parasites. Medicines such as sodium stibogluconate, miltefosine, paromomycin, and amphotericin B, which have long been the backbone of treatment, are becoming less effective in some endemic regions as the parasite evolves ways to survive them. Another major challenge is the toxicity of several existing medicines. Some drugs can damage the kidneys or liver, while others, such as miltefosine, cannot be used during pregnancy because they may cause birth defects. These limitations highlight the urgent need for safer, affordable, and easily administrable medicines. Equally concerning is that despite decades of research there is still no licensed human vaccine against visceral leishmaniasis. Tragically, the true burden of visceral leishmaniasis remains largely unseen. The disease mainly affects economically disadvantaged populations, where people often live in unhygienic conditions that expose them to sandflies carrying the Leishmania parasite. Coupled with limited access to healthcare and low disease awareness, many patients never receive a diagnosis or treatment. As a result, the true human toll of the disease is almost certainly far greater than official estimates suggest. Ironically, the agent of this neglected disease, Leishmania donovani, is one of the most sophisticated human parasites, hijacking host immune cells as their niche and rewiring their signaling, metabolism, antioxidant defense, and cytokine responses to promote its own survival. By suppressing protective immunity while activating pathways that protect infected cells, it establishes long-lasting infection. These remarkable strategies mark Leishmania as a valuable model for understanding host-pathogen interactions, immune evasion, and chronic infection. These remarkable survival strategies are also the reasons why extensive research is needed to come up with a permanent cure for VL.

Breaking the Parasite's Defenses

The search for new drugs against VL has become an urgent need. To overcome the growing resistance of Leishmania to existing drugs, identifying new drug targets has become a major research priority. Numerous studies have focused on host cell proteins and receptors that are exploited by the parasite to establish infection and evade immune defense. Our recent study has identified the adenosine A2A receptor (A2AR) as a promising drug target because of the receptor mediated cAMP/PKA signaling pathway that activates heme oxygenase 1 (HO-1), the antioxidant enzyme that the parasite exploits to suppress host's protective immune responses. These findings highlight the potential of host-directed therapies as a new strategy to combat drug resistance and improve treatment outcomes. However, because these drug targets are also essential for normal host functions, extensive research is needed to verify that targeting them is both safe and effective, without causing any unintended harm to the patient.

However, fighting against VL go far beyond discovering new drugs. Rapid advances in vaccine development are urgently needed to prepare the immune system in recognizing and eliminating Leishmania parasites before they can establish infection, but it is also one of the greatest scientific challenges. Leishmania hides and multiplies inside our immune cells, making it difficult for the body to detect and eliminate the parasite. Its complex life cycle and affecting host cell antigen presentation make it even harder to develop a vaccine against it.

New Technologies Offering New Hope

Because the disease primarily affects neglected communities and many cases go unreported, it often limits the attention, funding, and resources needed to advance scientific research. Despite these challenges, researchers around the world continue to progress in the fight against VL. One of the most exciting advances in the fight against VL is the application of CRISPR gene-editing technology. Scientists are identifying genes essential for the parasite's survival and mutating them to develop live-attenuated vaccines by creating genetically weakened Leishmania parasites. These weakened parasites cannot cause disease but can safely stimulate the immune system to develop long-lasting protective immunity. At the same time, researchers are exploring innovative vaccines that target proteins in sandfly saliva. Because the parasite is transmitted through the bite of an infected sandfly, these vaccines aim to trigger an immune response at the very site of infection, stopping the parasite before it can establish itself

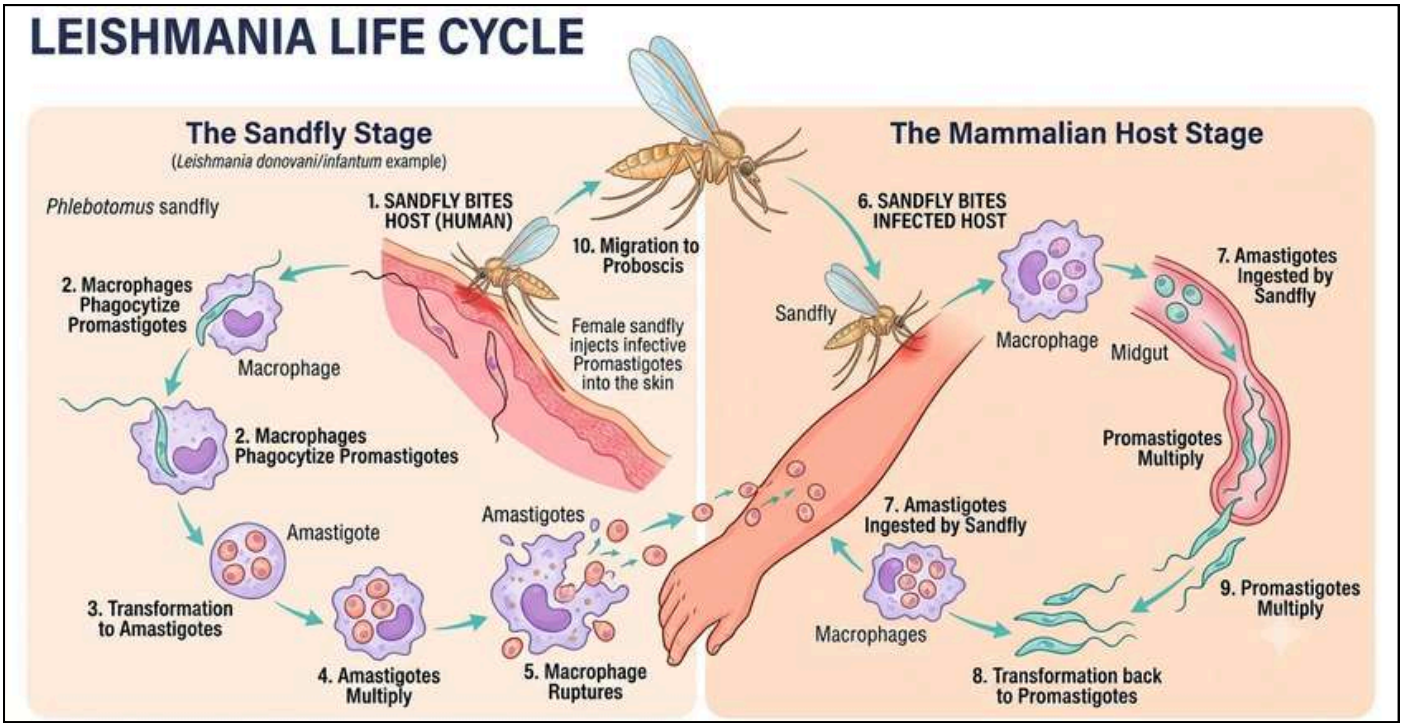

Figure 1. Life cycle of Leishmania donovani showing transmission between the female Phlebotomus sandfly and the mammalian host, with developmental transitions between extracellular promastigotes and intracellular amastigotes.

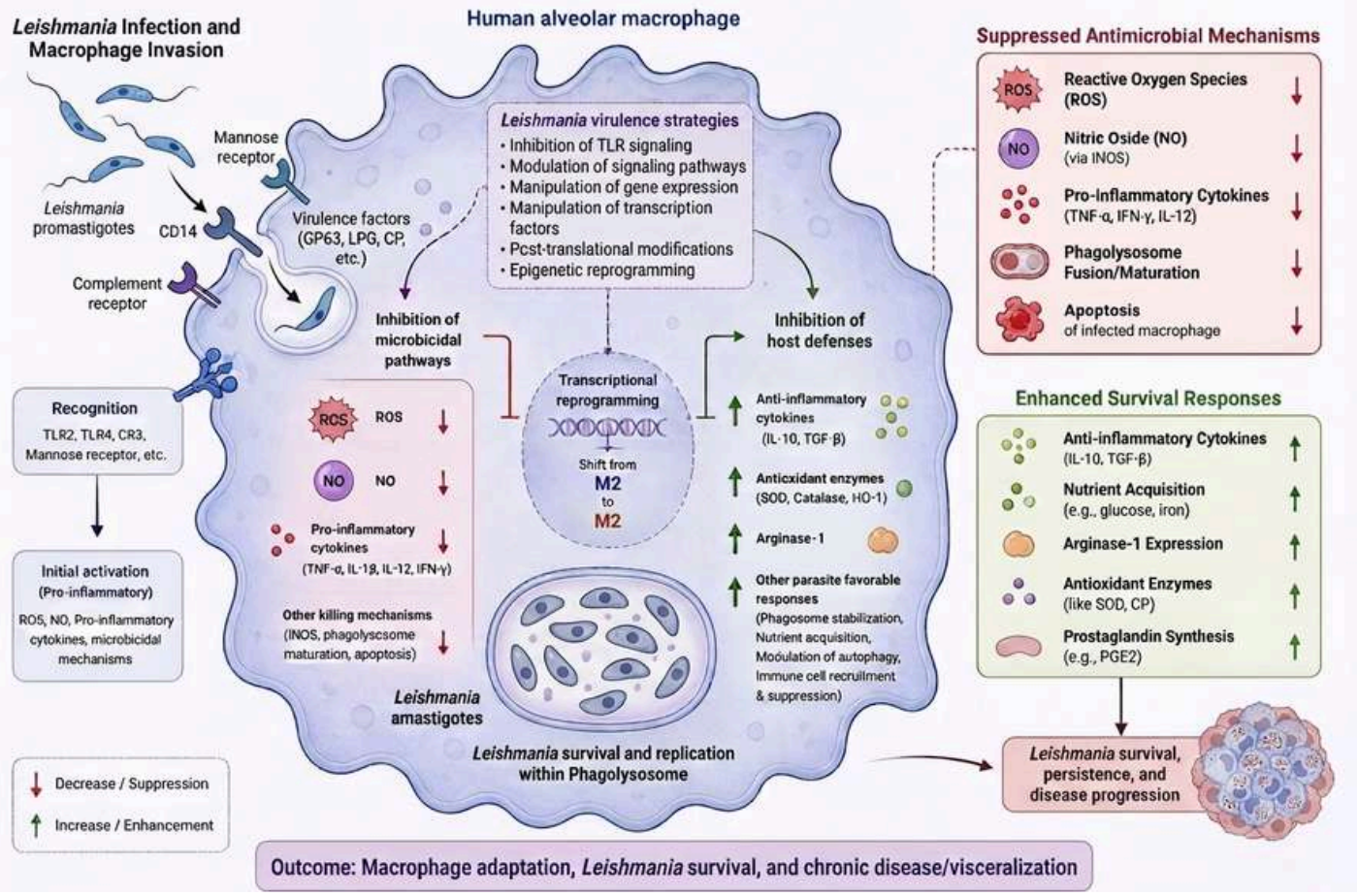

Figure 2. Schematic representation of the immune evasion strategies employed by Leishmania within host macrophages. Following phagocytosis, the parasite suppresses antimicrobial responses, including reactive oxygen species (ROS), nitric oxide (NO), pro-inflammatory cytokines, phagolysosome maturation, and apoptosis, while promoting anti-inflammatory signaling, antioxidant defenses, and metabolic adaptations that facilitate intracellular survival, replication, and disease progression.

in the body. One promising approach uses virus-like particles (VLPs) carrying GP63, a key Leishmania surface protein used to invade host cells and evade the host immune system. In preclinical studies, this vaccine strategy stimulated strong antibody and T-cell responses, reduced parasite burden, and protected mice from severe disease, highlighting GP63 as a promising candidate for future human vaccines. If successful, these next-generation vaccine strategies could significantly reduce disease transmission and move us closer to eliminating this devastating disease.

Early diagnosis is another critical piece of the puzzle. The first symptoms of VL closely resemble those of many other diseases, leading to delayed diagnosis and treatment. Although rapid diagnostic tests such as the rK39 strip have greatly improved the diagnosis of visceral leishmaniasis, they detect antibodies produced against parasite antigens rather than the parasite itself. Since these antibodies can remain in the body long after recovery, the test cannot always distinguish an active infection from a past one. It is also less reliable in immunocompromised patients since production of antibodies would be much less. Researchers are therefore developing non-invasive urine-based antigen tests and portable molecular techniques such as Loop-Mediated Isothermal Amplification (LAMP), which can accurately detect active infections without requiring sophisticated laboratory equipment.

The Next Generation of Treatments

The future of more effective visceral leishmaniasis treatment lies in developing drugs that directly target the parasite rather than the infected human cells. Researchers are identifying biological processes that are unique to Leishmania, allowing future drugs to kill the parasite while minimizing damage to healthy tissues. Promising targets include parasite kinases, proteases such as gp63, aminopeptidases, enzymes

involved in sterol and folate metabolism, and proteins required for DNA replication and energy production. Because many of these molecules are absent from or structurally different in humans, drugs designed against them have the potential to selectively eliminate the parasite while minimizing toxicity to the host.

Drug delivery is also undergoing a transformation. Nanotechnology-based delivery systems are being designed to transport medicines directly to infected macrophages, the immune cells where Leishmania hides and multiplies. By delivering drugs precisely to infected organs such as the liver and spleen, these targeted formulations could increase treatment effectiveness while reducing toxicity to the rest of the body.

Researchers are also working toward shorter, all-oral treatment regimens that are easier to complete than lengthy hospital-based therapies. Compounds derived from plants, microorganisms, and other natural sources are also being investigated as safer and more biodegradable alternatives to conventional drugs. At the same time, improvements in medicinal chemistry are helping optimize these compounds into effective therapies with fewer side effects. Combination therapies that use multiple drugs with different mechanisms of action would be an important strategy for slowing the development of resistance while improving treatment outcomes.

Towards a World Free of Kala-Azar

Over the next decade, research on VL is likely to become increasingly precise. Advances in genomics, immunology, single-cell technologies and structural biology are revealing how the parasite survives inside immune cells and manipulates the body's defense. Understanding these complex host-parasite interactions is helping scientists design new and better treatment that not only eliminate the parasite but also restore the immune system's ability to fight infection naturally.

However, eliminating visceral leishmaniasis will require far more than scientific breakthroughs alone. Countries where the disease remains endemic must work together to strengthen surveillance, prevent reemergence, and ultimately eliminate the parasite. At the same time, greater public awareness is essential so that people recognize the symptoms early and seek medical care without delay.

Continued investment is needed to develop affordable medicines, shorter and more effective treatment regimens, and convenient oral therapies that are easier to administer in resource-limited settings.

Equally important is the development of rapid, accurate, and inexpensive diagnostic tools that can be used even in remote locations.

By combining scientific innovation with stronger public health efforts, international collaboration, and sustained political commitment, we can move closer to a future where VL is no longer a neglected disease but one that is controlled, and ultimately eliminated.

Acknowledgement:

Grant numbers are BT/PR42168/MED/29/1596/2022 and BT/PR54303/BMS2/156/84/2024.

Prof. Anindita Ukil and Dr. Tapasi Das's contributions to visceral leishmaniasis research are highlighted in their recent publication in mBio (2026) https://doi.org/10.1128/mbio.02581-25. Their study explains how the Leishmania parasite weakens the body's natural immune defenses, allowing it to survive and multiply inside immune cells. By identifying a key signaling pathway that helps the parasite evade the immune system, their research provides a promising new target for developing safer and more effective treatments against visceral leishmaniasis.

EMERGING INSIGHT

Can Existing Medicines Be Repurposed to Fight Drug-Resistant Kala-Azar?

Visceral leishmaniasis (VL), commonly known as kala-azar, is one of the most severe neglected tropical diseases (NTDs) and remains a major public health concern in tropical and subtropical regions. The disease is caused by protozoan parasites of the genus Leishmania, primarily Leishmania donovani in the Indian subcontinent and East Africa, and is transmitted by infected female phlebotomine sand flies. Following transmission, parasites invade host macrophages and multiply intracellularly, leading to systemic infection of the spleen, liver, bone marrow, and lymphoid tissues. If left untreated, VL is almost invariably fatal. Although the World Health Organization has made significant progress toward VL elimination through vector control, early diagnosis, and improved treatment strategies, the disease continues to affect thousands of people annually, particularly among economically disadvantaged populations. Because of its high mortality, socioeconomic impact, and limited therapeutic options, visceral leishmaniasis remains one of the priority neglected tropical diseases requiring continued research and innovation.

From Understanding the Parasite to Improving Patient Care

Over the past several decades, remarkable advances have been made in understanding the biology of Leishmania, parasite–host interactions, immune responses, and disease epidemiology. Molecular and genomic studies have identified numerous parasite virulence factors and mechanisms involved in intracellular survival. Improvements in diagnostic techniques, including rapid diagnostic tests (rK39), molecular diagnostics, and quantitative PCR, have enabled earlier and more accurate detection of infection. Advances in immunology have demonstrated that successful parasite clearance depends largely on a protective Th1 immune response characterized by interferon-γ (IFN-γ), interleukin-12 (IL-12), and macrophage activation, whereas disease progression is associated with elevated IL-10 and TGF-β production that suppress cellular immunity. Furthermore, improvements in experimental infection models, including macrophage assays, BALB/c mice, and hamster models, have greatly facilitated preclinical evaluation of novel therapeutic candidates.

The therapeutic landscape has also changed considerably. Pentavalent antimonials, once considered the major drug of VL treatment, have largely been replaced because of widespread resistance, particularly in the Indian subcontinent. Current treatment options include Amphotericin B, liposomal Amphotericin B, Miltefosine, Paromomycin, and Pentamidine.

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AREAS OF EXPERTISE
Immunology • Microbiology • Biological Sciences • Drug Discovery

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AREAS OF EXPERTISE
Parasitology • Host immune response • Microbiology • Molecular biology

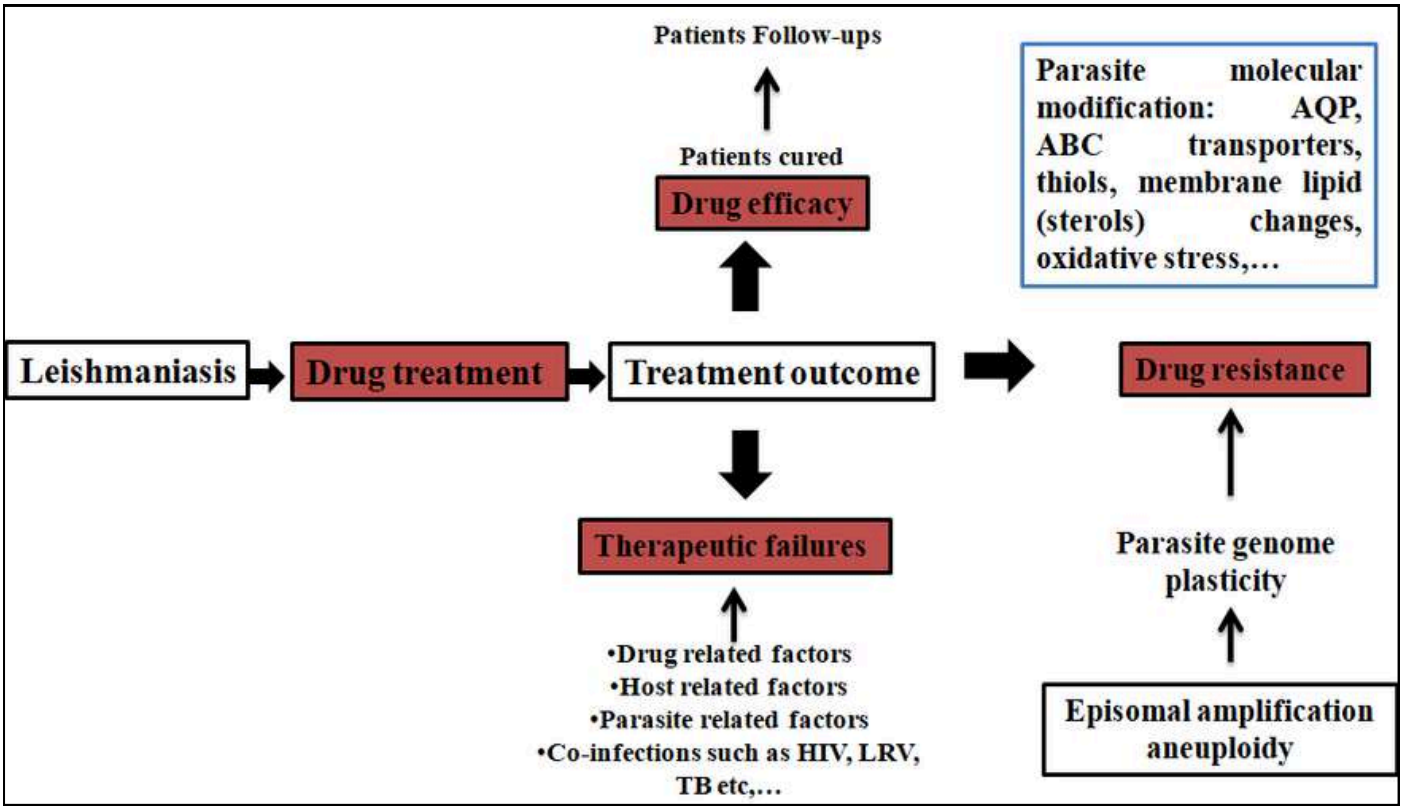

Figure 1. Factors leading to treatment failure and drug resistance in Leishmania.

These drugs have substantially reduced mortality and improved cure rates. However, none of these drugs acts as an ideal therapy because each drug has a limitations, including toxicity, prolonged treatment duration, high treatment costs, parenteral administration, hospitalization requirements, and reduced effectiveness in some endemic regions. Increasing reports of treatment failure and reduced susceptibility to Miltefosine and other anti-leishmanial drugs have raised serious concerns regarding the sustainability of current treatment strategies.

Giving Existing Medicines a New Purpose

One of the most significant advances in the field has been the recognition of drug repurposing as a practical and efficient strategy for anti-leishmanial drug discovery. Drug repurposing involves identifying approved or clinically investigated drugs for new therapeutic indications outside their original use. This strategy offers major advantages over conventional drug discovery because repurposed drugs already possess established safety profiles, pharmacokinetic data, manufacturing processes, and clinical experience, thereby reducing development time, costs, and regulatory barriers. Importantly, several anti-leishmanial drugs currently used in clinical practice are themselves successful examples of drug repurposing. Amphotericin B was originally developed as an antifungal drug, Miltefosine as an anticancer compound, Paromomycin as an aminoglycoside antibiotic, and Pentamidine for African trypanosomiasis before being adopted for visceral leishmaniasis. These successes provide strong evidence that repurposing existing medicines represents a scientifically valid approach for discovering new therapies against neglected tropical diseases.

New Technologies Accelerating Drug Discovery

Recent advances in computational biology, artificial intelligence, high-throughput drug screening, molecular docking, structural biology, metabolomics, transcriptomics, and systems pharmacology have accelerated the identification of repurposable drug candidates against *Leishmania*. Numerous FDA-approved drugs from diverse therapeutic classes including antimalarials, anticancer agents, antifungals, antibiotics, anti-inflammatory drugs, and metabolic

modulators have demonstrated anti-leishmanial activity in experimental studies. In parallel, increasing emphasis has been placed on evaluating not only parasite-killing activity but also the immunomodulatory effects of candidate drugs, recognizing that durable parasite clearance requires restoration of protective host immune responses in addition to direct parasite elimination.

The Remaining Challenges in Defeating Kala-Azar

Despite these important advances, several major scientific challenges remain. Drug-resistant Leishmania donovani has emerged as one of the greatest threats to VL control programmes. Parasites acquire resistance through multiple mechanisms, including altered drug uptake, increased drug efflux, gene amplification, chromosomal instability, metabolic adaptation, and enhanced antioxidant defense systems. Furthermore, treatment failure is a multifactorial phenomenon influenced not only by parasite resistance but also by host immune status, HIV co-infection, malnutrition, pharmacokinetic variability, treatment adherence, and environmental factors. Consequently, overcoming drug resistance requires therapeutic approaches that address both parasite biology and host immunity(Figure 1).

There is a limited evaluation of repurposed drugs against clinically resistant or relapse-derived Leishmania donovani isolates. Most published studies continue to rely on maintained laboratory strains that may not accurately represent parasites circulating in endemic regions. Similarly, relatively few investigations comprehensively examine the immunological effects of repurposed drugs alongside their direct anti-parasitic activity. Additional studies evaluating pharmacokinetics, combination therapy, resistance mechanisms, biomarkers of treatment response, and long-term safety are still required before repurposed medicines can be incorporated into routine clinical practice.

Our Contribution: Finding New Uses for Existing Drugs

Against this background, our research contributes to the field by investigating FDA-approved repurposed drugs against clinical isolates of Leishmania donovani exhibiting reduced susceptibility to currently available anti-leishmanial drugs. Unlike many previous studies performed using laboratory-adapted strains, our work evaluates clinically relevant isolates through both in vitro and in vivo experimental models. The study identifies Buparvaquone as the most potent repurposed candidate while also demonstrating promising anti-leishmanial activity for Disulfiram, Chloroquine, and Artemisinin. In addition to parasite inhibition, the research evaluates host-cell toxicity and immunomodulatory responses, demonstrating that selected repurposed drugs can reduce parasite burden while promoting protective Th1 immune responses. These findings provide important preclinical evidence supporting further investigation of repurposed medicines as safer, faster, and more cost-effective therapeutic alternatives for drug-resistant visceral leishmaniasis.

The Road Ahead

Overall, the current state of the field demonstrates substantial progress in understanding Leishmania biology, host immunity, and therapeutic development. Nevertheless, drug resistance, treatment failure, toxicity, prolonged treatment regimens, and the limited pipeline of novel anti-leishmanial drugs continue to threaten disease control and elimination programmes. Drug repurposing has emerged as one of the most promising strategies to address these challenges because it builds upon existing medicines with known safety profiles while substantially reducing the time and cost required for drug development. Continued research integrating molecular biology, immunology, pharmacology, and translational studies is expected to accelerate the discovery of effective repurposed therapies capable of overcoming drug-resistant kala-azar and improving patient outcomes worldwide.

Dr. Ramendra Pati Pandey's contributions to this field, together with Ph.D. Research Scholar Mr. Gajala Deethamvali Ghousepeer, are highlighted in their recent publication, in Naunyn Schmiedebergs Arch Pharmacol (DOI: 10.1007/s00210-026-05634-w). Their research explores how existing FDA-approved medicines can be used in new ways to treat drug-resistant kala-azar. By testing these medicines against the parasite in laboratory and animal studies, their work aims to identify safer, more effective, and affordable treatment options for patients with visceral leishmaniasis.

EMERGING INSIGHT

Beyond Antibiotics: Can We Fight Drug-Resistant Pneumonia Without Traditional Antibiotics?

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AREAS OF EXPERTISE
Host-pathogen interactions • Bacterial pneumonia • Extracellular vesicles • Pore-forming toxins • Cellular immunology

When Antibiotics Are No Longer Enough

For nearly a century, antibiotics have transformed the treatment of bacterial infections, saving millions of lives and making modern medicine possible. However, this success is increasingly threatened by antimicrobial resistance (AMR), which is reducing the effectiveness of many frontline antibiotics while the discovery of new antibacterial drugs struggles to keep pace. Among the pathogens contributing to this global crisis is Streptococcus pneumoniae, a leading cause of community-acquired pneumonia, meningitis, and bloodstream infections. As resistant strains continue to emerge, it has become clear that simply developing more antibiotics is unlikely to provide a long-term solution.

This realization is reshaping infectious disease research. Rather than asking only how to kill bacteria, scientists are increasingly exploring how pathogens establish infection, evade immune defence, and damage host tissues. By targeting these processes instead of bacterial survival alone, it may be possible to develop therapies that are both effective against drug-resistant pathogens and less likely to drive the evolution of resistance.

Our understanding of pneumococcal disease has changed considerably over the past decade. Research from many laboratories, including our own, has revealed that disease progression is governed not only by bacterial replication but also by a complex dialogue between bacterial virulence factors and host immune responses. One of the most exciting developments has been the recognition of extracellular vesicles (EVs) as important mediators of this communication.

Extracellular vesicles are nanosized membrane-bound particles released by almost every cell type. Once considered merely cellular debris, they are now recognized as sophisticated biological messengers that transport proteins, lipids, and nucleic acids between cells, coordinating immune responses and tissue homeostasis. In 2022, we proposed that EVs could play previously underappreciated roles during pneumococcal infection, not only as biomarkers of disease but also as regulators of immunity, potential vaccine candidates, and therapeutic delivery vehicles.

Subsequent studies from our laboratory provided experimental evidence supporting this concept. We demonstrated that pneumolysin, the major pore-forming cytotoxin produced by *S. pneumoniae*, stimulates infected host cells to release extracellular vesicles carrying both bacterial toxin and host inflammatory mediators (iScience, 2024). Rather than remaining confined to the initial site of infection, these vesicles can disseminate inflammatory signals to neighbouring and distant cells, amplifying tissue injury. More recently, we found that EV-bound pneumolysin interacts with host cell membranes through mechanisms extending beyond its classical pore-forming activity (bioRxiv 2026), suggesting that bacterial toxins exploit host-derived vesicles to propagate disease in ways that were previously unrecognized.

These discoveries reinforce an important concept that successful bacterial infections are not determined solely by the pathogen

but by the intricate interactions between microbial virulence factors and host biology. Understanding these interactions is opening entirely new therapeutic opportunities that extend beyond conventional antimicrobial strategies.

Turning Existing Medicines into New Weapons

A complementary approach emerging from our research is drug repurposing. Developing a new antibiotic is a lengthy, expensive, and high-risk process, whereas clinically approved drugs already have established safety profiles and can reach patients much more rapidly if new therapeutic applications are identified. Through computational simulations, biochemical tests, and mouse models of bacterial pneumonia, we found that sorafenib, an FDA-approved cancer drug blocks StkP, a key bacterial kinase that controls growth and virulence and is conserved across many clinically relevant drug-resistant pathogens (mBio, 2026). We showed that sorafenib disrupts key regulatory pathways required for disease progression, significantly reducing pneumococcal virulence in experimental models.

This work illustrates the promise of anti-virulence therapies-an emerging strategy that seeks to disarm pathogens instead of eliminating them outright. By targeting bacterial signalling pathways or toxins while preserving bacterial viability, these therapies may reduce the selective pressure that drives antimicrobial resistance. Although still in their early stages, anti-virulence approaches, together with advances in extracellular vesicle biology, are redefining how we think about combating bacterial infections and provide a glimpse of what the future of pneumonia treatment might look like.

The Questions That Will Shape the Next Decade

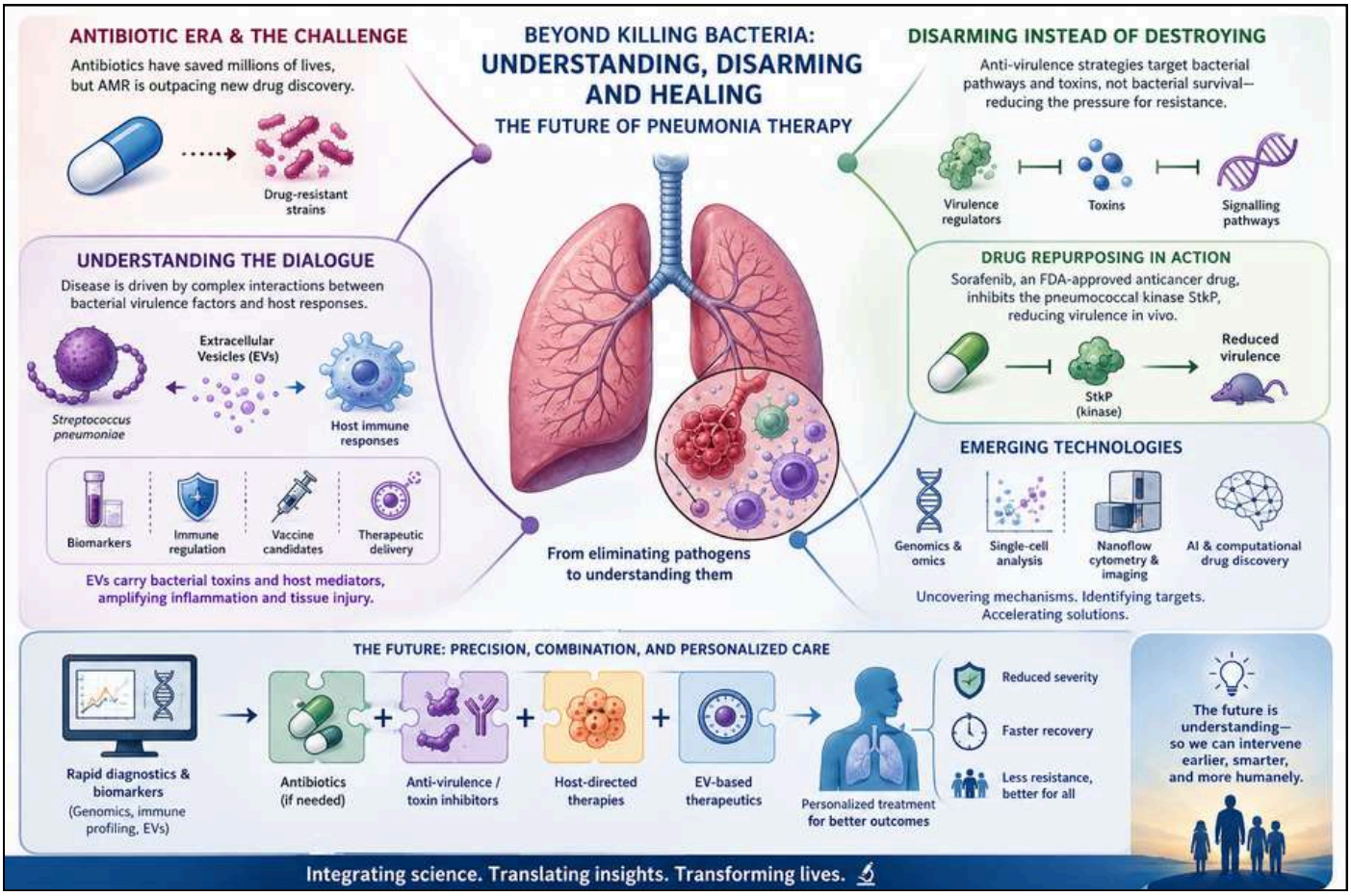

Figure 1: An illustration depicting emerging strategies to combat drug-resistant bacterial infections by moving beyond conventional antibiotics. The figure highlights how understanding host–pathogen interactions, extracellular vesicle biology, anti-virulence therapies, drug repurposing, and precision medicine may transform the treatment of pneumococcal pneumonia. Together, these approaches aim to disarm pathogens, modulate harmful immune responses, and enable more personalized and effective therapies for infectious diseases.

Where do we go from here? Despite remarkable progress, many fundamental questions remain unanswered. Why does S. pneumoniae exist harmlessly in the upper respiratory tract of many healthy individuals but cause severe pneumonia or invasive disease in others? How do bacterial virulence factors, host genetics, and immune responses interact to determine disease severity? And can we identify these processes early enough to intervene before irreversible tissue damage occurs?

Our work on extracellular vesicles has opened another intriguing area of investigation. We now know that EVs can transport pneumolysin and inflammatory mediators between cells, but many questions remain. How are bacterial proteins selectively packaged into these vesicles? Do different EV populations perform distinct functions during infection? Could circulating EVs serve as early biomarkers of disease severity or treatment response? Equally exciting is the possibility of engineering EVs as therapeutic delivery systems that can transport drugs, RNA molecules, or antibodies directly to infected tissues.

New Technologies Driving the Next Breakthroughs

Answering these questions will require advances across multiple disciplines. Single-cell sequencing, spatial transcriptomics, quantitative proteomics, nanoflow cytometry and high-resolution imaging are already transforming our understanding of host-pathogen interactions by revealing how individual cells respond during infection. At the same time, artificial intelligence is accelerating antimicrobial discovery by identifying promising drug candidates, predicting drug–target interactions, and uncovering new opportunities for drug repurposing. These technologies, combined with sophisticated infection models and computational biology, are making it increasingly possible to translate mechanistic discoveries into clinically relevant therapies.

Among the most promising trends is the growing shift toward anti-virulence and host-directed therapies. Rather than relying exclusively on antibiotics, future treatment strategies are likely to combine conventional antimicrobials with agents that neutralize bacterial toxins, inhibit virulence regulators, or modulate harmful inflammatory responses. Such combination therapies may not only improve patient outcomes but also reduce the selective pressure that drives antimicrobial resistance.

The Future of Precision Pneumonia Medicine

I believe that the next decade will witness a gradual transition from empirical treatment toward precision medicine. Future clinicians may look beyond simply identifying the infecting organism. Rapid genome sequencing, host immune profiling, and extracellular vesicle biomarkers could help determine which virulence pathways are active and which therapeutic combinations are most likely to benefit an individual patient. A patient with severe pneumococcal pneumonia might receive an antibiotic together with an anti-virulence drug, an immune-modulating therapy, or an extracellular vesicle-based therapeutic designed to limit tissue injury and promote recovery. Several developments are particularly worth watching. Clinical evaluation of repurposed drugs for bacterial infections is likely to expand, while bacterial virulence inhibitors and toxin-neutralizing therapies continue to advance toward translation. Extracellular vesicles are emerging not only as biomarkers for early diagnosis and disease monitoring but also as versatile platforms for targeted drug delivery. Together with artificial intelligence and precision diagnostics, these innovations are reshaping how we think about treating bacterial infections.

Looking Ahead

The history of infectious disease has largely been defined by our ability to eliminate pathogens. The future may instead be defined by our ability to understand them. By deciphering the molecular conversations between bacteria and their hosts, we are uncovering opportunities to intervene before infection progresses to severe disease. The next generation of pneumonia therapies is therefore unlikely to depend on a single revolutionary antibiotic. Instead, it will emerge from integrating anti-virulence strategies, drug repurposing, extracellular vesicle biology, host-directed therapies, and precision medicine into a more holistic approach to infection. Although significant scientific and translational challenges remain, these advances offer genuine optimism that drug-resistant pneumonia will become a more preventable and treatable disease in the years ahead.

Dr. Karthik Subramanian's research group at BRIC–Rajiv Gandhi Centre for Biotechnology investigates how *Streptococcus pneumoniae* causes disease and develops new treatment strategies to combat antibiotic-resistant bacterial infections. Their contributions to this field are highlighted in the team's publication in mBio (2026), titled "Sorafenib, a Clinical Kinase Inhibitor, Attenuates *Streptococcus pneumoniae* Pathogenesis and Reduces Disease Progression in vivo" (DOI: 10.1128/mbio.00618-26). The study shows that sorafenib, a drug originally developed for cancer treatment, can reduce the ability of *Streptococcus pneumoniae* to cause disease, offering a promising new approach for treating drug-resistant bacterial infections.

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EMERGING INSIGHT

Decoding the Molecular Language of Life: The Promise of Multiplex Sensing

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AREAS OF EXPERTISE

Inorganic-Organic Hybrid Materials • Molecular Recognition • Nanoparticle Research • Photophysical Processes • Responsive Softmaterials

Multiplex sensing: Looking beyond a single biomarker

Imagine planning your day based solely on today's temperature. Without knowing the humidity, wind speed, rainfall, or air pressure, your forecast would be incomplete and often inaccurate. Our bodies function in much the same way. Health and disease are rarely governed by a single biomarker; instead, they arise from a complex network of biological signals that change together. Measuring only one biomarker therefore provides only a limited snapshot of an inherently dynamic system. Instead, a sensing platform capable of detecting multiple analytes simultaneously provides a far more complete picture of the underlying biological processes. By measuring several biomarkers in a single analysis, multiplex sensing reduces the need for multiple independent tests, lowers cost, shortens analysis time, and requires only a small sample volume. More importantly, it improves diagnostic accuracy, enables earlier disease detection, and supports the growing shift toward personalized and precision medicine. Rather than relying on a single clue, multiplex sensing reveals the broader biological landscape, transforming diagnostics from isolated measurements into comprehensive health monitoring.

A traditional sensor is much like a thermometer; it measures one parameter exceptionally well. A multiplex sensor, in contrast, resembles a comprehensive health check-up, where multiple physiological indicators are evaluated together before a diagnosis is made.

The true strength of multiplex sensing therefore lies not simply in detecting more analytes, but in extracting more meaningful information from every measurement. Relationships between biomarkers often reveal far more about a biological system than the concentration of any individual molecule.

These advantages have fuelled the rapid growth of multiplex sensing in recent years. Advances in precision medicine, wearable technologies, point-of-care diagnostics, and portable analytical devices have created an increasing demand for rapid and comprehensive molecular analysis. Instead of sending samples to centralized laboratories for multiple independent tests, clinicians increasingly seek compact platforms capable of analysing several biomarkers simultaneously.

Similar needs extend well beyond healthcare to environmental monitoring, food safety, agriculture, and industrial process control, where reliable decisions frequently depend on information obtained from multiple chemical species rather than a single analyte.

For decades, however, most chemical sensors were designed to detect one target at a time. While highly effective for specific analytical tasks, such sensors cannot fully capture the complexity of biological systems. Diseases such as cancer, inflammatory disorders, metabolic syndromes, and infectious diseases involve intricate networks of interacting biomarkers whose concentrations change together over time. Equally important is the ability to monitor these dynamic changes. A single measurement represents only a snapshot, whereas continuous multiplex sensing can reveal disease progression, treatment response, and physiological trends that would otherwise remain hidden.

Nature itself provides an elegant blueprint for this approach. Human

taste, smell, and immune systems do not rely on a single receptor; instead, they integrate information from multiple recognition events before generating a response. Multiplex sensing follows the same principle, combining several molecular interactions to produce a more reliable and informative analytical outcome. Supramolecular chemistry is particularly well suited to this challenge because molecular recognition is inherently dynamic. Weak non-covalent interactions—including hydrogen bonding, electrostatic interactions, π–π stacking, metal coordination, and hydrophobic forces—can be combined, tuned, or reversibly switched in response to external stimuli. This remarkable adaptability enables a single molecular framework to recognise different analytes under different conditions, making supramolecular systems exceptionally versatile platforms for programmable multiplex sensing.

The challenge of detecting many targets at once

Although multiplex sensing promises faster, richer, and more informative diagnostics, designing a single platform capable of detecting multiple analytes simultaneously is far from straightforward. Unlike conventional sensors that monitor one target at a time, multiplex systems must recognize several analytes independently while ensuring that each generates a unique, reliable, and quantifiable response. Simply combining multiple sensing elements into a single device does not guarantee successful multiplex detection (Figure 1).

One of the greatest challenges is cross-reactivity, where non-target molecules interfere with molecular recognition, leading to false-positive or false-negative responses. Analytes may also compete for common binding sites or modify the local sensing environment, resulting in signal suppression, signal enhancement, or changes in binding affinity. Such interactions can distort the analytical response, reducing both sensitivity and quantitative accuracy.

Another major obstacle is signal overlap. In many sensing platforms, different analytes generate similar fluorescence emissions, electrochemical responses, or optical signals, making it difficult to distinguish individual targets. Effective multiplex sensing therefore requires orthogonal sensing events, where each analyte produces an independent analytical signature or "chemical fingerprint." These fingerprints may arise from distinct fluorescence colours, emission lifetimes, Raman bands, electrochemical potentials, polarization signals, or other spectroscopic outputs. Much like several people speaking simultaneously in different languages, independent analytical signatures allow each molecular "voice" to be recognised without confusion, even when many analytes are present together. Designing such orthogonal responses while maintaining high sensitivity and selectivity remains one of the central challenges in materials chemistry.

Calibration presents an equally important challenge. Unlike single-analyte sensors, where the signal depends only on the concentration of one target, multiplex sensors often exhibit interconnected respon-

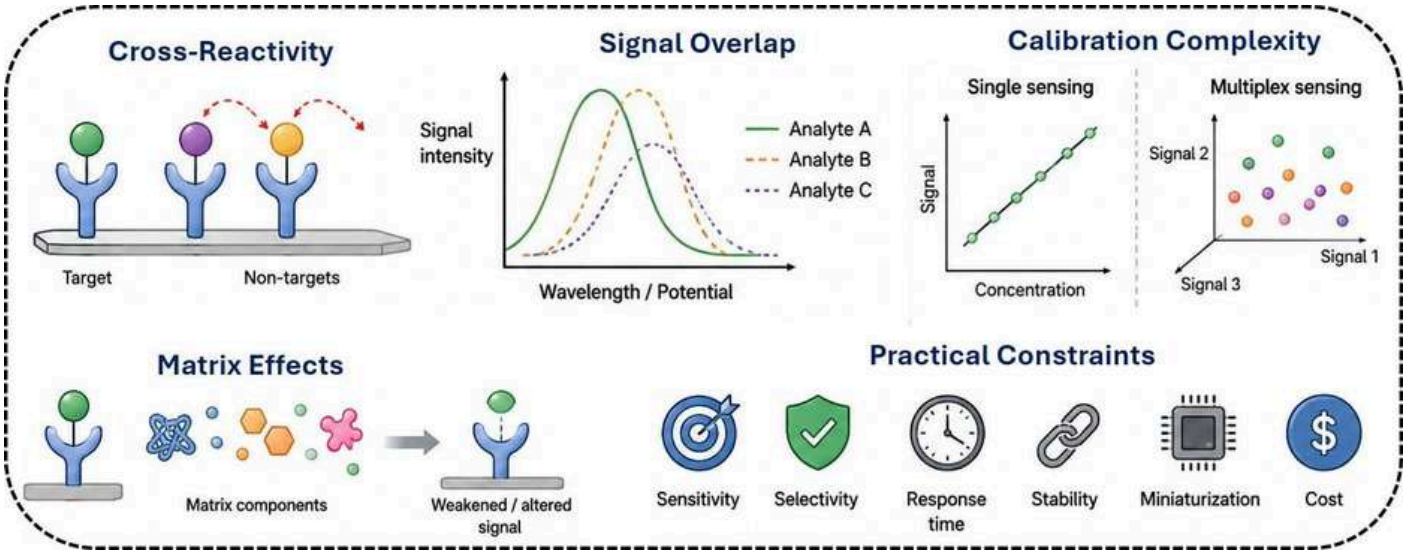

Figure 1: Major challenges associated with multiplex sensing.

ses in which one analyte influences the detection of another. Conventional one-dimensional calibration curves therefore become inadequate. Instead, multidimensional calibration models capable of accounting for simultaneous variations in multiple analytes are required to achieve reliable quantitative analysis.

Real biological and environmental samples further increase the complexity. Proteins, salts, metabolites, and numerous background species can foul sensor surfaces, mask weak signals, or alter the local chemical environment through nonspecific interactions. Variations in pH, temperature, ionic strength, and sample composition introduce additional matrix effects that can compromise reproducibility and analytical accuracy. As multiplex sensors become increasingly sophisticated, they must also balance sensitivity, dynamic range, response time, long-term stability, miniaturization, manufacturability, and cost without sacrificing analytical performance.

Researchers are overcoming these challenges through advances in molecular design, functional materials, and computational analysis. Highly selective recognition elements minimize cross-reactivity, while engineered nanomaterials amplify weak signals and improve signal discrimination. Ratiometric sensing, multichannel detection, and orthogonal spectroscopic outputs further enhance analyte identification. At the same time, chemometric analysis and machine-learning algorithms can deconvolute complex datasets, compensate for matrix effects, and extract meaningful information from overlapping analytical responses.

Together, these advances are steadily transforming multiplex sensing from an elegant laboratory concept into a practical technology for healthcare, environmental monitoring, food safety, and wearable diagnostics.

Engineering selectivity: Teaching one sensor to recognize many targets

One of the most fascinating aspects of multiplex sensing is that selectivity can often be engineered rather than discovered. Instead of designing an entirely new sensor for every analyte, researchers can manipulate the sensing environment or molecular recognition process so that the same sensing platform responds selectively to different targets under different conditions. This adaptability is one of the defining strengths of supramolecular sensing.

Perhaps the simplest strategy is to modify the sensing environment. Parameters such as solvent composition, pH, ionic strength, or temperature can dramatically influence host–guest interactions. For example, polar protic solvents weaken the interaction between receptors and strongly basic anions through competitive hydrogen bonding, thereby suppressing unwanted binding while enhancing selectivity toward other analytes. Similarly, changing the solution pH alters the protonation state of the receptor, effectively switching specific binding sites on or off and controlling which analytes can be recognized.

Another widely used approach employs selective masking agents. Certain molecules bind strongly to specific interfering species, temporarily removing them from the sensing process without affecting the target analyte. For instance, ethylenediamine selectively complexes Cu^{2+} ions, whereas cysteine exhibits a high affinity for Hg^{2+}. Such masking strategies simplify complex analytical mixtures and significantly improve sensing selectivity.

Selectivity can also be regulated using external stimuli. Light-responsive molecules undergo reversible conformational changes upon irradiation, exposing or shielding particular recognition sites and thereby altering analyte binding. Likewise, acid- or base-induced protonation and deprotonation can reversibly block one binding event while promoting another. These stimulus-responsive systems effectively transform a single molecular receptor into a programmable sensing platform capable of performing multiple recognition tasks on demand.

An even more sophisticated strategy is relay recognition, in which molecular recognition occurs through a programmed sequence of events rather than a single binding process. One analyte first interacts with the sensor to generate a new recognition environment, enabling a second analyte to form a ternary complex. Alternatively, the second analyte may displace the first—a mechanism widely exploited in metal-ion displacement assays, where an incoming anion replaces a coordinated metal ion and produces a distinct optical or electrochemical response. Such sequential recogniti-

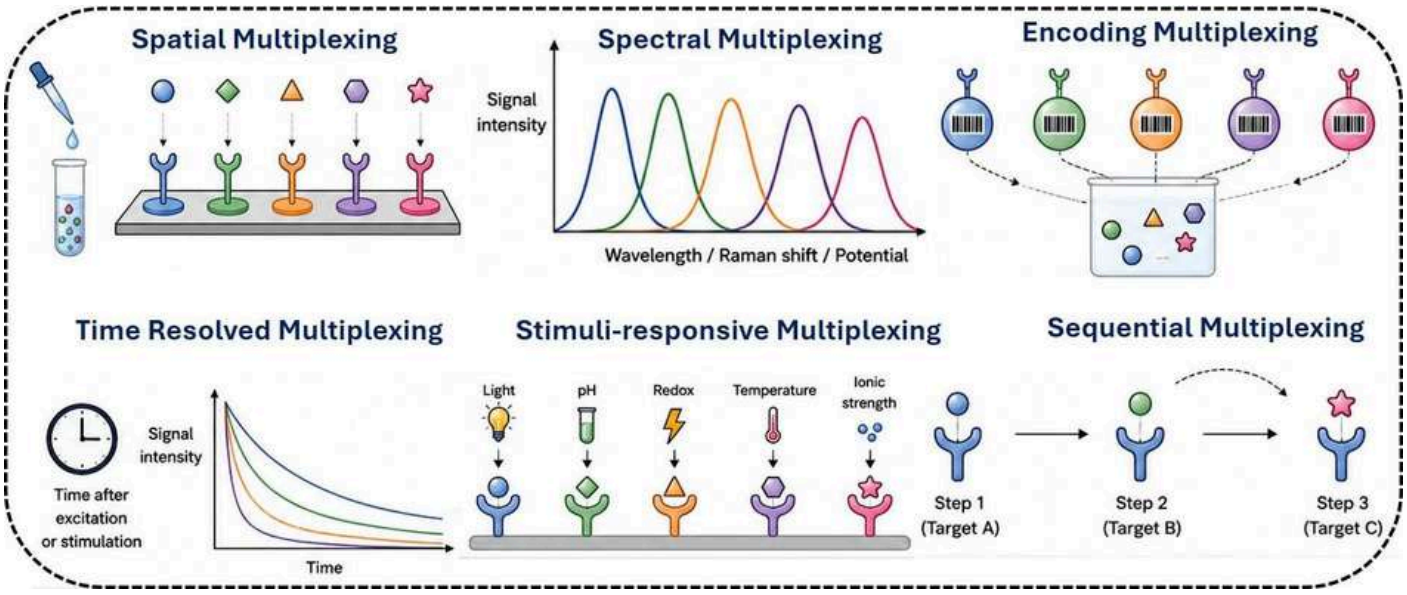

Figure 2: Various strategies for achieving multiplex sensing.

on processes substantially expand the analytical capability of a single sensing platform.

Collectively, these approaches illustrate that multiplex sensing is far more than the integration of multiple receptors into one device. Instead, it represents the intelligent programming of molecular recognition, where chemical interactions are deliberately controlled in space, time, and chemical environment to enable the selective, accurate, and simultaneous detection of multiple analytes (Figure 2).

From proof-of-concept to practical technology

Designing a multiplex sensing platform is only the beginning; demonstrating that it performs reliably under realistic conditions is equally important. A sensor that works under carefully controlled laboratory conditions may not necessarily deliver accurate results when confronted with complex biological or environmental samples. Consequently, rigorous validation is essential before multiplex sensing can be translated into practical applications.

Understanding the molecular recognition process is the first step toward reliable sensor design. Hill plot analysis provides valuable insight into whether analyte binding is cooperative, non-cooperative, or negatively cooperative, revealing how one recognition event influences subsequent binding events. Such analyses can also identify allosteric effects, where binding of one analyte alters the affinity of the receptor for another. Because multiplex sensing often involves multiple simultaneous or sequential recognition processes, these cooperative interactions play a crucial role in determining overall sensor performance.

Equally important are interference and cross-reactivity studies. A robust multiplex sensor must be challenged with structurally related molecules and common interferents present in real samples to ensure that each analyte is recognised selectively. Beyond simple selectivity tests, researchers should also investigate competitive binding, signal suppression or enhancement, and other inter-analyte effects that may influence quantitative measurements.

A detailed understanding of molecular recognition also requires the determination of binding stoichiometry and affinity constants. Methods such as Job's plot, nonlinear regression analysis, and, where appropriate, isothermal titration calorimetry provide quantitative information on host–guest interactions. These measurements not only validate the sensing mechanism but also guide the rational optimization of receptor design.

Analytical performance must then be evaluated comprehensively. Standard performance metrics, including the limit of detection (LOD), limit of quantification (LOQ), linear dynamic range, sensitivity, response time, precision, reproducibility, and recovery should be established for both individual analytes and the multiplex platform as a whole. Importantly, analytical

performance determined under single-analyte conditions may not remain unchanged when multiple analytes are present simultaneously. Competition for binding sites, signal overlap, cooperative interactions, and matrix effects can all influence sensitivity, dynamic range, and detection limits.

Unlike conventional sensors, where the analytical signal depends primarily on the concentration of a single analyte, multiplex sensing generates multidimensional datasets in which multiple responses are often interdependent. Consequently, simple one-dimensional calibration curves are frequently insufficient. Instead, multidimensional calibration models, chemometric approaches, and increasingly machine-learning algorithms are being employed to deconvolute overlapping signals, compensate for matrix effects, and accurately predict the concentrations of several analytes simultaneously. Rather than replacing traditional analytical chemistry, these computational tools extend its capabilities by extracting meaningful information from complex datasets that would otherwise be difficult to interpret.

Ultimately, rigorous mechanistic studies, comprehensive analytical validation, and advanced data analysis transform multiplex sensing from an elegant laboratory demonstration into a robust analytical technology capable of delivering reliable and quantitative information in real-world applications.

Looking ahead: The future of multiplex sensing

As sensing technologies continue to evolve, the future of multiplex sensing will involve far more than simply detecting an increasing number of molecules. The next generation of sensors will seek to understand how multiple biomarkers interact, revealing the complex molecular networks that underpin health, disease, and environmental processes. In this sense, multiplex sensing represents a shift from measuring individual chemical species to interpreting the molecular language of complex systems.

This transformation is being driven by the convergence of supramolecular chemistry, advanced functional materials, flexible electronics, artificial intelligence, and wireless communication. Future sensing platforms are expected to evolve into compact, self-contained analytical systems capable of continuously monitoring multiple biomarkers while processing and interpreting the data in real time. Rather than functioning solely as analytical devices, these intelligent sensors will increasingly serve as decision-support tools for clinicians, researchers, and environmental scientists.

Wearable and non-invasive diagnostics are likely to be among the first beneficiaries of these advances. Biomarkers present in sweat, saliva, tears, breath, and interstitial fluid can now be monitored without the need for repeated blood sampling. Future wearable devices may continuously analyse these biofluids while wirelessly transmitting results to smartphones or healthcare providers, enabling earlier disease detection, personalised treatment, and proactive health management instead of reactive diagnosis.

Artificial intelligence will play an increasingly important role in this evolution. Modern multiplex sensors generate complex multidimensional datasets that often contain hundreds of analytical variables. Machine-learning algorithms can identify subtle relationships among these signals, distinguish overlapping analytical responses, and continuously improve prediction accuracy as more data become available. As these computational tools mature, they will transform multiplex sensing from simple molecular detection into intelligent molecular interpretation.

Looking further ahead, multiplex sensing may become a cornerstone of digital health twins, where continuous molecular information is integrated with physiological, clinical, and wearable-device data to generate dynamic, personalised models of human health. Such systems could predict disease progression, evaluate treatment response, and support truly personalised medicine through continuous molecular surveillance rather than occasional clinical testing.

At the same time, future progress must balance analytical sophistication with practical considerations. Increasing the number of sensing channels can improve information content but also introduces greater molecular complexity, computational demands, and opportunities for signal interference. Likewise, next-generation sensing platforms should be designed with sustainability in

mind. Miniaturised devices require smaller sample volumes and fewer reagents, reducing analytical waste, while paper-based sensors, biodegradable materials, and low-power electronics can make multiplex sensing more environmentally responsible and accessible in resource-limited settings.

Ultimately, the success of multiplex sensing will not be measured simply by the number of analytes that can be detected simultaneously, but by the quality of the information that can be extracted from them. As supramolecular chemistry, intelligent materials, artificial intelligence, and wearable technologies continue to converge, multiplex sensing is poised to evolve from a powerful analytical technique into an integrated platform for understanding complex molecular systems. In doing so, it has the potential to transform not only diagnostics, but also environmental monitoring, food safety, precision agriculture, and the broader future of smart analytical technologies.

Dr. Nilanjan Dey's contributions to this field are highlighted in his recent publication, "One Probe, Two Chemistries: An Orthogonal Fluorescent Sensing Platform for Glutathione and Hydrazine in Biological Fluids and Food Samples " in Journal of Materials Chemistry B https://doi.org/10.1039/d5tb02823j. This study shows how a single fluorescent probe can detect two different molecules at the same time, making testing faster, simpler, and more efficient for biological samples and food safety applications.

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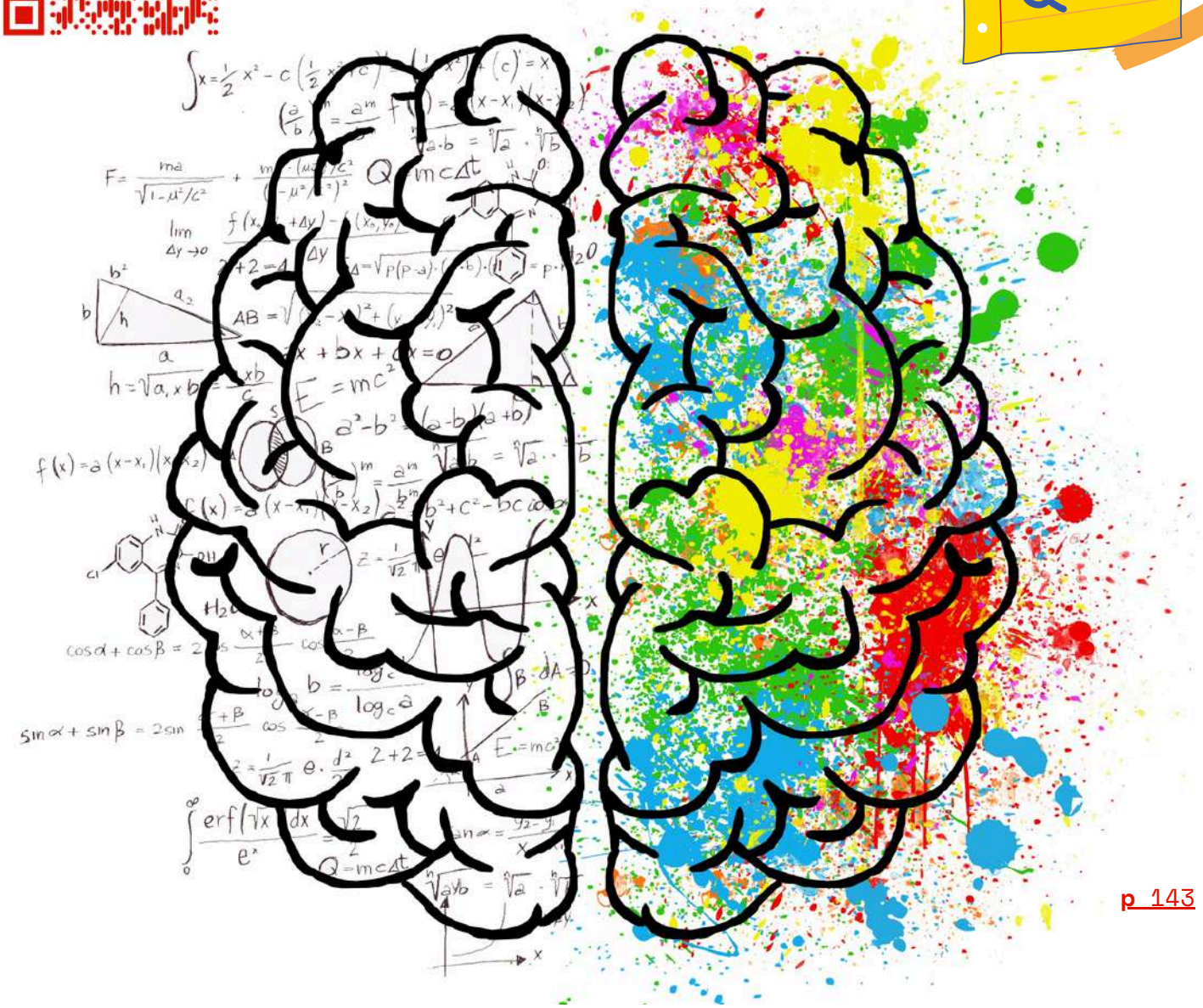
RESEARCHERS LIFELINE RESEARCH HEALTH



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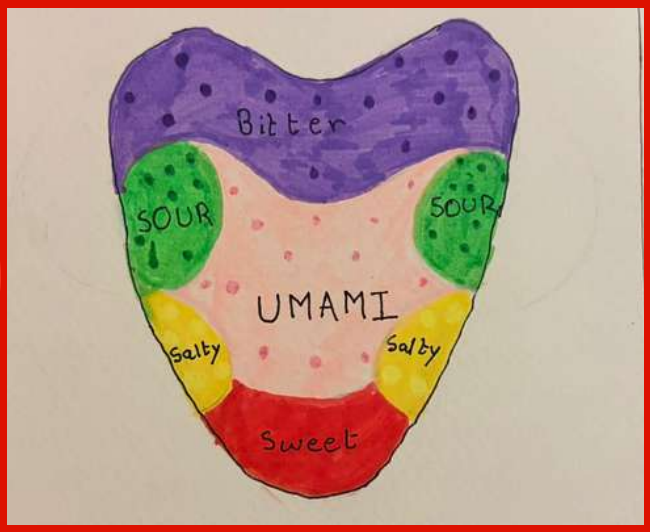
back to school

CURIOUS KID'S



NAME: **Chitrakshi Hota**

Grade: **4**

SCHOOL: **VIBGYIOR High International School**

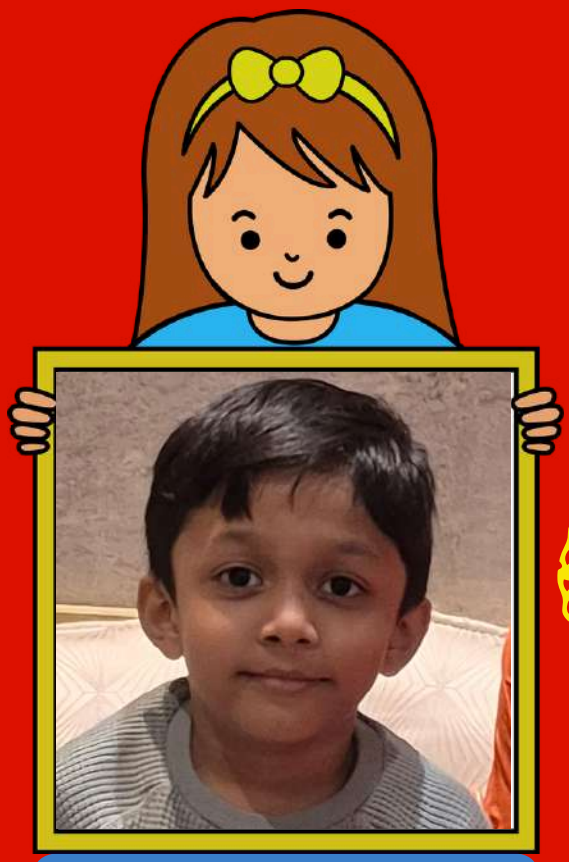
FOCUS:

How Does My Tongue Know What I'm Eating?

Have you ever wondered how your tongue can tell the difference between ice cream, lemon, chips, and vegetables? My painting explores the five basic tastes sweet, salty, sour, bitter, and umami. Tiny taste buds on our tongue act like little scientists, detecting these flavors and sending messages to the brain. Together, they help us enjoy food, stay safe from harmful substances, and discover the amazing science hidden in every bite!

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

back to school



CURIOUS KID'S

NAME: **Parth Shreyas**

Grade: 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.

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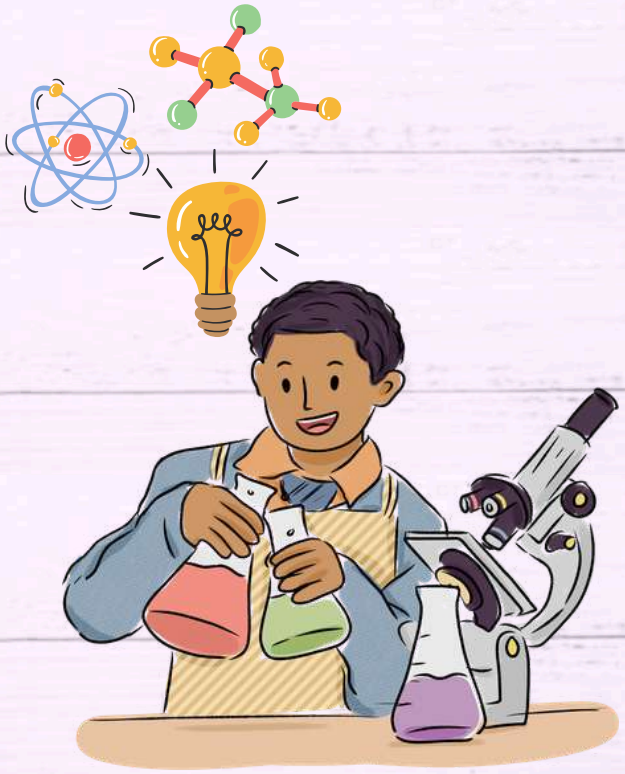

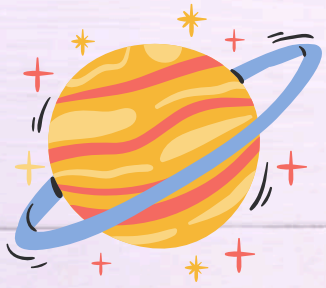

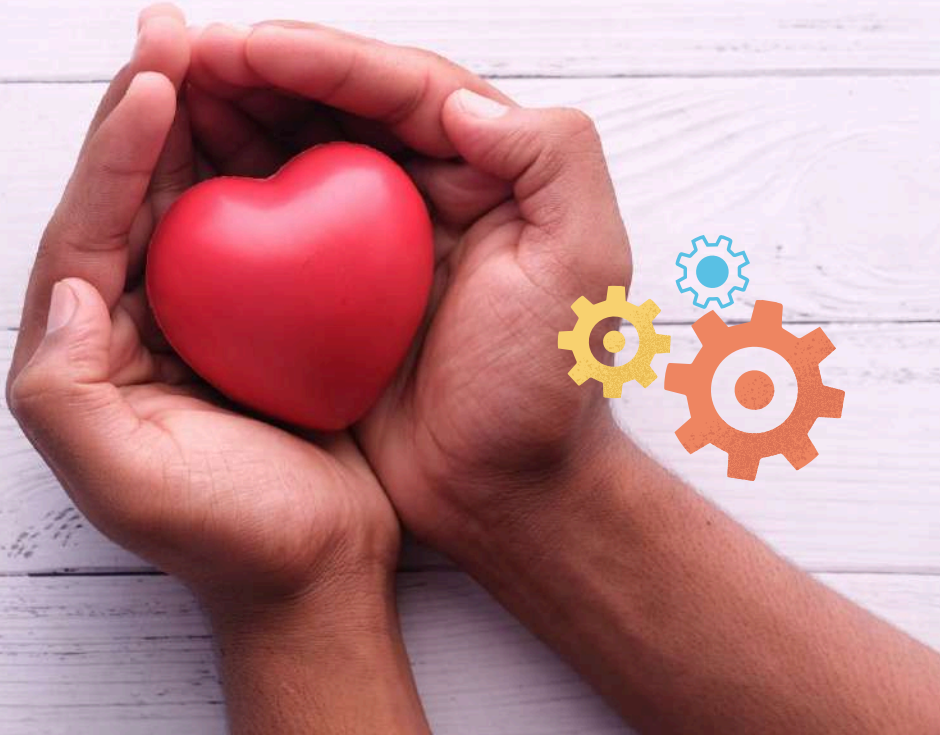

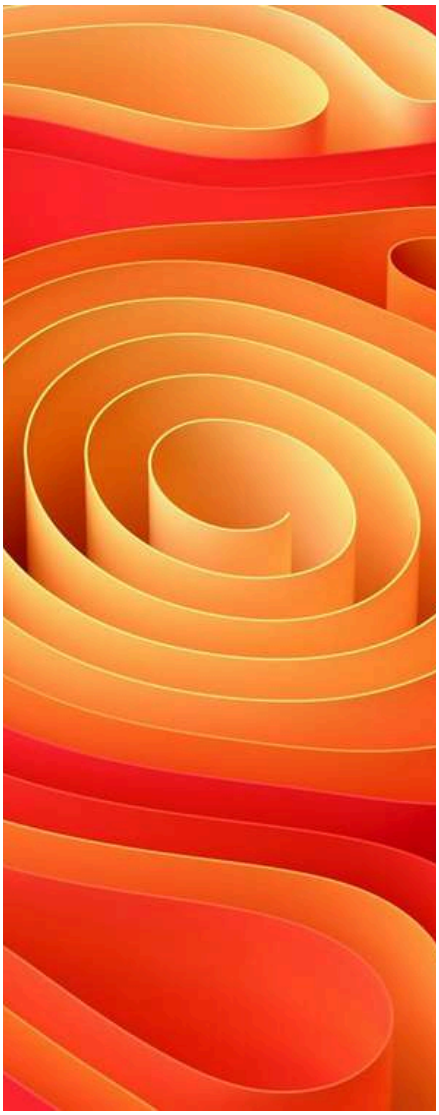

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