# VIGYAN 2047

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## 2026 resolution

# NO more lifestyle disorders

**VIGYAN 2047**

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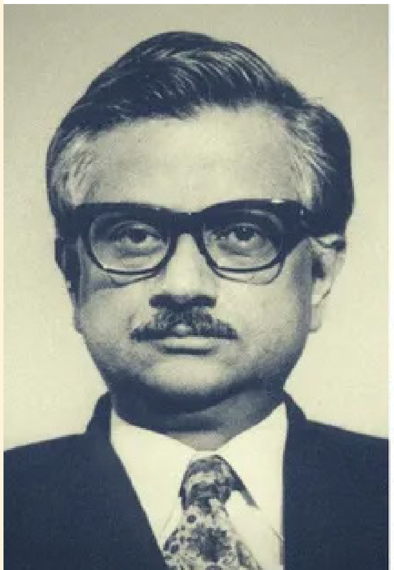
# In This Issue





# Editorial

## Youthful start to the year

Wishing you and our young nation a very happy new year.

Ranked consistently among the top 200–250 institutions globally, the Indian Institute of Science (IISc), Bengaluru, stands today as one of India's most respected centres of scientific research and innovation. From aerospace and materials science to artificial intelligence, climate studies, biotechnology, and national defence, IISc has shaped the intellectual and technological foundations of modern India.

Yet, the origins of this world-class institution do not lie merely in laboratories or policy documents. They trace back to an idea—one born of dialogue, vision, and deep concern for India's future.

More than a century ago, during a historic ship journey in 1893, Swami Vivekananda and Jamshedji Tata engaged in conversations that would quietly alter the course of Indian education. Vivekananda urged the creation of institutions that could advance scientific research, technical knowledge, and original thinking, enabling Indians to compete globally while remaining rooted in national purpose. Inspired by this call, Jamshedji Tata later laid the foundation for IISc—an enduring testament to the power of visionary education.

As India commemorates the birth anniversary of Swami Vivekananda, it is worth reflecting on how deeply relevant his ideas remain. Vivekananda was not opposed to science or modernity; he believed that India's regeneration depended on the union of scientific reasoning, technological capability, and moral strength. Education, for him, was not rote learning but a force that built character, courage, and creativity.

In today's context, this philosophy finds its strongest expression in STEM education—Science, Technology, Engineering, and Mathematics. For a young nation like India, where more than half the population is under 30, STEM education is more than a pathway to jobs. It nurtures problem-solving, critical thinking, innovation, and a scientific temper—qualities essential to addressing challenges in healthcare, energy security, climate resilience, and digital transformation.

Institutions like IISc demonstrate what sustained investment in STEM can achieve. They do not merely produce graduates; they generate ideas, technologies, and solutions that influence industry, policy, and society. This reinforces a central lesson from India's own history: national growth is built on long-term commitment to science and education, not short-term gains.

Equally important is Swami Vivekananda's insistence that education must reach the masses. Knowledge, he believed, should not remain confined to elite centres. Today, this translates into expanding STEM education in rural and underserved regions, bridging digital divides, and ensuring that talent is not constrained by geography or poverty.

STEM education also strengthens democracy. By encouraging rational inquiry, evidence-based decision-making, and openness to new ideas, it fosters a scientific temper—an idea later enshrined in the Indian Constitution and essential for a plural, progressive society.

As India moves toward its centenary of independence, Swami Vivekananda's vision offers both inspiration and direction. He did not call for blind imitation of the West, but for self-reliant knowledge creation, rooted in India's strengths and aimed at global contribution. STEM education, integrated with ethics and social responsibility, embodies this ideal.

Wishing you all a very happy new year once again, with a resolution to a renewed lifestyle, our cover story this issue.

**Nakul Parashar,** PhD
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# Letter to the Editor

I went through Vigyan 2047 (Vol. 2, Issue 12) and would like to congratulate the team on a well-curated and impactful edition.

The theme "2025 — The Year It Was" comes through clearly, and the editorial sets a thoughtful tone by highlighting both the promise and responsibility of science and technology.

Found it engaging, balanced, informative, and accessible to a wide audience. The feature on Group Captain Shubhanshu Shukla as Scientific Indian of the Year 2025 is inspiring and well suited for motivating young readers. Diversity of topics covered, especially the articles on quantum science and Marie Curie.

My observations and findings:

- Few sections bit more visual structuring.

- Brief "key takeaway" elements may further enhance readability for students and general readers.

Overall, this is a strong issue that reflects the growing quality and relevance of Vigyan 2047.

Congratulations to the entire team, and thank you for your continued efforts in science communication.

Warm Regards,

***Varun Singh***
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*9319109994*
*Varunelite9@gmail.com*

# CALENDAR 2026

# VIGYAN 2047

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## List of Holidays

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| 26 Jan | Mon | Republic Day |
| 04 Mar | Wed | Holi |
| 26 Mar | Thu | Ram Navami |
| 15 Aug | Sat | Independence Day |
| 28 Aug | Fri | Raksha Bandhan |
| 04 Sep | Fri | Janmashtami |
| 02 Oct | Fri | MG Birthday |
| 20 Oct | Tue | Dussehra |
| 08 Nov | Sun | Diwali |
| 24 Nov | Tue | Kartik Purnima |
| 25 Dec | Fri | Christmas |

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VIGYAN 2047 Volume 3 No. 1 January 2026 Pages 6–7

In The News

# Self-fertilizing wheat

Scientists at the University of California, Davis have developed wheat that can help generate its own natural fertilizer, potentially reducing pollution and cutting farmers' costs. Led by professor Eduardo Blumwald, the team used CRISPR gene editing to boost the plant's production of apigenin, a naturally occurring flavone. When released into the soil, the extra apigenin encourages beneficial bacteria to form biofilms—protective, low-oxygen layers that allow the enzyme nitrogenase to function. This enables the bacteria to convert atmospheric nitrogen into a form the wheat can use, a process known as nitrogen fixation. Unlike legumes, wheat cannot form root nodules to shelter nitrogen-fixing bacteria, so farmers largely rely on synthetic fertilizers. Yet plants typically absorb only 30–50% of applied nitrogen, with the rest contributing to water pollution, "dead zones," and greenhouse gas emissions. The modified wheat produced higher yields than standard plants even under very low fertilizer conditions, suggesting major potential benefits, especially in regions where farmers struggle to afford fertilizer. Wheat accounts for roughly 18% of global nitrogen fertilizer use, so even a modest reduction could save billions and lessen environmental harm. Researchers are also exploring similar approaches for other cereal crops. ◆

# Decades-old chemical challenge solved

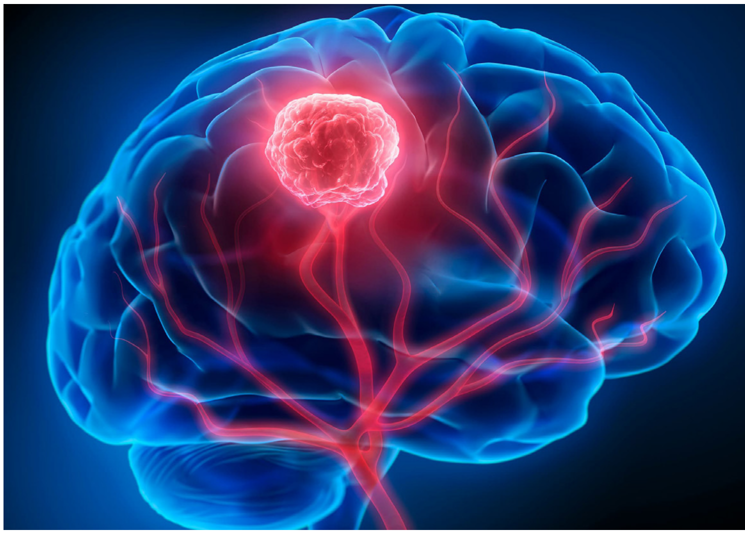
Researchers at the University of Santiago de Compostela's CiQUS center have developed a catalytic method that solves a long-standing challenge in converting natural gas into valuable chemicals. Natural gas is abundant but largely underused in chemical manufacturing because its main components—methane, ethane, and propane—are highly unreactive. The new approach, led by Martín Fañanás and published in Science Advances, efficiently transforms methane and related gases into versatile chemical building blocks. The team focused on allylation, a reaction that adds an allyl group to the gas molecule, creating a flexible starting point for producing pharmaceuticals and industrial materials. A major obstacle had been the formation of unwanted chlorinated byproducts that derail the reaction. To address this, the researchers designed a supramolecular catalyst built around a tetrachloroferrate anion stabilized by collidinium cations. This structure forms a hydrogen-bonded environment that enables photocatalytic activation of the alkane while suppressing problematic chlorination. The method is sustainable as well, relying on abundant, low-toxicity iron and mild, LED-driven conditions. In a key demonstration, the team synthesized the bioactive compound dimestrol directly from methane. Together with related advances, this work highlights a path toward cleaner, more efficient use of natural gas in chemical production. ◆

# Coral reefs could be overtaken by algae

A new study in Communications Biology examines rare coral reefs in Papua New Guinea to understand how rising ocean acidification may reshape reef ecosystems by 2100. As oceans absorb more atmospheric $CO_2$, seawater becomes increasingly acidic, weakening the limestone skeletons that support corals. To observe long-term, ecosystem-wide effects, researchers from the Australian Institute of Marine Science (AIMS) studied reef communities exposed to naturally high $CO_2$ near shallow volcanic seeps in Milne Bay. These sites act as real-world analogs of future ocean conditions. Senior author Dr. Katharina Fabricius explains that these "natural laboratories" reveal which species can endure persistent acidity. Surveys across 37 sites showed a clear trend: as $CO_2$ levels rise, corals decline while fleshy algae expand, ultimately smothering reefs. The team also documented steep reductions in baby corals, indicating slower reef growth and recovery—threatening the many species, including fish and humans, that depend on healthy reefs. Ocean acidity has already increased 30%, with pH projected to fall from 8.0 to about 7.8 by 2100. The findings show no sudden tipping point, but rather a steady shift toward algae-dominated ecosystems unless global $CO_2$ emissions fall significantly. ◆

# Nasal nanodrops eradicate brain tumors

Researchers at Washington University School of Medicine and Northwestern University have developed a noninvasive nanomedicine strategy aimed at treating glioblastoma, one of the deadliest and fastest-growing brain cancers. The method uses engineered nanoscale structures called spherical nucleic acids (SNAs), delivered through simple nasal drops, to activate the brain's immune defenses. In mouse studies, the treatment successfully reached glioblastoma tumors and stimulated strong immune activity while avoiding invasive procedures normally required for similar therapies. The findings appear in PNAS. Glioblastoma is difficult to treat partly because therapeutic drugs struggle to cross into the brain, and because tumors are "cold," meaning they provoke little natural immune response. To address this, researchers designed SNAs with gold cores coated in DNA capable of activating the STING immune pathway, which helps the body detect and attack abnormal cells. When delivered intranasally, the SNAs traveled along nerves connecting the nasal passages to the brain, concentrated in tumor-associated immune cells, and triggered targeted immune activation without affecting other organs. When combined with drugs that stimulate T cells, the therapy eradicated tumors in mice and provided long-term protection against recurrence. The team is now exploring ways to expand the nanostructure's immune-activating capabilities for future clinical use. ◆



VIGYAN 2047 Volume 3 No. 1 January 2026 Pages 8–13

COVER STORY

# Lifestyle Disorders

## A Story of Modern Living and Its Hidden Costs

AK Gupta

There is a quiet epidemic unfolding around us—one that does not announce itself with dramatic symptoms or sudden outbreaks, yet touches nearly every home, every workplace, and every family we know. It is the epidemic of lifestyle disorders, a new age of illnesses born not from microbes or contagion, but from the very way we live our modern lives. As cities grow taller and lives grow faster, our days have become a delicate balancing act between deadlines, digital demands, processed meals, and stolen hours of sleep. In the pursuit of success and convenience, we have drifted into habits that slowly chip away at our health without our noticing.

Look around in any community today: the teenager battling obesity, the young professional with high blood pressure, the homemaker managing diabetes, the senior citizen struggling with anxiety and insomnia. These stories, once rare, are now strikingly familiar. What makes lifestyle disorders especially deceptive is their slow, quiet nature—they creep into our routines and settle into our bodies long before we recognise their presence.

Yet within this challenge lies a profound truth: our lifestyles created these disorders, and our lifestyles can remedy them. The power to reverse this tide lies, quite remarkably, in our daily choices.

Lifestyle disorders—hypertension, diabetes, obesity, heart disease, stress-related conditions, sleep disturbances—were once rare in the young. Today, they affect people in their teens and twenties. They arise from subtle shifts in how we eat, work, move, rest, and cope with pressure. Let us examine each disorder more deeply.

### Obesity: When Comfort Turns into a Silent Burden

Obesity is often misunderstood as simply a matter of weight gain, but in reality, it represents a profound imbalance in metabolic health. In modern life, calorie-rich foods are easily accessible, affordable, and aggressively marketed. At the same time, physical activity has drastically reduced due to long hours of desk work, reliance on vehicles, and leisure time centred around screens. Over time, this combination creates a slow but steady accumulation of fat—particularly visceral fat, which wraps around internal organs and increases the risk of diabetes, heart disease, and joint problems.

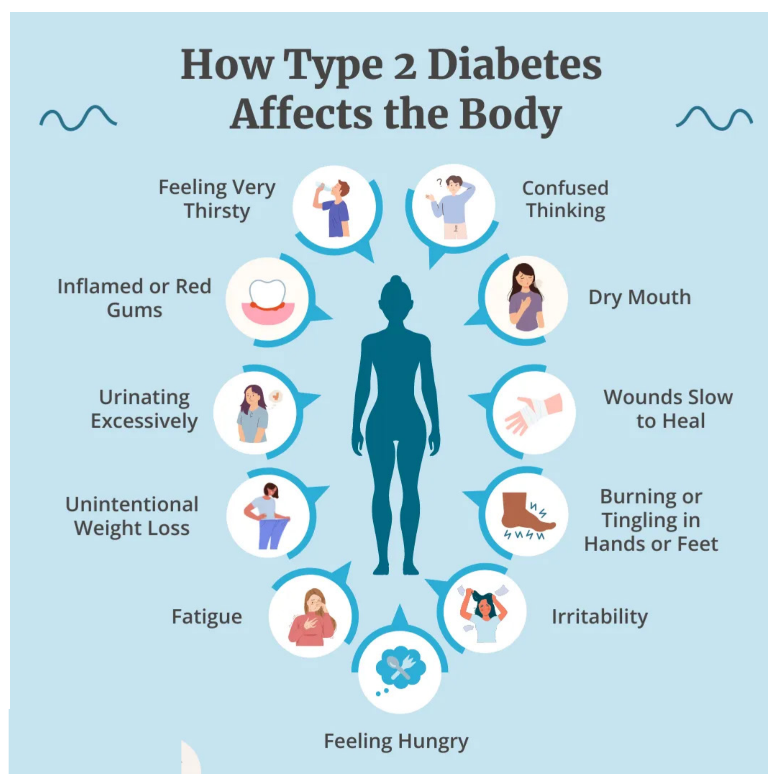

Obesity also has emotional and psychological dimensions. Many people eat not out of hunger but to soothe stress, boredom, or anxiety. Food becomes comfort, reward, or escape, and the cycle becomes hard to break. The remedy begins with understanding that sustainable change is not about drastic dieting or punishing workouts—it is about restoring balance. Small changes such as mindful eating, choosing whole foods, reducing sugar intake, ensuring hydration, walking daily, and setting realistic goals can gradually reset the body. Obesity is not merely a number on a scale; it is a call to rethink the way we nourish ourselves—physically and emotionally.

## Hypertension: The Pressure We Do Not Feel Until It Hurts

Hypertension is often called the "silent killer" because it presents no obvious symptoms until significant damage has already occurred. Modern lifestyles—high stress, excessive salt intake, lack of movement, irregular sleep patterns, and dependence on processed foods—play a central role in raising blood pressure. Today, even young adults in their twenties and thirties are being diagnosed with hypertension, a condition once associated with aging. The danger lies in its slow attack on vital organs. Uncontrolled hypertension damages the heart, kidneys, brain, and blood vessels, increasing the risk of heart attacks and strokes. The good news? It is one of the most preventable lifestyle disorders. Remedies revolve around adopting a heart-friendly routine: reducing salt and processed foods, engaging in at least 30 minutes of brisk walking daily, avoiding alcohol and smoking, practising deep-breathing exercises, and monitoring blood pressure regularly. Sleep hygiene also plays a crucial role. Hypertension responds remarkably well to consistent lifestyle adjustments, proving that small daily changes can protect us from major health crises.

## Type-2 Diabetes: When the Body's Engine Slows Down

Type-2 diabetes emerges when the body becomes resistant to insulin or fails to use it effectively. Sedentary living, high-sugar diets, obesity, and chronic stress all contribute to this condition. What makes diabetes particularly concerning is its ripple effect: it affects the



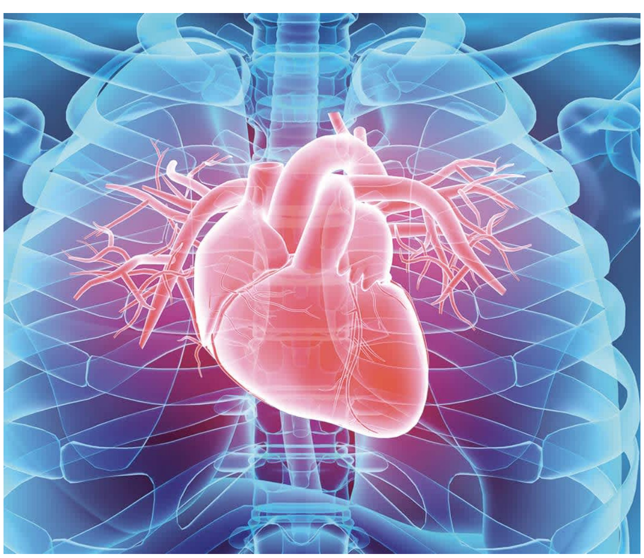
eyes, kidneys, nerves, heart, and even mental health. India, with its rapidly urbanising population, is already known as the "diabetes capital of the world."

Diabetes does not develop overnight. It begins with years of fluctuating sugar levels, overeating refined carbohydrates, and insufficient physical activity. Many people are diagnosed only after experiencing fatigue, slow healing, frequent urination, or unexplained weight changes. The remedy lies in reshaping everyday routines: choosing whole grains over refined ones, adding fibre-rich foods, exercising regularly, prioritising sleep, and reducing stress. Weight management significantly improves insulin sensitivity. With early detection and a disciplined lifestyle, diabetes can often be prevented, delayed, or controlled without complications. Managing diabetes is ultimately about understanding the body's natural rhythm and working harmoniously with it.

## Heart Disease: The Betrayal of an Overworked Organ

The heart—our tireless engine—beats over 100,000 times a day, asking for little in return except care. Yet modern life places immense strain on it. High cholesterol, smoking, stress, poor diet, and lack of exercise weaken the cardiovascular system slowly and silently. Heart disease has become one of the leading causes of death globally, affecting not only the elderly but increasingly the young.

Long working hours, emotional stress, sleep deprivation, and high-fat foods all burden the heart. The good news is that the heart is highly responsive to lifestyle improvements. A diet rich in fruits, vegetables, nuts, seeds, and healthy fats like olive oil supports better blood flow and cholesterol balance. Regular aerobic exercise strengthens the heart muscle and lowers risk factors. Stress-management practices, such as meditation or yoga, help calm the cardiovascular system. Avoiding smoking and alcohol further reduces strain. Heart disease may be formidable, but it is largely preventable with consistent care and mindful choices.

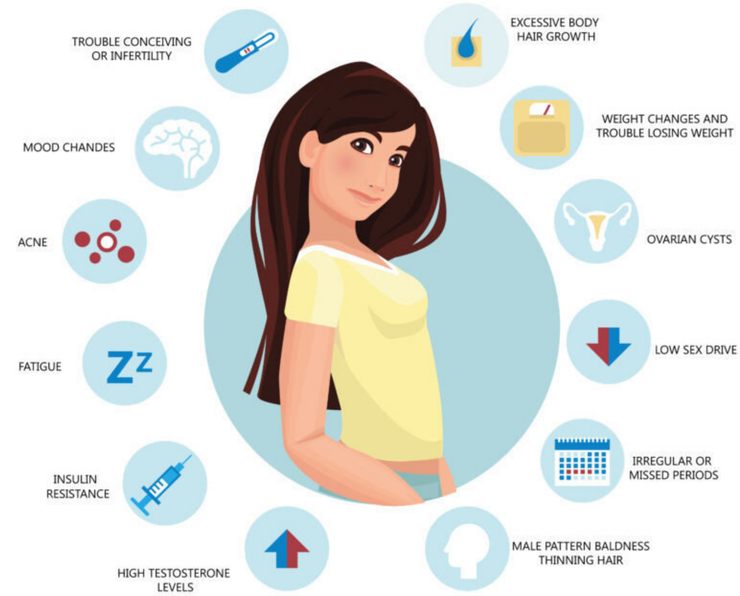


## Stress, Anxiety, and Mental Health Disorders: The Invisible Weight We Carry

In an age where productivity is celebrated and rest is undervalued, stress has become an uninvited companion in many lives. Long commutes, constant notifications, competition, financial pressure, and personal responsibilities create an atmosphere where the mind never truly relaxes. Chronic stress leads to anxiety, irritability, panic attacks, digestive issues, hormonal imbalances, and even weakened immunity.

Mental health disorders are not signs of weakness; they are signs of overwhelm. The remedy lies in re-establishing boundaries between work, rest, and personal time. Simple practices like mindfulness meditation, deep-breathing exercises, journaling, or nature walks significantly reduce mental strain. Connecting with supportive people, engaging in meaningful hobbies, and seeking counselling when


needed are equally important. Sleep and nutrition also influence mood and emotional stability. When we treat mental health as seriously as physical health, healing becomes possible. Strength lies not in pushing through, but in recognising when to pause.


## Sleep Disorders: When Nights Become Battlegrounds

Sleep disorders are among the most underestimated lifestyle problems of our time. Screens glowing late into the night, irregular routines, caffeine consumption, and stress disrupt our natural sleep cycle. Many people lie awake for hours, wake up frequently, or sleep lightly without feeling rested. Chronic poor sleep contributes to obesity, hypertension, diabetes, irritability, reduced concentration, and premature aging.

The remedy begins with respecting sleep as a biological necessity, not a luxury. Establishing a consistent sleep schedule trains the body to unwind naturally. Disconnecting from screens at least an hour before bed, dimming lights, avoiding late meals, and creating a calm sleeping environment help regulate circadian rhythms. Mindful relaxation techniques—such as reading, meditation, or gentle stretching—signal the brain that it is time to rest. Quality sleep rebuilds the body, sharpens the mind, and restores emotional balance. In truth, sleep is the most powerful natural healer we possess.

## PCOS: A Modern Hormonal Imbalance Rooted in Lifestyle and Stress

Polycystic Ovary Syndrome (PCOS) has quietly become one of the most widespread hormonal disorders among young women today. More than a reproductive issue, PCOS reflects a deeper metabolic and emotional imbalance shaped by modern routines. Irregular meals, high-sugar diets, sedentary lifestyles, chronic stress, and disrupted sleep collectively strain the delicate dance of hormones that regulate ovulation, insulin sensitivity, weight, and mood. Many women experience a complex constellation of symptoms—acne, weight fluctuations, irregular cycles, hair loss, excessive hair growth, fatigue, and emotional upheaval—without realising they stem from a common root. PCOS often emerges gradually, beginning with subtle insulin resistance and progressing into hormonal disharmony that affects fertility, metabolism, and long-term health. Yet, PCOS is not a life sentence. It is the body's signal urging a recalibration of lifestyle: nourishing foods, structured routines, movement, rest, and emotional care. When addressed holistically and patiently, PCOS becomes a manageable and often reversible condition.

## Homeopathy in Lifestyle Disorders

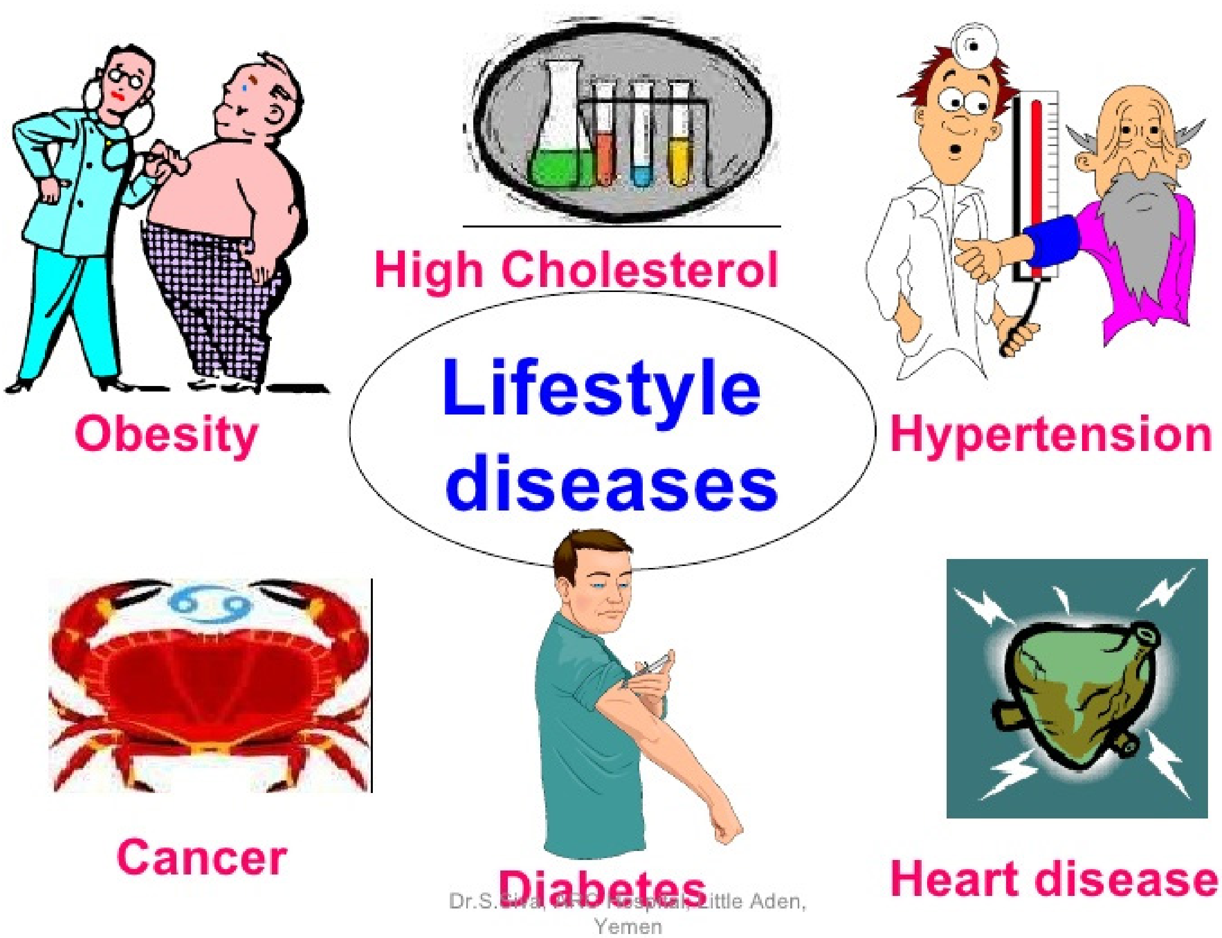
We've heard a lot about various courses of action to battle the lifestyle disorders. Here's a perspective from Homeopathic standpoint.

In a world where lifestyle disorders are shaped as much by our emotional landscapes as by our daily habits, Homeopathy offers a gentle and deeply human form of healing. Instead of treating disease as an isolated malfunction, it views the individual as a whole—a tapestry of emotions, behaviours, constitutional tendencies, and lived experiences. What Homeopathy seeks to correct is not merely a symptom, but the unique internal pattern that gives rise to imbalance.

Homeopaths often observe that two people with the same diagnosis—say, diabetes or hypertension—may exhibit completely different emotional triggers, forms of stress, sleep rhythms, cravings, or metabolic patterns. This is why Homeopathy does not prescribe by disease alone; it prescribes by person. Remedies are chosen not by matching a label, but by understanding who the patient is: how they feel, cope, react, suppress, and adapt. In this way, Homeopathy aligns seamlessly with the very nature of lifestyle disorders, which are themselves deeply tied to long-term behavioural and emotional tendencies.

A central strength of Homeopathy lies in its ability to address the emotional roots of disease. Stress, often silent and unacknowledged, fuels much of today's metabolic and cardiovascular dysfunction. In such situations, remedies like Ignatia, used for unresolved grief or emotional shock, or Nux vomica, suited to the overworked, overstimulated individual, can help restore calm and balance. Arsenicum album may ease the anxious mind, while Phosphorus offers support to those who feel emotionally porous and easily exhausted. As emotional equilibrium returns, physiological systems often follow: blood pressure steadies, cravings diminish, fatigue lightens, and sleep becomes more restorative.

Beyond the emotional realm, Homeopathy also offers support in metabolic and hormonal imbalances. Many lifestyle disorders begin with sluggish digestion, irregular metabolism, or hormonal fluctuations. Remedies such as Calcarea carbonica, ideal for slow metabolism and weight gain, or Lycopodium, often used for bloating and evening hunger, help rebalance internal rhythms. Sulphur, traditionally associated with inflammation and heat, and Graphites, linked with thyroid-related weight issues, further extend Homeopathy's role in metabolic correction. These remedies do not work in isolation; they become most powerful when paired with conscious lifestyle choices—healthier food, regular movement, and mindful routines.



In the case of hypertension, Homeopathy recognises that the heart is affected not only by blood chemistry but by emotional pressure. Some individuals suffer under the weight of high responsibility and perfectionism, a pattern addressed by Aurum metallicum. Others carry grief silently, a state that often calls for Natrum muriaticum. Crataegus offers gentle cardiac support, while Aconitum calms sudden surges of fear or panic. By treating the emotional core of hypertension, Homeopathy helps bring long-lasting stability.

Sleep, the quiet architect of healing, is another domain where Homeopathy shines. Remedies such as Coffea cruda for racing thoughts, Gelsemium for anticipatory anxiety, Passiflora for nervous exhaustion, and Nux vomica for stress-linked insomnia help restore natural sleep patterns without sedatives. When sleep improves, nearly every aspect of health follows suit—hormonal balance, immunity, appetite, and emotional resilience.

From a homeopathic lens, PCOS is not simply a hormonal irregularity but a complex interplay of emotional stress, inherited tendencies, metabolic imbalance, and constitutional weakness. Homeopathy looks beyond ultrasound findings or hormone levels to understand how the woman experiences her body: her emotions, cravings, sleep patterns, personality traits, and the stresses that shape her hormonal rhythm. Remedies such as Pulsatilla, often suited to gentle, emotionally sensitive individuals with irregular cycles; Sepia, ideal for women overwhelmed by responsibility and hormonal fatigue; Lachesis, helpful when symptoms worsen before menses; or Calcarea carbonica, used for slow metabolism and weight gain, are chosen according to the woman's unique constitution. When matched correctly, homeopathic remedies can help regulate cycles, reduce insulin resistance, ease acne and hair-related issues, improve mood stability, and restore energy. Homeopathy works gradually but deeply, supporting the endocrine system and helping the body return to its natural hormonal rhythm. When combined with lifestyle adjustments—balanced meals, regular movement, mindful stress reduction—homeopathy becomes a powerful ally in restoring harmony for women living with PCOS.

Homeopathy also strengthens overall vitality. People often report improvements not only in their primary complaint but in mood, energy, immunity, digestion, and hormonal balance. A stronger constitution is simply better equipped to resist the gradual erosion caused by unhealthy habits or prolonged stress.

Importantly, Homeopathy does not present itself as an alternative to essential medical care. It does not replace emergency interventions, diagnostic evaluations, or necessary medications. Instead, it enhances healing by addressing the dimensions of disease that pharmaceuticals often overlook—the emotional patterns, constitutional tendencies, and subtle imbalances that accumulate over time.

Together with lifestyle modifications, Homeopathy offers a pathway that is sustainable, compassionate, and deeply attuned to human nature.

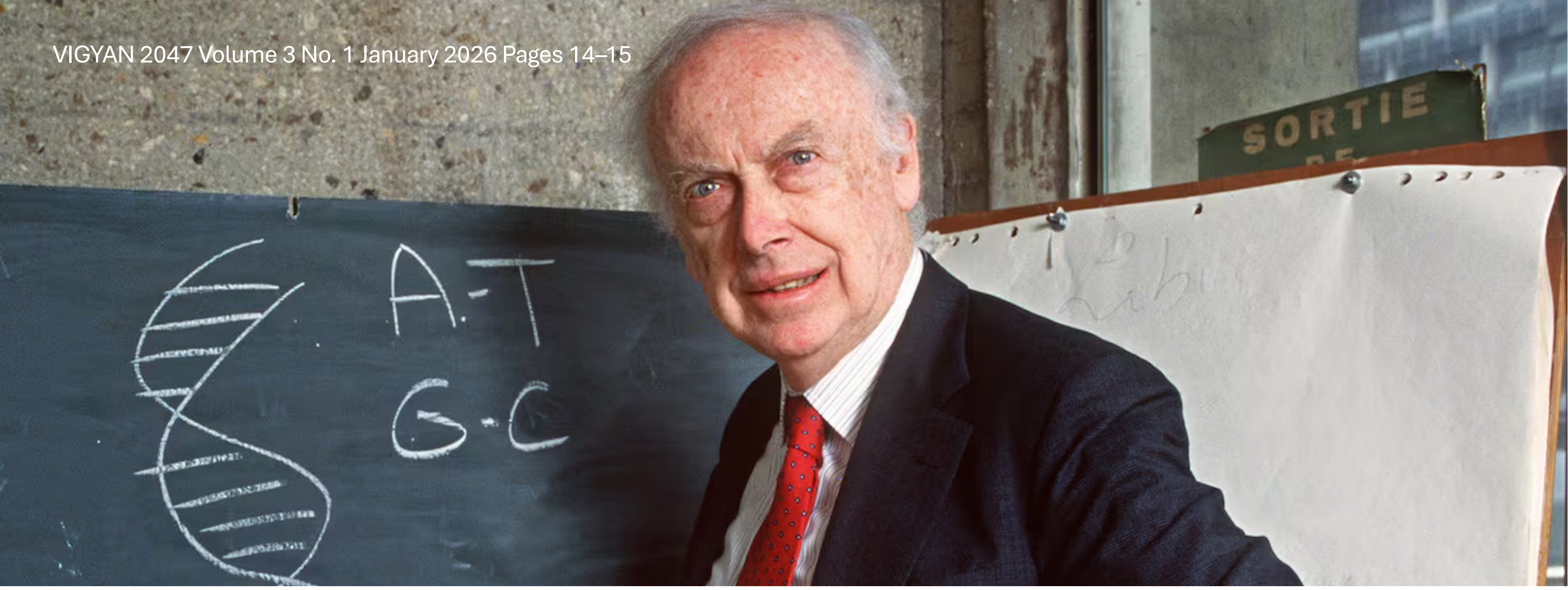
Lifestyle disorders are not errors—they are messages. They arise when the body whispers, then pleads, for us to slow down, rethink our rhythms, and realign our habits with our well-being. Modern medicine, mindful living, and Homeopathy each contribute something unique and valuable to this journey. Healing is not about choosing one path over another, but about weaving together the wisdom of many.

Recovery begins with small acts of awareness: a mindful bite, a conscious breath, a night of uninterrupted rest, a thought gently redirected, a remedy that supports the whole person, and a compassionate decision to listen to one's body. Our bodies remember how to heal. All they ask is that we pay attention.

So let's pledge—no more to lifestyle disorders. ◆

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

VIGYAN 2047 Volume 3 No. 1 January 2026 Pages 14–15




# James Dewey Watson
## The Brilliant Mind the World May Choose to Forget

Partha Pratim Majumder

Edward O. Wilson, the legendary father of sociobiology, once described him as "the most unpleasant human being I had ever met." He later became the first living Nobel laureate to auction his Nobel Prize medal. Reflecting bitterly on his fate, he admitted that because of some of his controversial views and outspoken beliefs, he had virtually turned into an "unperson." In his own words, "No one really wants to admit I exist." He lamented that being perceived as an "unperson" led to his removal from several corporate boards, leaving him with no financial sustenance other than his academic income. This "unperson" was none other than James Dewey Watson, one of the towering figures of the twentieth-century science. Watson received the Nobel Prize at the remarkably young age of 34, based on research he had published in 1953 when he was just 25. His historic 1953 paper in Nature, co-authored with Francis Crick, ended with one of the most legendary understatements in the hisotory of science: "It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material." Watson passed away on 6 November 2025 at the age of 97.

Almost everyone in the world today knows that Watson, along with Francis Crick, Maurice Wilkins and Rosalind Franklin, helped unravel what they famously called "the secret of life": DNA, the molecule present in every cell of every living organism. Within just a few decades of its discovery—and tragically, without Rosalind Franklin witnessing its full glory as she died of ovarian cancer barely five years later—the structure of DNA profoundly reshaped an astonishingly wide range of disciplines, including biology, evolutionary theory, medicine, archaeology, and forensic science. Watson and Crick revealed that DNA consists of two intertwined strands shaped like a slightly twisted ladder, a "double helix." The steps of this ladder could unzip to replicate themselves—an elegant mechanism that explained how genetic information is copied and preserved across generations. This single discovery revolutionized life sciences and laid the foundation of modern genetics and biotechnology.

Watson himself was always a young man in a great hurry. He joined the University of Chicago to study zoology at just 15 and soon developed a deep interest in genetics. He earned his PhD from Indiana University under Salvador Luria, a leading microbiologist and a Nobel laureate himself. By then, Watson had become convinced that genes were not composed of proteins, as many scientists believed at the time, but were instead made of DNA. In 1951, during a symposium in Naples, he saw an X-ray diffraction photograph of DNA shown by Maurice Wilkins, and his conviction that genes were made of nucleic acids became unshakeable. Determined to understand the structural chemistry of DNA rather than remain confined to bacterial biochemistry or virology, Watson later wrote that he simply could not force out of his mind "a potential key to the secret of life." Ambition drove him: it was, as he said, "certainly better to imagine myself becoming famous than maturing into a stifled academic who had never risked a thought."

Watson aspired to go to Cambridge University to work in structural chemistry. With the support of his mentor Luria, he secured a position at the Cavendish Laboratory as a research assistant, initially studying the myoglobin protein under John Kendrew. However, once at Cavendish, he was assigned to share an office with Francis Crick, who also shared his firm belief that genes must be made of DNA. At the 1962 Nobel ceremony, Watson would later recall that almost immediately on entering the Cavendish, he realized his destiny lay with Crick rather than with Kendrew's work. "With Francis to talk to," he said, "my fate was sealed." Their collaboration led to the publication of their DNA model in Nature in 1953—a paper that changed biological thinking forever. Watson later admitted that even he could not have foreseen "the explosive impact of the double helix on science and society."

After 1953, Watson worked on X-ray diffraction studies of RNA at Caltech, then returned to Cavendish to collaborate again with Crick on the structural principles of viruses. Later, at Harvard University, he worked on understanding RNA's crucial role in protein synthesis, helping shape the emerging field of molecular biology. In 1968, he was invited to lead the Cold Spring Harbor Laboratory (CSHL) in New York. Although not known initially as an administrator, Watson demonstrated extraordinary ability to raise funds and transform CSHL into one of the world's leading centres of biological research. Under his stewardship, the once-struggling institution became a premier site for breakthroughs in cancer genomics, molecular and cellular biology, plant molecular biology and neuroscience. CSHL also became famous for its influential scientific meetings and advanced training courses, playing a key global role in DNA science. The author recalls being privileged to attend a meeting on human genome diversity in 1997 at CSHL, where Watson personally interacted with participants and even hosted them at his home—a vivid personal memory.

In the late 1980s, as genome scientists began dreaming of sequencing the entire human genome—three billion nucleotides across 23 chromosomes—many dismissed the idea as fantasy. But in 1990, Watson was appointed leader of the monumental Human Genome Project. At that time, DNA sequencing was slow, expensive and technically challenging, making the effort one of the boldest scientific enterprises in history. Watson's willingness to take on such an extraordinary challenge reaffirmed his fearless scientific spirit. However, he resigned in 1994 following strong disagreements with the Director of the U.S. National Institutes of Health. Watson believed firmly that the genomic information must remain a public good and not be restricted through patents or commercial exploitation—a position that later shaped international norms regarding open scientific data. The NIH Director disagreed, insisting on patenting opportunities, leading to Watson's exit.

He then became President of CSHL in 1994. Around this time, he read The Bell Curve, a highly controversial book on intelligence and social hierarchy. Nathaniel Comfort, who is writing a biography of Watson, has said that Watson's acceptance of the book's arguments marked the point where he "lost his scientific critical edge." In 2007, Watson made deeply offensive remarks to The Sunday Times, stating he was pessimistic about Africa's prospects because "all our social policies are based on the fact that their intelligence is the same as ours—whereas all the testing says not really." Though he apologized, acknowledging there was no scientific basis for his comments, he was removed from his role as Chancellor of CSHL. Named Chancellor Emeritus, he eventually lost that title as well after a 2019 PBS interview in which he reaffirmed his discredited views, insisting that racial differences in IQ were genetic rather than socio-historical in origin. Francis Collins, a leader of the Human Genome Project and of many other global genetics initiatives, condemned the remarks as profoundly misguided and hurtful. Comfort later observed that Watson's greatest flaw was "overbelieving in the power of DNA"—a kind of genetic determinism that overshadowed his judgment. Thus, Watson emerged as perhaps the most celebrated scientist of the 20th century, and simultaneously one of the most controversial and infamous pesons of the 21st.

Beyond the science, Watson's life remains a study in complexity: a brilliant mind whose discoveries reshaped humanity's understanding of life itself, yet whose later views isolated him socially, professionally, and morally. His story continues to provoke reflection on the responsibilities that accompany scientific genius, the ethics of leadership in science, and the enduring necessity of humility when wielding knowledge as powerful as the human genome. ◆

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**Acknowledgements:** I am grateful to Dr. Nakul Parashar for his help in editing an earlier version of this obituary. A slightly different version of this obit appeared in Journal of Genetics (2025) 104:30.

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# Different Perspectives of Time

Asit Chakrabarti

Just think, how much worried we are always regarding time! About its wastage, proper uses, doing routine works at proper times, what is the time now, at what time did that occur, etc, etc. But have we thought ever, actually what time itself is? Whenever we think of time, the pictures of ticking of the hands of a clock or the digital display on a watch appear before us. If we think closely, it becomes clear that those are not times, but measurements of something we call time. Time is some sort of experience we feel between two successive events. This experience is measured by similar type of an experience between two periodic natural events which is divided into years, hours, etc down to atto-seconds ($10^{-18}$ sec). The natural event may be some type of extremely regular motions, oscillations, or excitations. Thousands of years ago this regular incident was earth's rotation round the sun or around its own axis. Subsequently it was modified to radiation emitted due to electron transition between orbits of caesium atom yielding measurement accuracy to $10^{-10}$ sec. Now we can measure a time of few atto-seconds only. 2023 Nobel prize in Physics was awarded for attaining this accuracy practically. This minute amount of time is so small that depending on this scale we can measure time dilation, according to Einstein's general relativity, arising between two points at a separation distance of only 2 cm above earth's surface. But all these discuss only quantitative values of time, not any ideal definition of time. Philosophers, psychiatrists, physical researchers and neuro-scientists are continually studying to know the real self of time from the dawn of modern human civilization according to their different schools of thoughts.

As in many other instances, the great Greek philosopher Aristotle (384–322 BC) was possibly the first one to try to resolve this about two and a half thousand years ago. Indeed he understood the difficulty. He defined time as a 'number of motion with respect to the before and after'. He was also sceptical about its existence at all. He wrote, 'Since one part of time has been and is not, while the other is going to be and is not yet, One would naturally suppose that what is made up of things which do not exist could have no share in reality'. Also he wrote, 'Whether if soul did not exist time would exist or not ... for if there cannot be someone to count ... evidently there cannot

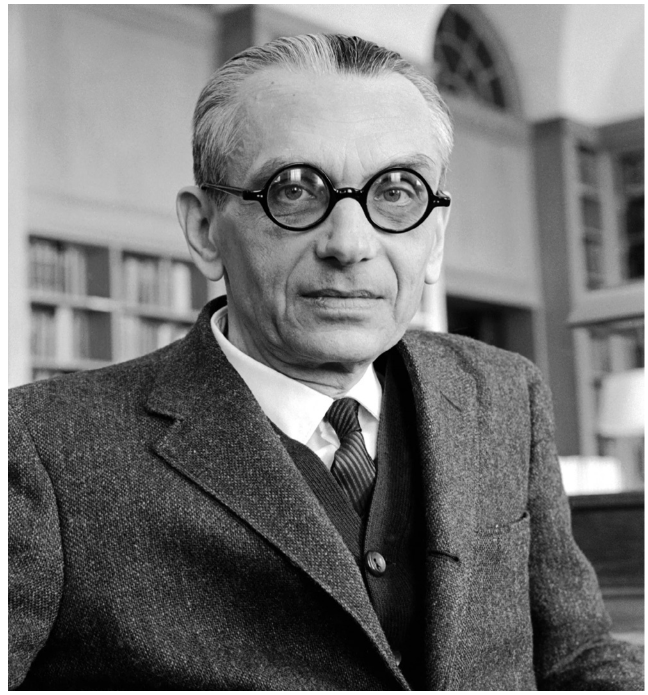
**Aristotle**

**Immanuel Kant**

be number ...'. Christian theologian and philosopher St Augustine (354-430) made it more complicated, 'What then is time? If no one asks me, I know what it is. If I wish to explain it to him who asks, I do not know'. His statement also echoed Aristotle, 'If no incident occurred (meanwhile) there is no past; if nothing new occurs there is no future; and if no incident occurs now there is no present'. Thus time is simply happening of some incident or its change. Otherwise, time is nothing. According to German philosopher Immanuel Kant (1724-1804), not only time, space also has no objective reality. Both of them are creations of mind and not features of the external world (which is) independent of us. Even the modern psychiatrist Robert Lanza (1956- ) opines, 'Without consciousness, space and time are nothing. .... We can't touch them. They are not objects, .... They go forever ... tools of animal sense perception...'. However, neuro-scientists explain it differently. According to them, we perceive past from the memories already collected by our brain and the future is formed by the calculations and anticipations of our brain about what to happen next. Thus time is an illusion created by mind. On the other hand, some demand that the length of a day appears different to a child relative to an aged person. Thus at least psychologically time is not absolute. Some scholars are of the opinion that our heart beats create our sensation of time.

Now let us come to the context of time concept according to modern physical sciences. This science was first strongly built up on calculus by men like Newton. Newton's time was absolute and is independent of observer, object and space in universe, at least for the universe known at his time. It is moving with same velocity along straight line with respect to everything. Neither it has beginning, nor end. It is universally true. It needs no definition. Like space and inertia it is known to all. But at the beginning of twentieth century, Einstein's theory of special relativity put a brake on this concept. Earlier simultaneity of two events was universal for all observers whatever be their states of motion. Special relativity theory proves that this depends on the velocity of the observer's reference frame. Suppose 'A' moves on a spacecraft with a velocity equal to 80% of light velocity while 'B' is sitting idle on earth. Both have clocks on their hands which are perfectly synchronised at the start. 'B' returns to earth after, say, 10 years according to his clock. But when comparing the times between his own clock with other's clock, both will agree that there is time difference. Moreover, the time difference will be same for them. This means that a clock in a moving frame appears to move differently seen from rest. So time is not at all absolute, but relative. Space and time are inter-linked. An imaginary man riding a photon will see his clock not ticking at all. Ten years

**Einstein**



**Kurt Godel**

after proposing special relativity, Einstein put forward general relativity theory according to which gravitation is not a force at all. The grand space time geometry under the influence of a heavy body gets too distorted to make the body move in the manner we generally know as the result gravitational force. Any mechanical incident in the universe is just the motion of an object in space-time geometry. At least theoretically, it is possible to go from the present to the past (time travel). After one of his close friend's demise, Einstein wrote to his wife, '... distinction between past, present and future is only a stubbornly persistent illusion. .... The only reason for time is so that everything does not occur at once'. Famous theoretical physicist Brian Greene (1963–) writes, If you fiddle with the wormhole openings, you can make it not only a shortcut from a point in space to another point in space, but a shortcut from one moment in time to another moment in time. Wormhole is a shortcut passages in space-time geometry. Still now it is a theoretical and hypothetical term, first coined by John Wheeler (1911–2008).

**Stephen Hawking**

Question arises, if one can go back from present to past he can do a heinous work like, say, killing his own grandfather, though in that case his present existence becomes invalid. This is known as grandfather paradox. Then why is not practically such action possible? There are different reasons for this.

# In thermodynamics it is proved that all natural processes are irreversible, i.e. the forward and reverse processes don't yield identical results. As a result, entropy, or disorderness in simple form, of the universe always increases through all natural processes. If we try to go to past from the present then entropy must decrease for it was less earlier. But any process to do that will increase it. Thus, it is not possible in physical world.

# According to British physicist Julian Barbour (1937–), we live in a particular universe in a particular state. There may exist another universe on other side of

**Michio Kaku**

**Brian Greene**

big bang event where time is moving backward. Even if time travel is possible in other universe, that has no consequence on our universe.

# According to quantum mechanics, all bodies have both wave and particle aspects, though it is prominent for subatomic bodies. But practically it may not be the whole picture. The dual aspect is only a mathematical model with which many incidents in subatomic world can be explained successfully. Or let us consider the space-time geometry. Infinite points are there. But that doesn't mean that infinite number of events are possible. Many points have no objective reality. Einstein himself wrote, 'Time and space are modes by which we think and conditions in which we live'. All these suggest that mathematical techniques or models are just the guiding factors to assess and predict the physical world.

On the other hand, Michio Kaku (1947–), a frontline researcher of string theory and a science communicator, opines that if time is like a moving stream of water and that stream can bent like a knot then definitely it is possible to reverse our journey from the present to past. It is a challenge to technology and may take long time to achieve. Though the famous mathematician Kurt Godel (1906–78) never supported this view and concluded that it is impossible to define time scientifically.

Recently many a scientists like Stephen Hawking (1942–2018), Paul Davies (1946–), Brian Greene (1963–) have elaborately discussed about the history and nature of time. But they have, probably consciously, avoided the very definition of time.

In conclusion, we conclude, according to French philosopher and psychologist Paul Ricoueur (1913–2005), 'We are not capable of producing a concept of time that is at once cosmological, biological, historical and individual'. According to English cleric, writer and collector Charles Cotton (1780–1832), 'Time is the most undefinable yet paradoxical of things; the past is gone, the future is not come, and the present becomes the past, even when we attempt to define it'. Then he joked, 'Relative to other time the present has one advantage that at least it is our own'. ◆

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# Tribology of Hydrodynamic Systems

Kamal Mukherjee

"HYDRODYNAMIC" SYSTEMS – it is the science which deals with the motion of an ideal & practical liquid. Thus, it uses the mechanics of moving fluids under the flow theory of fluids e.g. the conversion of flow energy into a mechanical work (centrifugal pumps, torque converter, hydraulic turbine, fluid coupling, etc.). Water and hydraulic oil (mineral oil) both are used in hydrodynamic systems.

This system is applicable in the fluid flow conditions in the transmission of motion. Here the flow equations are applicable e.g.:

**Flow (Q) = Area (A) x Velocity (V)**...Equation No. (1)

and **Bernoulli's principle.** The water is considered to be incompressible for most of the practical problems which may have all or any of the static, kinetic & pressure energies at a time. Thus, total energy of liquid is the sum total of all these three energies. This is known as Bernoulli's theorem & is a fundamental "**Law of Conservation of energy**" as applicable to a **flowing liquid.** Mathematically it is shown as:

**Pressure head + Velocity head + Datum head = Constant** or **P + ρV2/2 + ρgh = C**... Equation No. (2)

This sum is a *constant* along a streamline (Fig.-1).

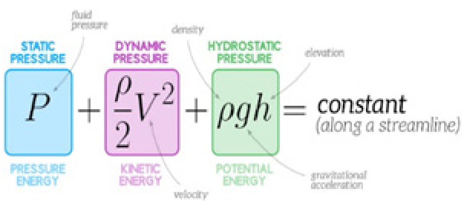


**Fig.–1: Bernoulli's equation**

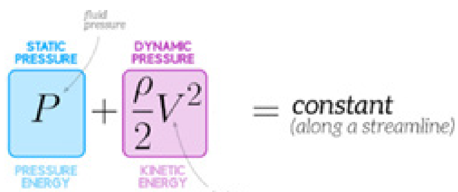


**Fig.–1A: Simplified Bernoulli's equation**

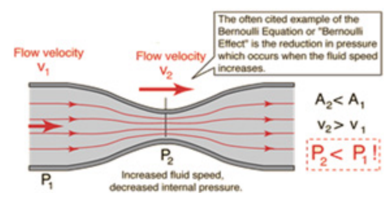


**Fig.–1B: Application of Bernoulli's equation at the restriction of flow in pipe**

If we assume that there is no significant change in the height of the fluid (horizontal flow), then "**ρgh**" term cancel as h=0 and we get the simplified Bernoulli's equation as shown (Fig.-1A) as **P + ρV2/2 = C**, assuming the potential energy to be negligible=0. Bernoulli's principle follows that if the speed '**V**' of a fluid is larger in a given region of streamline flow, the pressure '**P**' must be smaller in that region along the streamline (Fig.-1B).

While washing a car using a plastic pipe we press the tip of pipe, water jet is visible & car can be easily washed (Fig-2). In this case the tip area is reduced so according to Bernoulli's effect, the pressure would be less (contrary

**Fig.- 2: Narrowing of pipe for car wash an example of Bernoulli's principle**

to common belief). As the flow of water is constant & the area of the tip is less so the velocity of the water will be more as per flow equation No. (1). This is the kinetic energy of the water. According to simplified Bernoulli's equation (2): **P + ρV2/2 = C**, as the velocity of water '**V**' is more, the pressure of water '**P**' at that point (tip point) will be less than before as it has gained the kinetic energy. **Thus, the Bernoulli's principle is used in any flow of fluid condition like in pipe nozzle, centrifugal pump, torque converter, water turbine, Archimedes screw etc.**

# Hydrodynamic Systems with WATER for House Hold & Industrial Applications

## Centrifugal Pump

Now centrifugal pumps are the world's most commonly used pumps to move fluids. These pumps are often used for pumping any low-viscosity liquid in domestic, industrial, agricultural etc, applications. They form a very big part of urban living. The commonly known Tulu pumps are small pumps used for lifting the water to reduce the load of water carrying from lower to upper stairs in the house. In centrifugal pump, the liquid goes through the inlet i.e. impeller having series of curved vanes– the key component – the heart of a centrifugal pump. Fluid enters the impeller at its axis (the 'eye') and and is pushed outwards by means of a centrifugal force towards the periphery of the impeller & finally goes away along the circumference of the vanes (Fig.-3).

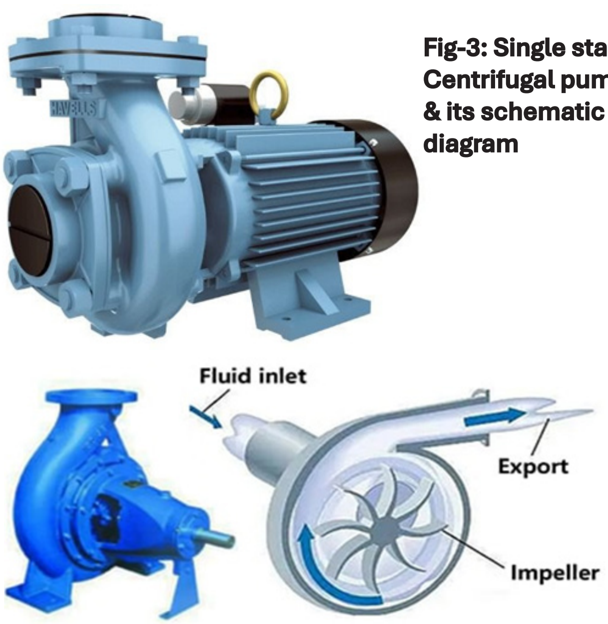


**Fig-3: Single stage Centrifugal pump & its schematic diagram**

The rotational motion of the impeller accelerates the fluid out through the impeller vanes into the pump casing which is specially designed to constrict the fluid from the pump inlet, direct it into the impeller, then slow it and control the fluid before discharge at high pressure normally called as "head". This device is most often used to transfer fluid between two different locations in a broad range of industrial applications, including municipal (water and sewage facilities), power generation, mining, agricultural, and the petroleum and chemical sectors, among several others.

## Hydraulic Turbines

In hydroelectric power plant the erosions on the runners of turbine (Fig-4) have a significant impact in hydroelectric energy generation. This erosion is because of the corrosion by hard & suspended particles, which is due to the high concentration of sediment that originates from run-off-river that strike to the turbine runners, causing wear and tear of the mechanical components. In case of power plants under Himalayan Rivers, the turbines need to undergo repair and maintenance in a regular basis, due to a substantial erosion loss of material from the turbine runners.

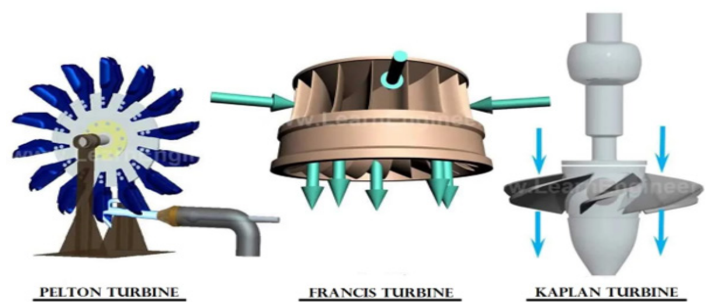


**Fig-4: Various turbine runners**

# Hydrodynamic systems with MINERAL OIL (special industrial application)

The automatic transmission forms a system in which gearshifts are automatically actuated through **the torque converter.** Torque converter takes the place of the clutch found on standard shift vehicles having a large doughnut shaped device that is mounted between the engine and the transmission. It uses oil (transmission fluid) to transmit power through basically of three elements: the turbine, the stator, and the impeller.

Finally in transmission, the direction of transmission fluid goes on various paths by solenoid valves (electronically controlled control valves) in accordance with sensor information on the vehicle speed, throttle opening, and other aspects of vehicle operation. The power finally moves through different set of planetary gears for different gear ranges as per the vehicle speed. They are used in the automatic transmission in payloaders, heavy-duty trucks/trailers (Figs-5, 6, 7).

**Fig-5: Payloders**

**Fig-6: Heavy Duty Trucks**

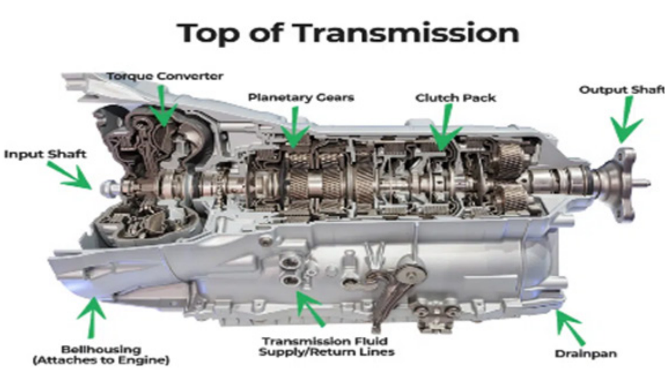


**Fig-7: Automatic Transmission with fluid torque converter**

## Tribology solutions for hydraulic turbines due to water erosion

Coating on the turbine runners' hard surface with an erosion-resistant hard surface coating is one method for decreasing the effect of erosion (Fig-8). In the Nepalese hydropower sector, ceramic pastes, ceramic paints, and strong welding alloys are frequently employed. In the High Velocity Oxygen Fuel (HVOF) process, hydropower firms have lately employed tungsten carbide-based ceramics (86WC-10Co-4Cr). Spray parameters and particle properties influence the performance of such coatings. The erosion resistance of a similar coating measured on high velocity jet erosion test equipment demonstrates that the same powder sprayed by different coating manufacturers exhibits varying erosion resistance. The coated turbine at the Cahua power plant increased energy output by 13.1 GWh during the same time period, which is nearly a 50% increase over the uncoated turbine's output. (as reported by *Shekhar Aryal et al*).

**Fig-8: Erosion of Peltton runners**

## Tribology solutions for gears in loss of lubrication (LOL) conditions

Loss of lubrication (LOL) in any oil wetted systems is a common phenomenon denoted by starvation of lubrication which causes metal-to-metal contacts (highly undesirable) e.g. in torque converter, automatic transmission, heavy reduction units/ gearboxes, hydraulic systems using the mineral/ synthetic oil, aerospace operations - all refers to a malfunction of the lubrication system. This can be due to oil losses caused by leakage, off-design conditions such as windmilling or overheating of the system etc. Under LOL, the oil supply is interrupted and machine elements such as gears and bearings are no longer lubricated as designed, thus exposed to overheating which leads to increased friction and wear in tribosystems. It causes, surface failures of gears and bearings, such as scuffing etc. Scuffing of gears occurs suddenly and leads to instantaneous welding of the mating gear flanks with failures in corresponding flank areas. This causes damage to the gear profile. Continued operation under LOL will result in a drastic increase of component temperatures and thermal overheating & loss of power transfer in gearboxes. Synthetic oil gives better results in such cases.

**Fig-11 (A): Impeller Coating**

**Fig-9 (B): Effect–Impeller Coated, after 6 months in sewerage operation**

## Coatings: Abrasion-resistant coatings to extend the service life of pump impellers

Solid impingement, changing viscosity of the pumped liquid, abrasive and impacting loads—this is the reality of a typical pump impeller. It's no wonder that expectations regarding the operating lifespan are limited. Just like in real life—with increasing age, the performance, or to put it technically correctly, the pump efficiency, decreases rapidly. Coatings are applied when high wear resistance, reduced friction, or longevity are needed. (Fig-9, 9A & 9B). DLC (**Diamond-like carbon**) coatings show great potential for friction and wear reduction in both lubricated and LOL conditions due to their high hardness, heat, and wear resistance. DLC coatings can be deposited by a wide variety of physical and chemical vapor deposition techniques (PVD and CVD, respectively). These coatings can exhibit low friction, very high hardness, excellent wear resistance, and chemical inertness for corrosion resistance (Martins et al. 2008). Triboactive coatings result in increasing or decreasing COF depending on the reduction of temperature due to friction.

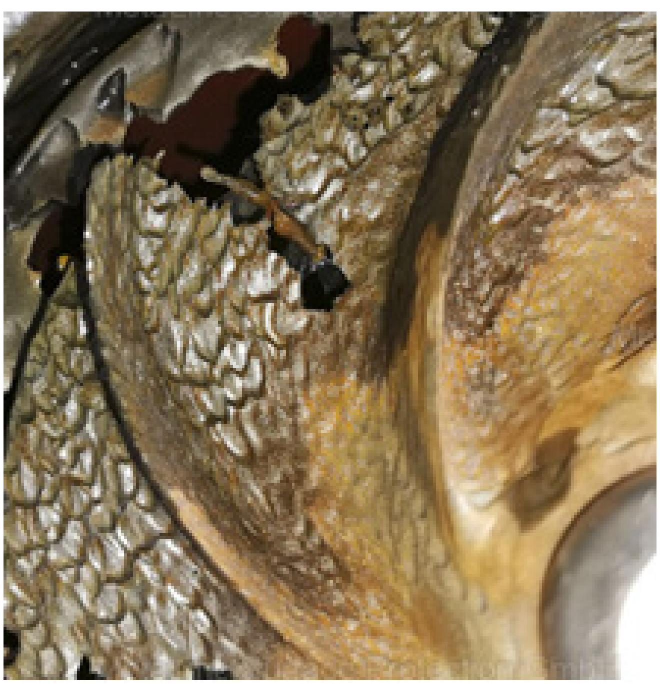

**Fig-11: Effect–Impeller Without Coating, after 6 months in sewerage operation**

## The secret is in the lining—fluoropolymer materials

Corrosive materials are some of the trickiest substances to handle, demanding not just great care, but also a careful selection of the type of pump. Chemical process pumps lined with fluoroplastic materials such as PFA (Perfluoro alkoxy tetra fluoro ethylene), ETFE (Ethylene tetra fluoro ethylene) and PVDF have excellent corrosion resistance capabilities, especially PFA.

## Surface finishing

While superfinishing of gear flanks is an established method of reducing gear friction in lubricated conditions, the effect is less distinct in LOL. ◆

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# Science behind Fasciculations in MND

Dr AK Gupta & Sanket Gupta

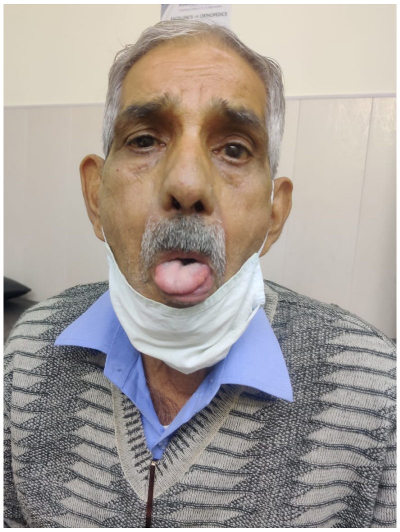
Muscle twitching is a familiar sensation to most people. An eyelid may flutter during stress, a calf may twitch after a strenuous run, or a random flicker may appear in the thigh while one is resting. These brief, harmless movements usually vanish as quickly as they appear. But in Amyotrophic Lateral Sclero-sis (ALS) or Motor Neuron Disease (MND), muscle twitching—known medically as fasciculations—carries a much deeper meaning. They become visible signs of what is happening inside the body at the level of its electrical wiring: the motor neurons.

To understand why fasciculations occur in ALS, it helps to think of motor neurons as power lines con-necting the brain to the muscles. These lines supply the “current” that allows muscles to contract when-ever we decide to move—whether to walk, breathe, speak, or swallow. When the power lines are intact, everything works seamlessly. But when they fray or begin to fail, the muscles they control may behave unpredictably. Just as a flickering bulb signals an unstable power supply, fasciculations are the flickers of muscle fibers receiving unstable signals from deteriorating neurons.

In ALS, the neurons primarily responsible for fasciculations are the lower motor neurons located in the anterior horn of the spinal cord and in certain regions of the brainstem. These neurons extend axons out to the muscle fibers, forming individual motor units. When ALS begins to affect these neurons, the ear-liest event is often their gradual degeneration. As individual motor neurons begin to malfunction or die, the muscle fibers they once controlled become partially denervated. Without proper electrical input, these fibers weaken, lose bulk, and become electrically unstable.

But the body does not accept this loss passively. It attempts to compensate in a remarkable way. The surviving motor neurons, sensing the loss of their neighbors, extend new branches in an effort to recon-nect with the orphaned muscle fibers. This process, called collateral sprouting, can temporarily preserve muscle function. It is somewhat like a neighborhood where many workers have quit their jobs, leaving tasks undone. The remaining workers attempt to cover multiple duties across multiple houses—not be-cause they were designed to do so, but because they want to keep things functioning. In early ALS, this process can delay noticeable weakness.

However, this overcompensation has consequences. These enlarged motor units, formed from the sur-viving neurons taking on more and more work, become electrically unstable. They cannot maintain the precise control they once had. As a result, they begin to fire spontaneously, without the brain sending a command. These spontaneous discharges of motor units appear as fasciculations, the brief rippling movements seen under the skin.



On the surface, a fasciculation may look like a tiny quiver or a brief worm-like movement. But inside the muscle, it represents a sudden burst of electrical activity from an overburdened, hyperexcitable neuron. When viewed through electromyography (EMG), these twitches appear as erratic firing patterns—fasciculation potentials—that help neurologists identify lower motor neuron dysfunction. EMG may also reveal other abnormalities such as fibrillation potentials, positive sharp waves, and signs of chronic neurogenic remodeling. These findings together support the diagnosis of ALS by showing that the motor neurons are not only dying but also attempting (and eventually failing) to compensate.

Although structural neuron degeneration explains much of the process, the biochemical environment in ALS adds another layer of complexity. Motor neurons in ALS often become hyperexcitable, meaning they fire too easily. This hyperexcitability is partly due to ion channel dysfunction. Neurons depend on sodi-um ($Na^+$) and potassium ($K^+$) channels to maintain a stable electrical state. In ALS, these channels may malfunction. Sodium channels may allow too much current inward, and potassium channels may struggle to restore the resting membrane potential. This leaves the neuron vulnerable to firing at random. An analogy can be drawn to an overcharged phone battery: one moment it jumps from 10% to 70%, the next moment it shuts off. The electrical system becomes erratic. Similarly, ALS neurons may fire spontane-ously because their internal electrical balance has become unstable.

Another biochemical contributor is glutamate excitotoxicity. Glutamate acts like the accelerator pedal in the nervous system, stimulating neurons to fire. In ALS, glutamate levels may become excessive, over-stimulating neurons and flooding them with calcium. If the accelerator is stuck and the brakes (the neu-ron's protective mechanisms) are weak, the system becomes dangerously unstable. The motor neuron fires repeatedly and uncontrollably, and over time, this leads to damage and cell death. Before the neu-ron dies, however, it may fire erratically—producing fasciculations.

Disruptions in calcium homeostasis also play a major role. Calcium acts almost like water in a dam: it must be tightly regulated. In ALS, the dam begins to leak. Calcium spills into the neuron through faulty channels or because internal buffering systems are overwhelmed. Too much calcium destabilizes the neuron's membrane and triggers spontaneous firing. Eventually, this leads to mitochondrial dysfunction and oxidative stress—further weakening the neuron. But long before the neuron dies, this biochemical chaos increases the likelihood of fasciculations.

It is important to emphasize that fasciculations do not cause weakness. They are symptoms of the motor neurons firing abnormally, not causes of muscle deterioration. Weakness in ALS arises because motor neurons are dying, not because the muscles are twitching. The twitching is just the electrical "noise" created by a failing system. A useful analogy is a damaged electrical wire: the sparks you see do not cause the wire to fail—the wire is failing, and the sparks are simply a sign of that failure. Similarly, fas-ciculations are signs of motor neuron instability, not the source of the problem.

This distinction becomes crucial when distinguishing the fasciculations of ALS from those occurring in benign conditions. The vast majority of twitching in healthy people is harmless. Stress, anxiety, exces-sive caffeine, fatigue, magnesium deficiency, and strenuous exercise can all cause twitching. These benign fasciculations are like the normal creaks a house makes at night—common, harmless, and unre-lated to structural damage. In contrast, ALS fasciculations occur alongside other alarming signs: pro-gressive muscle weakness, atrophy, abnormal EMG patterns, and spread of symptoms across different body regions. It is the combination of symptoms—not the fasciculations alone—that raises concern. Twitching by itself, especially if widespread but not accompanied by weakness or EMG abnormalities, is far more likely to be benign.

As ALS progresses, the pattern of fasciculations changes. Early in the disease, when sprouting is active and neurons are still compensating, fasciculations may be frequent and widespread. Patients may no-tice twitches in their legs, arms, face, or torso. As the disease advances, however, reinnervation be-comes insufficient. Motor neurons become overburdened and begin to die at a faster rate. Muscle fibers become permanently denervated, leading to atrophy. Fasciculations may persist, but they gradually give way to more pronounced weakness. Yet their presence remains a window into the underlying neuro-physiology of ALS.

## Physiotherapy in MND

Although physiotherapy cannot stop the motor neuron degeneration underlying ALS, it plays an essential role in **preserving mobility, easing discomfort, and maintaining independence for as long as possible.** Physiotherapy in ALS is less about strengthening weakening muscles—which cannot be reversed—and more about **optimizing the function of muscles that remain innervated,** protecting joints, and preventing secondary complications such as contractures, stiffness, and pain.

A helpful way to understand physiotherapy in ALS is to imagine a **scaffolding being erected around a fragile structure.** The scaffolding does not change the structure itself, but it supports what remains, prevents collapse, and allows it to function longer and more safely. Similarly, physiotherapy provides strategic support to muscles and joints, enabling patients to move with less effort, more comfort, and reduced fatigue.

Gentle, low-impact exercises can improve **range of motion, posture, breathing mechanics, circulation, and energy management.** Techniques such as stretching, soft-tissue mobilization, and assisted movements help ease cramps and stiffness, which often accompany fasciculations and motor unit hyperexcitability. As the disease progresses, physiotherapists play a vital role in recommending **mobility aids,** orthotic supports, and adaptive equipment, helping patients conserve energy and maintain autonomy. Importantly, physiotherapy also teaches safe strategies for movement, reducing the risk of falls—a significant concern in ALS as weakness spreads.

Physiotherapy does not aim to challenge weakened muscles aggressively, because doing so can increase fatigue and sometimes accelerate discomfort. Instead, it focuses on **preservation, comfort, and energy-smart movement,** ensuring that patients live with the highest possible quality of life throughout the journey of the disease.

## The Homeopathic Support

Homeopathy does not cure ALS or halt the progression of motor neuron degeneration. However, many patients find that individualized homeopathic remedies offer **comfort, emotional balance, and symptomatic relief,** particularly in managing anxiety, sleep disturbances, restlessness, cramps, and the heightened sensitivity associated with fasciculations.

Homeopathy views each patient as a unique constellation of physical and emotional responses. Rather than focusing solely on the disease label, homeopathy examines **patterns of stress, personality traits, emotional triggers, sleep quality, fatigue, cravings, and coping styles.** This individualized approach can be particularly supportive in ALS, where emotional resilience plays a significant role in overall well-being.

Certain remedies are traditionally used to address specific symptom clusters often seen in ALS:

- **Magnesia phosphorica** and **Zincum metallicum** are frequently chosen when fasciculations, cramps, and muscle twitching are distressing—similar to applying a gentle "soothing blanket" over irritable muscle fibers.
- **Gelsemium** may assist when patients experience trembling, weakness, or anticipatory anxiety.
- **Arsenicum album** is often used for restlessness, nighttime fear, and exhaustion.
- **Phosphorus** may help individuals who feel emotionally sensitive, easily fatigued, or overwhelmed by sensory stimuli.
- **Nux vomica** can support those with irritability, sleep-disturbance, and stress-driven symptoms.

The role of homeopathy in ALS is best understood through analogy: it does not repair the damaged wiring of the motor neuron system, but it can **dim the noise, cushion the emotional impact, and ease the sensory irritability** that accompanies the illness. Many patients report better sleep, reduced anxiety, greater emotional calm, and improved ability to cope with physical symptoms. ◆

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Research Paper

# Glimpses of the Future: Technology Forecasting as a Catalyst for Nations on the Rise

Ankkur Goel

## Introduction

Developing nations today live in a world shaped by accelerating technological change and shifting global economic structures. In such a rapidly evolving global order developing nations find themselves under unique pressures—their societies are not static—they face shifting demographic profiles emergent health challenges & disease burdens, climate vulnerabilities, rising aspirations and accelerating digital transformations. What was sufficient infrastructure or industrial capacity a decade ago might now be redundant or obsolete. Progressive societies need to evolve rapidly to keep pace with new demands on infrastructure, skills, and institutions. And thus, to remain relevant and equitable, such countries need to think ahead. They need to anticipate not only *what* is but also *what could* be.

We live in an era where knowledge and ideas increasingly drive value. Many developing countries are striving to become knowledge economies—economies in which human capital, innovation and information flow matter far more than raw materials or unskilled labour. A knowledge economy is characterized by continuous learning, high levels of R&D, strong intellectual property regimes and digital connectivity that enable the creation, transfer, adaptation, and diffusion of innovation.

But, only a handful of nations today can aptly be called full-fledged knowledge economies. Countries such as Sweden, Finland, Denmark, Switzerland, Singapore and Israel lead global indices of innovation, high-value services, and research intensity. Their capacity to transform research into commercial value, attract best talents and sustain high technology ecosystems gives them outsized influence in defining standards, platforms, and supply chains. The gap between these leaders and most other developing countries is not just one of sheer scale—but of vision, institutional structure, innovation ecosystem, foresight, and adaptability.

## The global scenario

Some economies illustrate how strategic attention to knowledge, R&D, and innovation can transform national prospects. China, in around four decades, has revolutionized from a largely agrarian low-value industrial base into a global manufacturing and R&D powerhouse. Recent IMF analysis and forecasts have continued to put China among the faster-growing major economies in the mid-2020s. Hong Kong, with its compact, services-heavy economy and open trade position rebounded through the early 2020s from pandemic shocks and recorded renewed positive GDP growth in recent years—illustrating how flexible well-integrated urban economies can recover and leverage connectivity. Taiwan, on the other hand, demonstrates an equally impressive model. A small but intensely technology-focused economy whose comparative strength lies in high-value-added manufacturing (notably semiconductors) and very high R&D intensity. Taiwan's investments in research and engineering capabilities have produced outsized export and productivity returns helping it retain strategic industrial niches globally.

More broadly, global patterns of R&D investment underline the payoff of sustained technological focus. Across the OECD and major non-OECD players gross domestic expenditure on R&D (GERD) has continued to grow in the first half of the 2020s. China's share of global R&D rose strongly and business sector R&D expanded in many other advanced economies. While small innovation-dense countries (for example, Israel, South Korea and some Nordic nations) show very high R&D-to-GDP ratios these investments are strongly correlated with higher value-added exports, faster productivity gains and the capacity to generate and capture new market segments—the very attributes that distinguish knowledge economies from commodity-centric or low-value manufacturing systems.

## Charting the path ahead

In this fast-changing world, short-term reactive policy-making or purely incremental upgrades can leave countries locked into outdated pathways. Instead, deliberate anticipation—a structured effort to scan, project and assess technological futures—becomes a strategic necessity. For most developing economies, that gap needs to be bridged not incrementally but strategically. They need to identify trajectories of technological change early, align public investments and policies accordingly, and monitor their progress with regular course realignments and corrections. In short, they need a practice of technology forecasting and assessment embedded into their development planning that is both challenging and indispensable if they are to avoid lock-in to outdated paths, circumvent being perpetually on the fringe of waves of innovation and to ensure that their domestic resource allocations, including, human, financial and regulatory, are not wasted on dead ends.

For many developing countries, the lesson is clear but not simple, ambition alone is insufficient. It often isn't enough to spend more! States need to choose wisely where to build capacity, when to catalyze private investment and how to shape institutions and skill systems so that R&D and innovation sustainably translate into tangible social and economic returns. This is the intended purpose of Technology Forecasting and Assessment—to reduce fog from the future and turn scarce public resources into sustained competitive advantage.

## Defining Technology Forecasting (TF) and Technology Assessment (TA) & the imperative need

Technology Forecasting (TF) is the systematic practice of anticipating future technological trajectories their maturation timelines, and, the social, economic and institutional conditions that can determine whether those technologies create value locally. Forecasts are not crystal balls, rather, they are disciplined constructions of possible futures grounded in evidence—historical trends, patent and publication signals, performance curves, expert elicitation, scenario development, and quantitative models. As with any forecast, the goal is not perfect prediction but informed anticipation, to illuminate possible futures, help guide strategy, and reduce the element of surprise. Since technology evolves not in a vacuum but amidst interplay with institutions, markets, regulations and societal acceptance therefore, effective forecasting has to be always interdisciplinary. Effective TF should account for uncertainties, multiple competing paths, disruptive shifts, and bottlenecks in adoption.

Technology Assessment (TA) examines the likely impacts of a technology—environmental, social, regulatory and distributional—and identifies barriers to adoption and scaling. When coupled, TF and TA allow decision-makers to see not only which technologies may matter, but how, when and under what conditions they can be embedded in a national development path. Upon effective amalgamation, forecasting and assessment exercises help decision-makers see not just what might come, but what should come given local goals and tradeoffs.

For many developing economies, the stakes are unusually high. They often confront three interrelated challenges—constrained resources, fast-changing external environments, and, a strong mismatch between aspirations and capacity. In such contexts, naive or reac-tive planning might possibly yield large misallocations—or even worse, strategic lock-in to suboptimal technologies. Wrong technological pathway characteristically entrenches inefficiencies for decades.

By contrast, embedding foresight allows more deliberate and resilient development. Well-timed, well-targeted foresight can direct investments into sectors with high spillovers (for example, electrification plus distributed renewable generation that enables industry, services, and rural livelihoods), uncover adoption barriers (skills, standards, supply chains) and create institutional mechanisms when new windows of opportunity open. Forecasting also helps in aligning disparate actors—ministries, universities, industry and financial institutions—around a shared narrative, thereby, reducing fragmentation in innovation ecosystems that often afflicts and distresses developing countries.

## Delving further into the need for Technology Forecasting

- **Prioritization:** Technology forecasting helps prioritize sectors and capabilities. A country cannot invest in everything, so, which areas are most likely to yield competitive advantage or resilience in the coming decades? Which emerging fields align with national strengths or needs (e.g., in agriculture, water, energy, health, materials)? A well-structured forecasting exercise helps select candidates that deserve focused public investment, R&D, incentives, infrastructure, and skill-building.
- **Shaping trajectories:** Forecasts help governments and institutions anticipate disruptions and transitions. For instance, a country heavily reliant on fossil-fuel energy should anticipate the shift to decarbonization technologies (renewables, energy storage, carbon capture etc.). Developing nations face more risk in being late entrants into such transitions. Forecasting enables path management—not just reacting to disruptions, but shaping trajectories via policy nudges, standards, and institutional support.
- **Setting the cradle:** Foresight exercises can reveal adoption barriers, institutional gaps, and sociotechnical challenges. Suppose a promising technology is forecast to mature globally within 10–12 years; a developing country may need to build regulatory capacity, supply chains, intellectual property regimes, skills, public acceptance, or standards to be ready. In other words, forecasting is not just about which technologies may come, but how and when and for how long they can be locally embedded.
- **Avoiding reinvention of the wheel:** From a funding and risk-management angle, public R&D, infrastructure investments, subsidies, incentives, and regulations often involve long payback times. Forecasting helps mitigate the risk of backing obsolete paths. In broader terms, forecasting is a hedge against technological surprises.
- **Building bridges and effective coordination:** Technology forecasts foster strategic alignment and coordination across ministries, research institutions, industry, and educational bodies. In many developing economies, fragmentation in innovation ecosystems is a structural weakness. A shared vision informed by foresight can help align otherwise siloed actors.

## The fruits (outcomes) of Technology Forecasting

A rigorous foresight and assessment exercise has the capability to deliver multiple types of useful insights.

Such insights turn technology foresight from an academic exercise into a navigational tool for public strategy, industrial policy, and institutional design.

## Learning from the World—Global experiences in Technology Foresight

Across the globe many nations—both advanced and emerging—have undertaken structured Technology Forecasting and Assessment exercises to align science, innovation, and national development. These initiatives reveal how foresight, when coupled with policy commitment and institutional continuity, can yield remarkable dividends. From the United Kingdom's participatory foresight panels to China's long-term strategic technology roadmaps and from Singapore's agile innovation frameworks to Finland's ecosystem-based foresight culture, each experience offers valuable insights. Together, they affirm a universal truth—that progress is rarely accidental—rather, it is the result of nations consciously envisioning their technological futures and investing with purpose, patience, and imagination.

**United Kingdom:** National foresight at scale first became widely visible in the 1990s with the United Kingdom's Technology Foresight programme. Launched in the early 1990s and run in successive rounds, UK Foresight convened large multidisciplinary panels to map promising technology areas, produce roadmaps and link research priorities to industrial strengths. The exercise

| Indicator | Outcomes |
|---|---|
| **Technology roadmaps & timelines** | Which technologies might become via-ble (or obsolete) by which year; what intermediate milestones to watch. |
| **Technology clusters or ecosystems** | Identifying sets of related domains that may coevolve (e.g. sensors + IoT + AI in agriculture). |
| **Bottlenecks & enablers** | Infrastructure, regulation, human capital, standards, supply chain, adoption limits. |
| **Scenario variants** | Alternative pathways. |
| **Strategic options & pivot points** | Where policy or investment interventions could shift the trajectory. |
| **Gap analysis and capacity building** | What institutional, regulatory or skill gaps must be filled to realize particular trajectories. |
| **Risk or contingency assessment** | Early warning of possible dead ends, failure modes, lock-ins, or disruptive substitution. |
| **Benchmarking and global context** | Compares domestic trajectories with global trends, enabling informed positioning. |

did not attempt to "predict" any single winners, rather, it identified areas where public intervention, coordination and translation mechanisms could possibly create leverage—and it explicitly fed into research council priorities and collaborative funding instruments. Evaluations and impact studies reflected measurable downstream effects: reallocation of some public R&D funds toward Foresight-identified priorities, creation of networks and consortia, establishment of numerous follow-on applied research institutes, and, improved dialogue between government, industry and academia. The programme created a shared narrative and improved horizon-awareness across policy departments.

**China:** The People's Republic of China offers a contrasting example of foresight embedded in its national strategy. In 2006, the Chinese State Council published the National Medium- and Long-Term Program for Science and Technology Development (2006–2020), a consciously catalytic blueprint that set explicit targets (including raising gross R&D expenditure towards ~2.5% of GDP and increasing the contribution of S&T to growth). The plan combined priority sector lists (energy, materials, biotech, information technology, advanced manufacturing) with concrete policy levers, funding increases, talent programmes and measures to reduce technology import dependence. Tangible outcomes have been phenomenal with China's GERD and business-sector R&D investment rising rapidly in the 2000s–2010s. The country moved up global value chains in electronics, clean energy, and biotech and stateled incentives accelerated domestic capabilities in areas of strategic importance. Intangible gains included stronger national innovation institutions, mission-oriented coordination between ministries and clearer industrial targets. The Chinese case illustrates how coupling national foresight with scaleable finance and institutional reforms can deliver rapid capability building—and why governance design matters to convert investment into productive innovation.

**Singapore:** Singapore's RIE (Research, Innovation & Enterprise) planning provides a third model: continuous, rolling foresight tightly integrated with budgetary commitments and industrial policy. Successive RIE roadmaps (e.g., RIE2015, RIE2020 and the current RIE2025) identify a small set of national domains (manufacturing & connectivity, health & biomedical, urban solutions, digital economy) and back them with multi-year funding envelopes and institutional actors. The hallmark here is discipline: foresight led to explicit funding commitments (RIE2025 targets ~S$25 billion and ≈1% of GDP over 2021–25), public-private consortia, and mission projects that derisk early adoption for industry. The economic returns are visible in Singapore's persistent attractiveness for high-value manufacturing and biomedical investment, cluster formation, and continually rising productivity in targeted sectors. The intangible return is a tight, agile policy-research loop that allows priorities to be revised without losing implementation momentum. Singapore shows how coupling foresight with sustained. Predictable investment and industry engagement can make a small economy technologically punch above its weight.

**Finland:** The Finnish experience—a unique mix of decentralized foresight activities and national initiatives such as Finnsight and TEKES-led programmes—highlights both strengths and limits of foresight. Finland historically combined broad foresight exercises with strong public funding agencies (Tekes, integrated into Business Finland in 2018) and close researcher-industry linkages; outputs included targeted funding instruments, cluster support, and an emphasis on upgrading human capital and networks. Tangible outcomes included internationally competitive ICT and clean-tech capabilities and a reputation for strong public-private cooperation. But the Finnish story also carries a cautionary lesson: foresight and funding do not guarantee market success when global technological disruptions or platform shift rapidly (the disruption of Finnish mobile handset leadership is a classic example). The learning is that foresight should be iterative, embedded in learning institutions, and coupled with policies that foster continual adaptation (not just one-time roadmaps). Finland's mixed record underscores that national foresight is most effective when it becomes a continuous capability—a habit of policy—rather than a single report.

## The case of India—TIFAC and Technology Vision 2020

India, too, carried out an impressive, exhaustive, valuable and well-documented national foresight exercise demonstrating a compelling example of how a developing country attempted to institutionalize technology forecasting in its planning apparatus. In the mid-1990s, the Technology Information, Forecasting and Assessment Council (TIFAC)—an autonomous body under India's Department of Science & Technology (DST)—launched a pioneering exercise known as Technology Vision 2020 under the leadership of then-TIFAC Chair Bharat Ratna Dr. A. P. J. Abdul Kalam.

The exercise enlisted hundreds of experts across academia, industry, and government. It was a sincere attempt to imagine the sector-specific technologies India would need by 2020, and the institutional, regulatory, and human capabilities required to support them for creating an enabling ecosystem. The Vision produced a suite of documents covering multiple sectors, right from agro-food processing, chemicals, waterways & road transportation, engineering & electronics to cross-cutting enablers like biotechnology, telecommunications and strategic industries. Much more than a mere list of technologies, the exercise produced roadmaps, driving-force analyses and recommendations on capacity building, standards, and institutional mechanisms.

Over the subsequent decades, many of the forecasts or priorities set in Vision 2020 shaped funding programs, public-private consortia, and institutional initiatives. For exam-ple, TIFAC's later activities around Home Grown Technology (HGT) schemes, technology cluster development. Foresight updates, and innovation programs reflect continuity from the original vision. By 2020, the document was celebrated as a foundational guide for India's scientific and technology ecosystem. Critics and observers note that while not all predictions came true, the exercise's lasting value lay in orienting institutional attention, creating networks of technology experts, surfacing latent capacity gaps, and offering a shared narrative of where India should aim technologically.

Critically, the TIFAC experience exemplified two practical lessons for other developing countries. First, foresight should be broad and participatory viz. it should draw on domain experts but also include implementers and users to surface realistic adoption constraints. Second, foresight is most valuable when it is connected to implementation levers like, funding instruments, standard-setting, skill development and public procurement, so that identified priorities can be translated into measurable progress rather than remaining aspirational lists.

## The *Yagya* of undertaking technology-forecasting and assessment

When we think of technology forecasting it is alluring to imagine a set of rigid steps or models that can somehow predict the future with mathematical precision. Yet, in reality, the art of forecasting is more like a continuous conversation—between data and imagination, between what is possible and what is desirable, and, between the intrinsic capabilities and constraints of an economy. For many developing countries, especially those at a stage of accelerated industrial and digital transformation, such exercises are best viewed not as rituals of prediction, but as frameworks for exploration and preparedness.

Many nations have found it useful to begin with systematic "horizon scanning", an activity that seeks to identify faint but significant signals of change—the kind that rarely make headlines but may shape the markets and societies of tomorrow. Horizon scanning can include careful observation of patent trends, research publications, venture-capital flows, and even social-media debates around emerging technologies. The European Commission's Joint Research Centre (2023) and the OECD's Strategic Intelligence Toolkit (2024) both describe how automated text-mining combined with expert interpretation, can uncover such early signs of technological movement.

Once these signals are gathered, they often need human interpretation. This is where expert consultations, Delphi studies, and participatory foresight workshops become valuable. The strength of such exercises lies not in unanimity but in diversity—in bringing scientists, entrepreneurs, policymakers, and even citizens into a shared dialogue about possible futures. As seen in the UK and Finland, involving multiple voices often yields more balanced and realistic foresight than relying solely on academic or bureaucratic expertise.

From here, many countries move toward scenario building—the imaginative heart of forecasting. Scenarios don't claim to "see" the future; rather, they offer structured stories of how it might unfold under varying assumptions. Singapore's Futures Unit and the Netherlands' Rathenau Institute have shown how scenario planning helps governments and industries test their readiness for disruptive shifts, whether in energy systems, automation, or healthcare. Similarly, "backcasting"—working backwards from a desirable future—helps identify what choices should be made today to reach that goal.

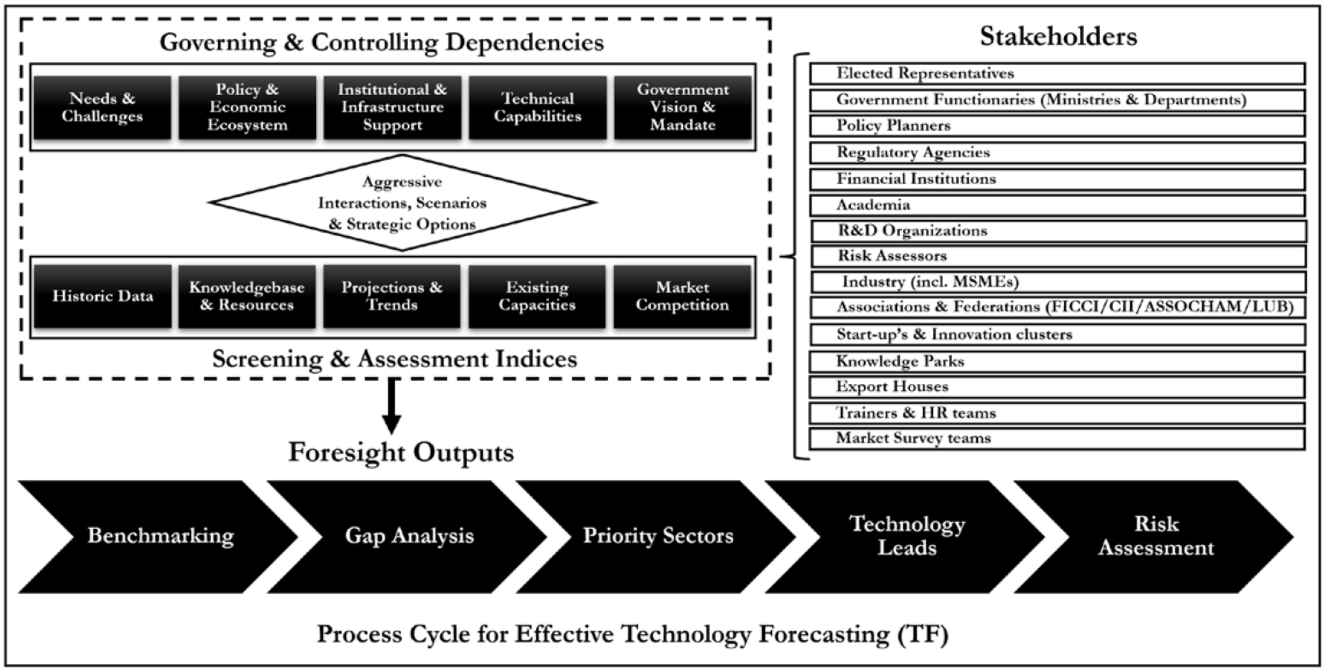
To make these ideas operational, technology roadmaps are often prepared. A roadmap links long-term visions with near-term actions: which capabilities need to be built, which technologies merit local development, and which regulatory or skill gaps should be filled. When such maps are periodically updated and anchored in public R&D or industrial policy, they become powerful navigational tools.

It is equally important to articulate here that developing nations need institutional continuity—not as one-time exercises but permanent foresight cells or observatories that regularly update insights. Some countries have placed such units within science and technology ministries; while others have networked them across universities, industries, and policy thinktanks. The format matters far less than the spirit—foresight should become a habit, not an event. Very aptly, the UNESCO and UNDP often remind their stakeholders that nations that embed anticipation into governance tend to respond better to crises and opportunities alike.

## Why do such exercises often stumble or fade away

It is imperative and equally intriguing to ponder on the fact that when the benefits of foresight seem obvious, then why do so many well-intentioned initiatives fade away after a single study or report. The answer probably lies partially in the human nature and partly in institutional realities.

- **Fragmented responsibilities** are a common barrier. In many developing economies, ministries and departments operate in isolation—science in one corner, industry in another, and education somewhere else. Forecasting demands a panoramic view, yet administrative systems are built for narrow tasks. When no single agency owns the outcomes, follow-ups become nobody's priority.
- **Short political cycles** pose another challenge. Foresight is, by nature, a long-horizon investment. Its returns seldom coincide with electoral calendars. A change in leadership




can easily sideline a visionary document. The experience of several OECD countries shows that enduring foresight requires bipartisan or crossministerial commitment, not just an individual champion.

- **Data and capacity constraints** also limit the quality of forecasts. Access to reliable data on intellectual property, startups, or emerging R&D themes is still uneven across the Global South. Without these inputs, even the most well-designed exercises risk becoming speculative rather than evidence-based.
- **Lack of followthrough mechanisms** is another critical bottleneck. A foresight study, no matter how insightful, remains a publication unless its recommendations are linked with funding, regulation, and appropriate skill-development programmes. In our own country, for instance, the Technology Vision 2020 exercise under TIFAC led to several thematic reports and sectoral roadmaps, but translating them into actionable programmes required separate institutional effort—a harsh reminder that ideas need instruments.
- **Cultural and psychological barriers** should also not be ignored. Bureaucratic systems are typically risk-averse; they reward compliance more than curiosity. In such an atmosphere, long-term experimentation most often becomes uncertain and, therefore, undesirable. Building a culture that values exploration—where small failures and setbacks are tolerated as part of learning curve—is as crucial as any other formal mechanism.

These constraints are not unique to developing nations, but their impact is deeper where resources are scarce and administrative bandwidth is a limiting factor. The encouraging lesson, however, is that all of them can be mitigated through continuity, openness, and a genuine belief that looking ahead is an investment, not a luxury.

## Lessons from the private sector

Interestingly, the private sector has long practiced its own forms of technology forecasting—though under more pragmatic labels such as *strategic planning, R&D road mapping,* or *innovation scouting.* These exercises, though driven by profit, offer valuable lessons for nations seeking to institutionalize foresight.

One of the earliest and most enduring examples comes from **Shell,** whose *Scenario Planning Unit* began in the 1970s. The company did not attempt to predict oil prices but to imagine multiple global futures, right from energy transitions to geopolitical realignments. That flexibility allowed Shell to navigate oil shocks more steadily than many competitors. The moral here was simple: preparedness often matters more than prediction. **Toyota's** philosophy provides another interesting case. For decades, the company has invested in long-term R&D through the Toyota Research Institute and parallel ventures such as Woven by Toyota. Rather than betting everything on one trend, Toyota has pursued parallel technological paths—hybrids, battery-electric vehicles, and hydrogen fuel cells. This multipathway approach reflects a deep foresight: uncertainty becomes an asset when managed deliberately.

Similarly, **IBM's** research laboratories have long treated scientific exploration as a strategic necessity rather than an optional indulgence. Many of the world's computing standards, memory systems, and AI advances trace their roots to IBM's insistence that industrial research must precede industrial revolutions. Giants like **Alphabet (through its X-Moonshot Factory)** and **Siemens (via next47)** demonstrate how even in fast-moving digital landscapes, structured foresight remains essential. Alphabet treats ambitious ideas as "experiments" that may or may not graduate into independent ventures. Siemens, on the other hand, created dedicated innovation arms to explore technologies that did not fit neatly into existing business lines. Both approaches reveal a willingness to explore without immediate payoff—a trait many public systems may perhaps emulate!

The thread that binds these examples is not wealth but vision—a belief that structured imagination, backed by modest but consistent investment, pays dividends over time. If companies can commit to such habits in order to stay relevant and profitable, nations can certainly do so to stay progressive.

## Closing reflections—The future belongs to the prepared mind

Technology Forecasting, at its heart, is an act of curiosity and hope. It is not about predicting the future, but about preparing for it intelligently. For developing countries, the task is less about adopting imported models and more about cultivating a national habit of anticipation—to observe patiently, think collectively, and act decisively. The journey may not follow a fixed roadmap, but as history and industry alike suggest, those who invest in fore-sight rarely regret it.

In the final reckoning, Technology Forecasting and Assessment are primarily about cultivating a national temperament—one that values reflection as much as reaction. For developing nations, where priorities shift quickly and resources are always stretched, the courage to pause and think ahead may itself be the rarest form of progress. There will always be those who argue that the future is too uncertain to forecast, or that the pressing needs of the present must take precedence. Both arguments carry truth. Yet, it is equally true that without anticipation, nations drift—reacting to change rather than shaping it. Forecasting does not remove uncertainty; it simply teaches us to walk through it with awareness. History has shown that foresight, when blended with humility, becomes wisdom. The intent is not to prescribe a single path, but to kindle a culture that asks better questions, sooner. Technology foresight, approached in this spirit, is not an academic exercise, rather it is an act of national mindfulness—one that helps societies align their as-pirations with their capabilities.

India and other developing economies stand today at a threshold where their future will be determined not merely by how fast they grow, but by how wisely they choose. And wisdom, as ever, begins with the will to look beyond the present—to imagine, to assess, and to prepare.

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# Lighting the Path to a Sustainable Future

## How Light Technology Is Driving Global Sustainability

Zahid H. Khan

## Introduction

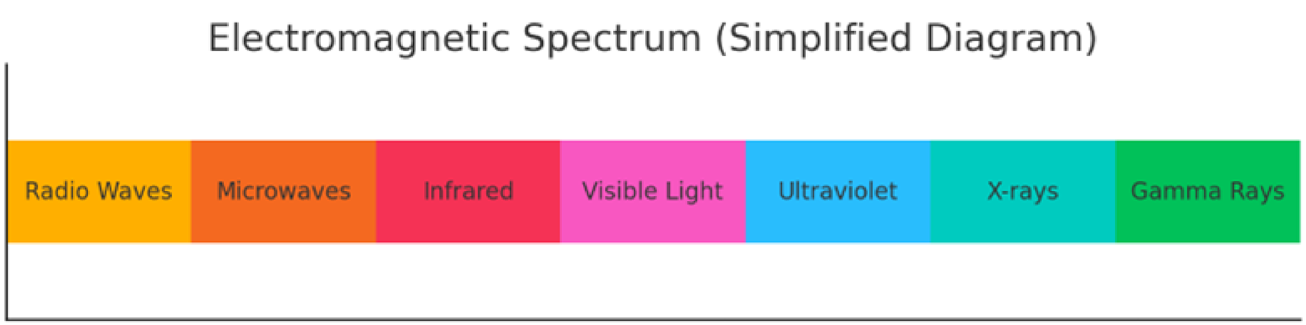
Light is one of nature's most powerful gifts. It sustains life on Earth, shapes weather and climate, and enables us to explore and understand the world around us. Beyond the narrow band of visible light lies a vast spectrum—stretching from microwaves to X-rays—that powers communication, healthcare, industry, and scientific discovery.

As the world faces urgent challenges such as climate change, healthcare accessibility, energy security, and equitable education, light-based innovations are delivering smarter, cleaner, and more sustainable solutions.

Recognizing the vital role of light in advancing society, the United Nations declared 2015 the "International Year of Light and Light-Based Technologies (IYL 2015)". Building on its success, UNESCO established the "International Day of Light (IDL)" in 2018 to celebrate how photonics science and technology improve lives—enhancing connectivity, supporting cultural preservation, strengthening environmental protection, and driving economic development.

Reflecting its strong alignment with the "UN Sustainable Development Goals (SDGs)", the IDL emblem incorporates the colours of all 17 SDGs, symbolizing how light contributes to ending poverty, reducing inequalities, and building a resilient planet. The theme for IDL 2026, "*Light for a Sustainable Future,*" reinforces this vision.

This article introduces, in clear and engaging language, how light and light-based technologies are shaping a better future for humanity. It is aimed at learners, educators, science enthusiasts, and anyone planning IDL-related outreach activities.



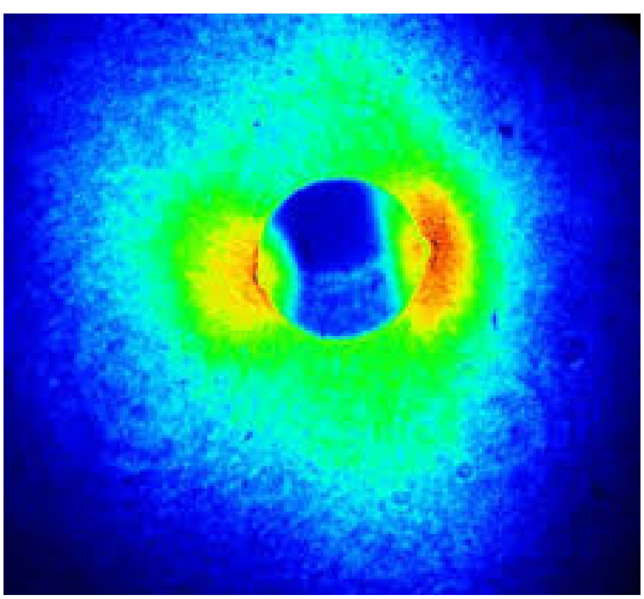

## Light for Clean Energy and Climate Stability

Every day, the Sun delivers vast amounts of free energy to Earth. Solar photovoltaic (PV) technology converts this sunlight directly into electricity—without smoke, pollution, or greenhouse gases. As costs decline and performance improves, solar power is lighting up homes, schools, industries, and remote villages. In areas beyond the electric grid, solar mini-grids and lamps offer clean power for the first time, reducing dependence on kerosene and diesel.


Lighting innovations also support climate action. LEDs use a fraction of the electricity required by older bulbs. When combined with smart controls that dim or switch lights off automatically, cities and households can significantly reduce energy waste. These advances show how the right use of light helps eliminate darkness while safeguarding Earth's environmental balance.

## Light for Better Healthcare and Well-Being

Optics and photonics are revolutionizing medicine. Laser tools allow surgeons to perform precise procedures with minimal discomfort and faster recovery. Optical imaging techniques—including X-rays, CT scans, MRI, and endoscopy—enable earlier detection of disease, saving millions of lives. Light-based therapies are used to treat skin disorders, certain cancers, and mood-related conditions such as seasonal depression.



Good lighting also contributes to safety and well-being. Well-lit streets prevent accidents and deter crime. Proper indoor lighting supports learning, productivity, and healthy sleep rhythms—reminding us that sustainability includes not only technology but also quality of life.

## Light for Communication and Knowledge Sharing

Each time we join an online class, send a message, or participate in a video call, we rely on pulses of laser light traveling through fibre-optic cables. These hair-thin strands of glass carry data across continents and oceans at nearly the speed of light.

By connecting hospitals with patients, teachers with students, and communities with opportunities, optical communication is helping ensure that information access becomes a right for all—not a privilege for a few.

**Led Lightings**

**Solar Lights**

## Light for Water, Food, and the Environment

Earth-observing satellites equipped with optical sensors provide invaluable insights on climate change, forest health, agricultural conditions, and ocean ecosystems. This knowledge supports disaster preparedness, environmental protection, and sustainable resource management.

Ultraviolet (UV) systems disinfect drinking water without harmful chemicals—a boon for rural and disaster-affected regions. In agricultural innovation, smart LED lighting in greenhouses enables year-round food production with less land, reduced pesticide use, and lower water consumption.

In every case, light supports a healthier planet and improves human resilience.

## Light for Education and Equality

For millions of students worldwide, daylight defines their learning hours. Solar lighting extends study time into the evening and enhances safety, especially for young children and girls traveling after sunset. When paired with digital education technologies and optical internet connectivity, it opens transformative learning opportunities.

Here, light becomes a tool of empowerment—expanding access, reducing inequality, and fulfilling core SDG goals.

## Responsible Use of Light

While artificial lighting is essential, excessive or poorly directed light creates light pollution, washing away the night sky, disrupting ecosystems, and affecting human sleep. Sustainable lighting designs—shielded fixtures, warmer colours, motion sensors, and timers—ensure light is used only where needed.

Protecting the night sky saves energy, supports wildlife, and preserves humanity's connection with the cosmos.

## Towards a Brighter Future in the Quantum Technology Era

Quantum technology—spanning computation, communication, cryptography, sensing, and advanced healthcare—is expected to reshape the world in the coming decades. Reflecting its significance, the United Nations has proclaimed **2025 as the International Year of Quantum Science and Technology.**

Photonics will be central to this transformation: from ultra-secure quantum communication systems to next-generation photovoltaic devices that harvest more energy from sunlight. These new advances promise tangible benefits—addressing climate challenges, boosting global connectivity, and safeguarding ecosystems.

## Conclusion

Light has guided human progress for centuries—as a symbol of knowledge, a source of life, and a catalyst for innovation. Used wisely and shared equitably, light-based technologies will continue to illuminate our path toward a sustainable, inclusive, and prosperous future for all. ◆

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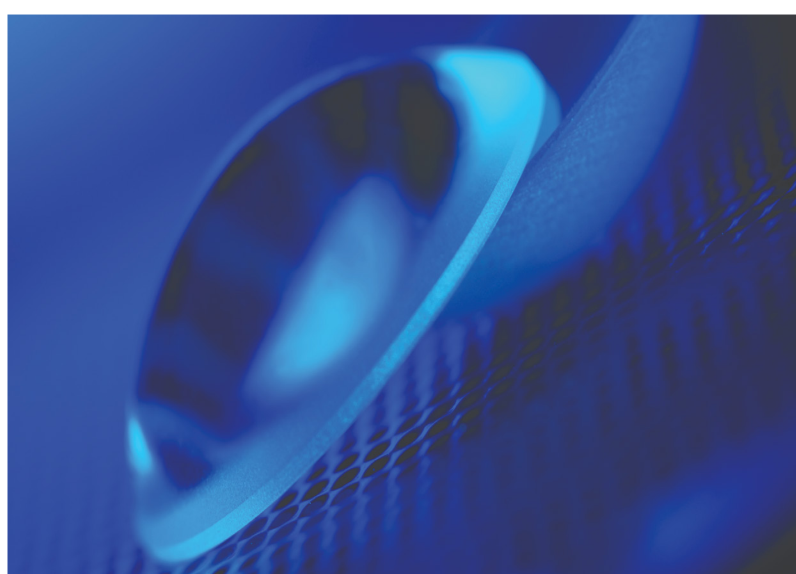


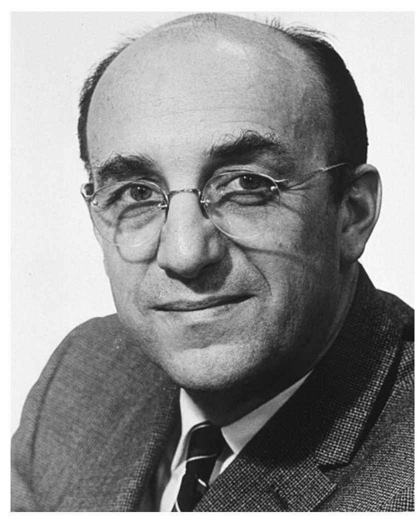
VIGYAN 2047 Volume 3 No. 1 January 2026 Pages 36–37

# Celebrating the January Born Scientists

Bhupati Chakrabarti

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

**Sir John Ernest Walker** was born 7 January 1941 and is a British chemist best known for his groundbreaking work on ATP synthase, which earned him the 1997 Nobel Prize in Chemis-try. After early research posts at the University of Wisconsin–Madison and in France, he met Fred Sanger in 1974 at a Cambridge workshop, leading to a long-term position at the MRC Laboratory of Molecular Biology. There he worked among leading scientists, including Francis Crick. Walker initially focused on protein sequencing and helped clarify features of the modified mitochondrial genetic code. In 1978, he shifted toward applying protein chemistry to membrane proteins, characterizing the subunits of mitochondrial membrane complexes and sequencing mitochondrial DNA. His most influential work involved crystal-lographic studies of the F1-ATPase catalytic domain of ATP synthase, performed with crys-tallographer Andrew Leslie. Their 1994 structure revealed three catalytic sites in distinct conformations shaped by the asymmetric central stalk, powerfully supporting Paul Boyer's binding change mechanism and the concept of rotary catalysis. This discovery formed the basis of Walker's Nobel Prize. Since then, Walker's group has produced most crystallo-graphic structures of mitochondrial ATP synthase and trained scientists who later solved major structures of bacterial complex I, mitochondrial complex I, and vacuolar ATPases.



**Roger Charles Louis Guillemin** was born on January 11, 1924 and was a French-American neuroscientist who helped establish modern neuroendocrinology. He received the U.S. National Medal of Science in 1976 and shared the 1977 Nobel Prize in Physiology or Medi-cine with Andrew Schally and Rosalyn Sussman Yalow for identifying key neurohormones. In 1954, Guillemin demonstrated that pituitary cells required signals from the hypothala-mus to produce hormones, supporting the theory of hypothalamic releasing factors. He moved to Baylor College of Medicine to expand this work, and Schally joined him in 1957. Their collaboration ended after five unproductive years, and the two became fierce rivals, each processing millions of animal hypothalami—Guillemin using sheep brains, Schally using pigs—to isolate trace quantities of releasing hormones. A major breakthrough came in 1969 when Roger Burgus in Guillemin's group identified thyrotropin-releasing factor (TRF), securing funding and leading to the discovery of another regulator, FRF. Guillemin and Schally independently determined the structures of TRH and GnRH, earning the Nobel Prize. After joining the Salk Institute in 1970, Guillemin led the Laboratories for Neuroen-docrinology until 1989, discovering somatostatin and helping isolate endorphins. His pro-tégé Wylie Vale later purified CRF, continuing the tradition of competitive discovery.

**David Morris Lee** was born January 20, 1931 and is an American physicist best known for his pioneering work in low-temperature physics, particularly the discovery of superfluidity in helium-3. A professor emeritus at Cornell University and distinguished professor at Texas A&M University, Lee conducted the Nobel-winning research in the early 1970s with Robert C. Richardson and graduate student Douglas Osheroff. Using a Pomeranchuk cell to study helium-3 only thousandths of a degree above absolute zero, they detected unexpected anomalies that proved to be phase transitions into a superfluid state. This breakthrough earned the trio the 1996 Nobel Prize in Physics. Beyond helium-3 superfluidity, Lee's work explored many aspects of liquid, solid, and superfluid helium systems. His contributions include identifying antiferromagnetic ordering in solid helium-3, discovering nuclear spin waves in spin-polarized atomic hydrogen with Jack H. Freed, and locating the tri-critical point on the phase separation curve of helium-4/ helium-3 mixtures with John Reppy. His former Cornell research group continues to study impurity-helium solids. Lee has received numerous honors, including the 1976 Sir Francis Simon Memorial Prize, the 1981 Oliver Buckley Prize (shared with Osheroff and Richardson), and the 1997 Golden Plate Award. He is also a member of the National Academy of Sciences and the American Academy of Arts and Sciences.

**Raja Ramanna** was born on 28 January 1925 and was an Indian nuclear physicist. He was the director of India's nuclear program in the late 1960s and early 1970s, which culminated in Smiling Buddha, India's first successful nuclear weapon test on 18 May 1974. Ramanna worked under Homi Jehangir Bhabha, and joined the nuclear program in 1964. Later became the director of this program in 1967. Ramanna expanded and supervised scientific research on nuclear weapons and was in charge of the team of scientists at Bhabha Atomic Research Centre (BARC) that designed and carried out the testing of the first nuclear device in 1974. Ramanna was associated with India's nuclear program for more than four decades, and also facilitated research for the Indian Armed Forces. He served in various roles such as Secretary for Defence Research, Government of India (1978–81), Scientific Adviser to the Minister of Defence (1978–81), Director-general of Defence Research and Development Organisation (1978–82), Chairman of Atomic Energy Commission (1983–87) and Secretary of the Department of Atomic Energy (1983–87). He later became the Minister of state for defence in 1990. He served as a Member of Parliament, Rajya Sabha from 1997 to 2003. Towards the later part of his career, he advocated against nuclear proliferation and testing.

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

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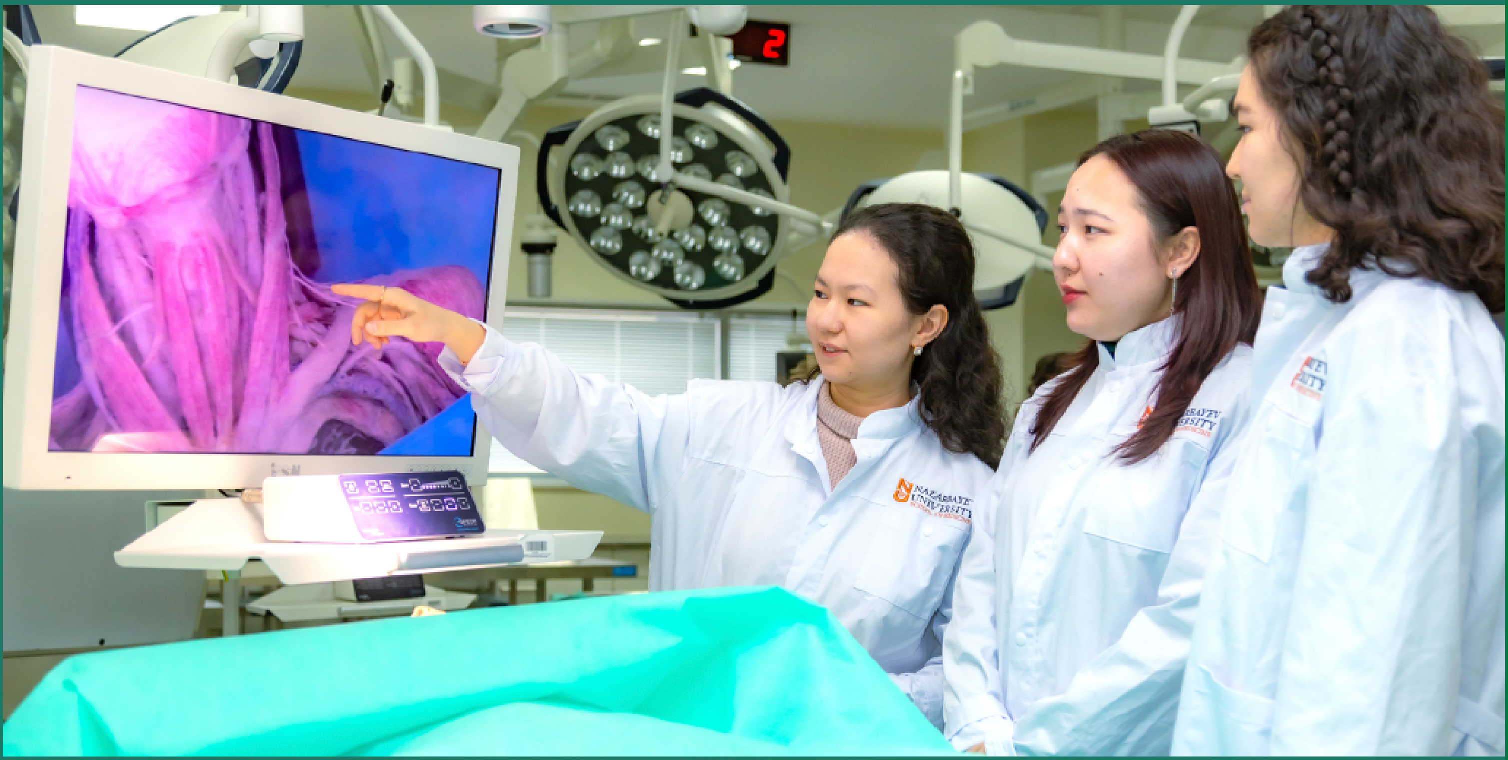

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