VIGYAN 2047

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- National Science Day
- Science of Happiness
- Tribology
- Motor Neuron Disease

SMART MOBILITY

INTELLIGENT TRANSPORT SYSTEMS

ITS-INDIA FORUM

VIGYAN 2047

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In This Issue

Remembering 28th February

Every year, as **28 February** returns on the calendar, India pauses for a moment of quiet pride and deeper reflection. The day marks a luminous instant in 1928, when **C. V. Raman** revealed to the world the subtle dance of light and matter—the **Raman Effect**—a discovery that would earn India its first Nobel Prize in Physics two years later. Nearly a century has passed since that announcement, yet the date has lost none of its radiance. It continues to remind us that science is not merely an accumulation of facts or formulas, but a way of seeing, questioning, and understanding the universe around us. For *Vigyan 2047,* National Science Day is far more than a ceremonial observance; it is a mirror held up to the nation's scientific conscience, inviting us to reflect on where Indian science has journeyed from, where it stands today, and where it must aspire to go as the country approaches its centenary of independence.

Raman's discovery was not simply an individual triumph etched into the annals of global science; it was a moment of national awakening. It proclaimed, with quiet confidence, that world-class science could emerge from Indian laboratories guided by originality, intellectual courage, and disciplined experimentation—even in the absence of opulence or abundance. That message resonates as powerfully today as it did in 1928. The Raman Effect is no relic resting in the museum of history; it lives on at the heart of modern Raman spectroscopy, a technique indispensable to materials science, nanotechnology, pharmaceuticals, environmental monitoring, forensic analysis, and biomedical diagnostics. Each time a contemporary laboratory employs these tools, Raman's legacy is gently reaffirmed. National Science Day thus celebrates a living, breathing science—one that continues to yield new knowledge, applications, and possibilities.

Yet the relevance of National Science Day in 2026 stretches far beyond a single discovery or a single name. We inhabit an age in which science and technology quietly, relentlessly shape almost every dimension of human existence—from public health and climate action to energy transitions, digital ecosystems, and national security. And yet, paradoxically, this is also an era in which scientific facts are increasingly contested, drowned in misinformation, half-truths, and spectacle. In such times, National Science Day assumes a deeper significance: it becomes an annual reaffirmation of rational inquiry, evidence-based reasoning, and the spirit of scientific temper. It reminds us that science is not the exclusive domain of laboratories or elite institutions, but a shared societal enterprise that thrives only when citizens engage with it critically and confidently.

As India looks toward **India@2047,** National Science Day must be seen not as a one-day ritual, but as a strategic and moral instrument—one that connects past excellence with present responsibility and future ambition. It reminds policymakers that investment in science cannot stop at laboratories and infrastructure, but must extend to education, communication, and outreach. It reminds educators that curiosity and imagination are as vital as curriculum and assessment.

The truest tribute to Raman lies not merely in remembering his Nobel Prize, but in sustaining a culture of curiosity, communication, and public engagement—one that allows science to fulfil its highest purpose in service of society.

Nakul Parashar, PhD
nakul@shantifoundation.global

Letter to the Editor

A Welcome Beacon for Science Communication

I wish to place on record my deep appreciation for the dedication and sustained efforts that have gone into bringing out the monthly *SF–Vigyan 2047*. I have been following the magazine with keen interest, and each issue reflects a rare combination of intellectual rigour, clarity of purpose, and an unwavering commitment to science popularisation. In a time when meaningful science communication is increasingly scarce, *SF–Vigyan 2047* stands out as a thoughtful and much-needed platform. Please accept my heartfelt congratulations to you and your entire team for this significant contribution to India's science communication landscape.

Having been engaged in science communication and popularisation for over five decades, I attach great value to initiatives that consciously work towards nurturing scientific temper, curiosity, and informed thinking among diverse sections of society. In this context, I would consider it an honour if you would be kind enough to consider my name for inclusion in the Advisory Committee of *SF–Vigyan 2047*. I believe my long association with science communication may be of some value in shaping the magazine's content direction, outreach strategies, and long-term vision.

I would also be happy to contribute regularly to the magazine through articles, commentaries, or other formats aimed at public engagement with science. It would indeed be a privilege to be associated with an initiative that so thoughtfully aligns science with society and the future aspirations of our nation. With my best wishes for the continued success and expanding impact of *SF–Vigyan 2047*.

Dr. Subhabrata Roychaudhuri
Science Association of Bengal, Kolkata

Editor's Note: *Thank you, Dr. Roychaudhuri. It will be our honour to have you on the Advisory Board of SF–Vigyan 2047. Your lifetime contribution to science communication will be invaluable to the magazine.*

An Enthusiastic Offer to Contribute

It is wonderful to learn about *SF–Vigyan 2047*. The vision, intent, and commitment reflected in the magazine resonate strongly with my own long-standing engagement with science and society. Platforms such as this are crucial if science is to meaningfully reach the public and inspire younger generations.

I would be delighted to be associated with *SF–Vigyan 2047* and would like to explore opportunities to contribute in a meaningful manner. As a food scientist and microbiologist by training, with a long professional association with **CSIR–CFTRI, Mysuru,** including my tenure as **Former Chief Scientist,** I would be happy to contribute articles focused on science popularisation and public understanding of food science, nutrition, microbiology, health, and allied areas. I would also be glad to assist in content review or mentor younger contributors, should you feel my experience could be of use. Please do let me know how I may best contribute to the magazine's present and future initiatives.

Dr. Renu Agrawal
Former Chief Scientist, CSIR–CFTRI, Mysuru

Editor's Note: *Thank you, Dr. Agrawal. Your long and distinguished association with science and science communication is widely recognised. We would be delighted to have your association with SF–Vigyan 2047 as well as with the broader STEM awareness initiatives of Shanti Foundation.*

Support VIGYAN 2047

Vigyan 2047 is a public-funded science communication initiative of the Shanti Foundation (www.shantifoundation.global), dedicated to spreading scientific awareness and nurturing scientific temper through well-researched, accessible popular science writing. Launched in October 2024, the magazine has grown into a trusted platform for scientists, educators, students, and informed readers. Now in its third year of publication, it reaches audiences across the Indian Subcontinent and beyond, reflecting the rising demand for credible, non-sensational science communication.

Originally launched as a fully digital publication, Vigyan 2047 ensured open access in its formative phase. As readership expanded, sustained demand emerged for a printed edition, particularly from educational institutions, libraries, and senior educators. In response, the magazine introduced a limited print run while continuing its digital presence.

Initially offered free of cost as a public service, Vigyan 2047 later adopted a modest subscription model to partially cover printing and distribution costs. Encouragingly, annual subscriptions are steadily increasing, signalling both content relevance and reader trust. To sustain and responsibly scale this growth, the magazine now seeks support through advertisements, institutional subscriptions, and individual patronage.

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In The News

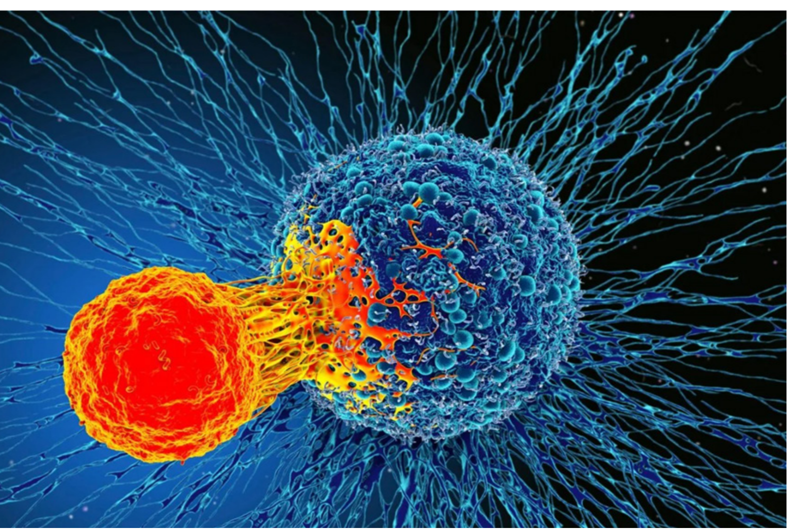
Massive cosmic collisions around a nearby star

Astronomers have directly observed the aftermath of two massive collisions between large rocky and icy bodies around the nearby star Fomalhaut, an unprecedented discovery beyond our solar system. Early planetary systems are chaotic, with frequent impacts among comets and asteroids, but the largest collisions were thought to be rare. Yet two such events were detected around Fomalhaut in just 20 years, first in 2004 and again in 2023, suggesting these violent smashups may be more common than expected. Fomalhaut, located 25 light-years from Earth, is about 440 million years old, making it a valuable analog for the early solar system. Using the Hubble Space Telescope, astronomers observed bright points of light that initially appeared to be planets. Further analysis revealed they were actually expanding dust clouds created by collisions between planetesimals at least 60 kilometers wide.

One supposed planet, Fomalhaut b, later disappeared, supporting the dust-cloud explanation. A newer cloud, even brighter, reinforces this conclusion. Scientists estimate hundreds of millions of similar objects orbit the star. Ongoing observations with Hubble and the James Webb Space Telescope will track these clouds and help astronomers distinguish real exoplanets from collision debris in future searches. ◆

Cancer drug made tumors vanish

After decades of disappointing results, a redesigned cancer immunotherapy targeting the CD40 receptor is showing new promise. CD40 agonist antibodies once produced strong anti-tumor effects in animals but caused serious side effects and limited benefits in people. In 2018, Jeffrey Ravetch and colleagues at Rockefeller University engineered a more potent CD40 antibody, called 2141-V11, and changed how it was delivered—injecting it directly into tumors rather than intravenously. Results from a phase 1 clinical trial, recently published in *Cancer Cell,* included 12 patients with advanced cancers such as melanoma, breast cancer, and renal cell carcinoma. Tumors shrank in six patients, and in two cases the cancer disappeared completely. Notably, tumors that were not injected also regressed, showing a rare systemic immune response. None of the patients experienced the severe toxic side effects seen with earlier CD40 drugs. Analysis revealed that treated tumors became filled with immune cells forming structures similar to lymph nodes, known as tertiary lymphoid structures, which are linked to better immunotherapy outcomes. Larger trials are now underway to identify which patients benefit most and how to expand responses. ◆

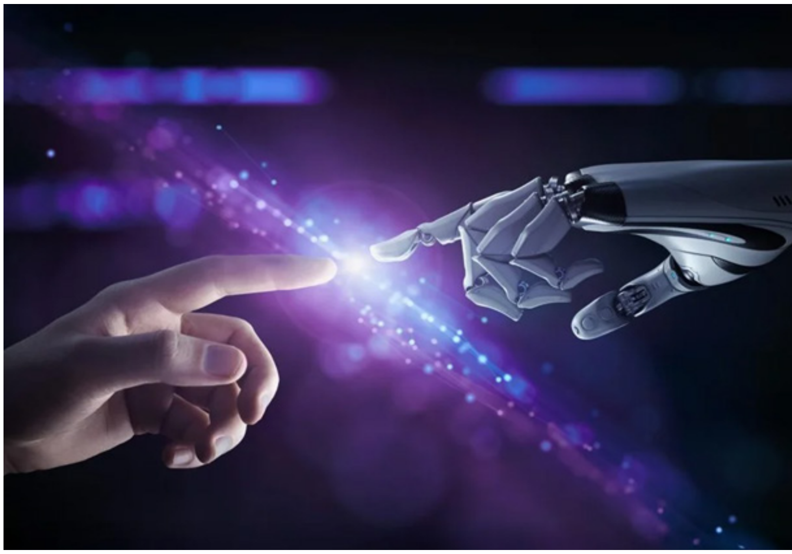


Wildfire smoke may be dangerous

Scientists have found that pollution from wildland fires may be far greater than previously estimated. A new study in *Environmental Science & Technology* shows that wildfires and prescribed burns worldwide emit about 21% more organic gases than earlier calculations suggested. These findings highlight an overlooked source of air pollution that can affect human health, air quality, and climate. When vegetation burns, it releases a mix of gases and particles, including volatile organic compounds (VOCs). The study emphasizes the importance of intermediate- and semi-volatile organic compounds (IVOCs and SVOCs), which are harder to measure and often ignored. These compounds can more easily form fine particles in the atmosphere, making them especially harmful to breathe in. Researchers analyzed global fire data from 1997 to 2023 and combined real-world measurements with laboratory experiments to estimate emissions from different vegetation types. They found that wildland fires release an average of 143 million tons of organic compounds into the air each year. Although human activities still produce more pollution overall, fires emit similar amounts of IVOCs and SVOCs. Regions such as Equatorial Asia, Northern Hemisphere Africa, and Southeast Asia face overlapping pollution from fires and human sources, creating complex air quality challenges. ◆

Myth that AI stifles human creativity

Researchers at Swansea University have found that artificial intelligence can enhance human creativity rather than simply automate work. In a large online study involving more than 800 participants, people used an AI-powered design system to create virtual car models. Instead of quietly optimizing designs behind the scenes, the system presented users with a wide and deliberately diverse range of options—from highly effective designs to unusual and even flawed ones. The study showed that this approach encouraged deeper engagement. Participants spent more time designing, felt more involved, and ultimately produced better results. Lead researcher Dr. Sean Walton explained that AI worked best as a creative partner, inspiring exploration and collaboration rather than just efficiency. Published in *ACM Transactions on Interactive Intelligent Systems,* the research also challenges how AI tools are evaluated. Simple metrics like clicks or copied suggestions miss important emotional and cognitive effects. The team argues for broader evaluation methods that consider how AI influences thinking, motivation, and creativity. As AI becomes more common in creative fields, the findings suggest its greatest value may lie in helping people explore ideas, take risks, and think differently. ◆



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SMART MOBILITY

The changing face of Intelligent Transport Systems

Akhilesh Srivastava & Shiv Kumar

Transportation has always shaped how societies function. It determines how people commute to work, how students reach schools, how goods travel to markets, and how cities breathe, move, and grow. For centuries, mobility has evolved—from animal-drawn carts to steam engines, from early automobiles to modern aviation. Yet today, the world stands at one of the greatest transformations in mobility history. This transformation is known as smart mobility, and it is quietly redefining how humanity thinks about movement, cities, the environment, and the quality of life.

Smart mobility is not simply an upgraded transportation system, and it is certainly not limited to electric cars or digital apps. It is a deeply scientific, technology-driven, human-centered approach to transportation that uses innovation, data analytics, engineering, behavioral science, and urban planning to create transport systems that are efficient, safe, sustainable, and inclusive. Instead of asking, "How do we move faster?" smart mobility asks a more meaningful question: "How do we move better?"

The need for smart mobility is rooted in the realities of our world today. Cities battle traffic congestion, costing billions in lost productivity and millions of lives in stress and frustration. Road accidents remain among the leading causes of death globally. Urban pollution chokes cities, and transportation contributes significantly to greenhouse gas emissions. Rapid urbanization is pushing millions more into city ecosystems that were never designed to carry such load. Fuel dependency continues to burden economies and geopolitics. Clearly, traditional systems of movement cannot sustain the future. Something smarter is essential. That "something smarter" lies in the science and technology behind smart mobility, strengthened by powerful real-world transformations already underway.

At the heart of smart mobility is data and artificial intelligence. Every movement—of a bus, car, cyclist, or pedestrian—creates information. Cities like Singapore have turned this data into intelligence. Singapore's Land Transport Authority uses AI-powered traffic monitoring, adaptive traffic signals, and predictive modeling to manage roads efficiently. This helps cut congestion, reduce waiting times, and create one of the smoothest public mobility systems in the world. Helsinki in Finland uses similar predictive analytics to design policies, aiming to eliminate the need for private car ownership altogether. Engineering science drives the next pillar: smarter vehicles. Consider Norway, where electric vehicles have transformed everyday mobility. Today, the majority of new cars purchased there are electric, thanks to battery technology advancements, supportive policies, and infrastructure. In China, cities like Shenzhen run almost (continued on page 10)

History of Electric Vehicles

Electric vehicles (EVs) are often thought of as a modern innovation—but their story stretches back more than a century. From early battery experiments to today's global boom in EV adoption, this evolution reveals how technology, economics, environmental priorities, and consumer demand intersect to shape transport history.

Electric vehicle development began in the 19th century with pioneers experimenting in batteries and motors. Early innovators developed functional electric carriages by the 1890s, and for a brief period around the turn of the 20th century, EVs competed closely with steam and gasoline cars in many cities due to their quiet operation and ease of use.

In fact, in the early 1900s, more than **one-third of automobiles on U.S. roads were electric** before gasoline models became dominant due to cheaper fuel and improved engines.

Although EVs almost vanished in the mid-20th century, they came roaring back in the 1990s and especially in the 21st century as battery technology improved and climate change became a global priority. The introduction of lithium-ion batteries and pioneering models like the Tesla Roadster helped launch a new era of practical, desirable electric cars.

Today, EVs are no longer niche alternatives— they are becoming mainstream. Recent data show:

Global EV Sales Growth (2024–2025)

Metric	Value
Total EVs sold worldwide (2024)	**17 million+ vehicles**
% of new car sales that were EVs (2024)	**20–22%**
% of new car sales that are EVs (2025)	**25%+**
Estimated global EV market size (2025)	**USD 892.6 billion**
Projected global EV market (2032)	**USD 2.13 trillion**

These figures show how quickly EV adoption is accelerating worldwide—from a small share of new sales just a decade ago to a significant portion today.

EV adoption varies by country, but the overall trend is clear: EVs are rapidly gaining ground.

Here's a snapshot of EV adoption rates in key markets:

Country/Region	EV Adoption (% of New Cars)
Norway	**~80%+**
China	**~50%** (2024)
Global average	**20–25% (2024–25)**

Notably, China alone accounts for a **majority of global EV sales,** reflecting aggressive electrification policies and strong manufacturing capacity.

Global	EV Sales Share (2025)
China:	56.5%
Europe:	20.1%
USA:	10.2%
Rest of World:	13.2%

India's EV story is gaining momentum, especially in the past few years. While adoption is not yet as high as in China or Europe, India's growth is notable—especially given its large population and transportation needs.

Key India EV Data (2024–2025)

Statistic	India EV Market
FY2024–25 EV sales	**~1.97 million** vehicles
EV market penetration (2024–25)	**~7.5% of total vehicle sales**
India cumulative EV sales (end of FY2025)	**~6.16 million** units
Growth in passenger EV sales (Oct 2025)	**57% YoY increase**
EV two-wheelers market share	**~6.2% of all 2W sales**

These figures show that although EVs are still emerging in India, the adoption trajectory is strong—with significant growth in two-wheelers, three-wheelers, and electric passenger vehicles.

Global vs. India EV Adoption

Global EV Adoption Over Time
2019: ~9% of new car sales
2024: ~20–22% of new car sales
2025: ~25%+ of new car sales
(Trend: Strong upward global adoption)

India EV Adoption (2024–25)
~7.5% of total vehicle sales
Rapid growth in 2W EV segment
Increasing passenger EV registrations
(Trend: Growing but emerging)

The data clearly show that electric vehicles have moved from niche to mainstream in just a few years. Where EVs once accounted for a tiny fraction of auto sales, they now comprise a **significant share—more than one in four new cars globally.** In India, although EV adoption is at an earlier stage, growth rates are strong and supported by policy pushes, infrastructure expansion, and rising consumer interest.

The history of electric vehicles is not only a story of technological progress—it's a global transformation in how humanity moves. From early battery experiments to today's rapid adoption, EVs are reshaping automotive markets, energy systems, and environmental strategies around the world.

Smart Mobility in India: some thoughts

India is experiencing rapid urbanization, rising vehicle ownership, traffic congestion, pollution, high accident rates, and growing energy demand. Traditional transportation systems are insufficient for future needs. Smart mobility—integrating technology, public transport modernization, electric mobility, intelligent systems, and urban planning—offers a transformative pathway for sustainable growth, economic efficiency, and improved quality of life.

National Policy Foundation

- **National Electric Mobility Mission Plan (NEMMP)**
- **FAME I & II (Faster Adoption & Manufacturing of Electric Vehicles)**
- **National Urban Transport Policy**
- **Smart Cities Mission**
- **National Parking Policy Draft**
- **National Digital Mobility Mission (emerging initiatives)**

These frameworks collectively promote EV adoption, intelligent transport systems, clean mobility, sustainable urban design, and digital integration.

Key Smart Mobility Pillars in India

1. Electric Mobility Transition

- FAME-II incentives for EVs and buses
- Large deployment of electric buses across states
- Growth in electric 2-wheelers and 3-wheelers
- Expansion of charging infrastructure

Policy Impact

- Reduced emissions
- Lower energy imports
- Economic stimulus for EV manufacturing
- Cost advantage for citizens over time

2. Metro Rail & Mass Rapid Transit

- Operational metros in Delhi, Mumbai, Bengaluru, Hyderabad, Chennai, Pune, Kochi and more
- Modern ticketing systems, integration, and expansions

Policy Impact

- Reduced road congestion
- Efficient mass transit backbone
- Cleaner urban environments

3. Intelligent Transport Systems (ITS)

- AI-enabled adaptive traffic lights
- CCTV and automated violation monitoring
- Electronic tolling (FASTag)
- Highway Automated Traffic Management Systems

Policy Impact

- Improved traffic efficiency
- Reduced human bias and corruption
- Better law enforcement and safety

4. Shared & Digital Mobility

- Ride-sharing platforms: Ola, Uber, Rapido
- Dockless bikes and e-scooters: Yulu, Bounce
- Integrated digital platforms for ticketing and travel planning

Policy Impact

- Reduced private vehicle dependence
- Improved last-mile connectivity
- Affordable mobility access

5. Smart City Mobility Innovations

- Integrated Command & Control Centres (ICCCs)
- Smart parking systems
- Bicycle lanes & pedestrian reforms
- Award-winning examples: Kochi, Indore, Surat

Policy Impact

- People-centric urban transport
- Enhanced safety & convenience

6. Bus Rapid Transit Systems (BRTS)

- Successful implementations in Ahmedabad, Indore, Surat, Pune, Rajkot

Policy Impact

- Affordable mass transport
- Lower city congestion

entirely electric public bus fleets, significantly reducing emissions and improving air quality. London has introduced electric taxis and Ultra-Low Emission Zones that encourage cleaner transportation choices. These examples show that electric mobility is no longer an experiment but a reality shaping the planet's future.

Communication technology makes mobility truly intelligent. Japan and South Korea are pioneering **Vehicle-to-Everything** (**V2X**) communication technology where cars communicate with other vehicles, road infrastructure, and traffic control centers. In the United States, pilot smart-highway projects enable connected vehicles to receive warnings about potential collisions, black ice, or sudden braking ahead. These advances reduce human error and pave the way for autonomous vehicles, shifting mobility from human reaction to intelligent anticipation.

Then comes Intelligent Transport Systems (ITS), the silent brain behind smart mobility. A striking example exists in **Barcelona,** where smart traffic lights, real-time passenger information systems, electronic parking guidance, and central control centers make transportation highly efficient. Copenhagen uses similar systems along with cycle-priority signaling, making it

7. Logistics & Freight Modernization

- GPS truck monitoring
- Dedicated Freight Corridors
- Port digitalization

Policy Impact

- Lower logistics cost
- Greater national competitiveness

Challenges & Concerns

- High infrastructure investment requirements
- Uneven adoption across states
- Charging infrastructure gaps
- Behavioral resistance to public/ shared transport
- Cybersecurity and data privacy risks
- Need for skilled workforce and maintenance support
- Rural–urban mobility disparity

Recommendations

A. Strengthen EV Ecosystem

- Expand national charging network, including rural corridors
- Encourage battery recycling and local manufacturing
- Promote EV financing support mechanisms
- Incentivize public transport electrification

B. Enhance Public Transport Integration

- National Mobility Card implementation across states
- Unified mobility platforms (Mobility-as-a-Service)
- First and last-mile connectivity funding

C. Scale Intelligent Transport Systems

- Nationwide ITS standards and deployment roadmap
- Data-sharing protocols between states and agencies
- Mandate ITS for Tier-1 and Tier-2 cities

D. Citizen-Centric Urban Mobility Reform

- Prioritize walking and cycling in planning
- Introduce congestion pricing where applicable
- Promote smart parking policies
- Inclusive mobility for elderly and differently-abled

E. Governance, Skills & Innovation

- Dedicated National Smart Mobility Mission Authority

- Industry–academia–startup innovation partnerships
- Mobility workforce training programs
- Indigenous technology development under “Make in India”

Suggested Implementation Roadmap

Short Term (1–3 Years)

- Accelerate EV incentives
- Deploy ITS in key metros
- Expand electric buses
- Build charging corridors

Medium Term (3–7 Years)

- Pan-India smart city mobility integration
- Widespread metro and BRT expansion
- Unified digital mobility platforms
- Strong cybersecurity frameworks

Long Term (7–15 Years)

- Autonomous mobility readiness
- Full smart city mobility ecosystems
- Carbon-neutral transport networks

Stakeholders

- Government of India (MoRTH, Urban Affairs, Power, Heavy Industries)
- State & Municipal Corporations
- Metro & Transport Authorities
- Startups & Private Sector
- Academia & Research Institutions
- Citizens & Civil Society

Smart mobility is not only India’s transportation strategy—it is India’s development strategy.

one of the world’s leading cycling cities. Meanwhile, London’s Oyster card system and Singapore’s unified mobility payment platforms demonstrate how integrated ticketing and transport networks change the everyday travel experience.

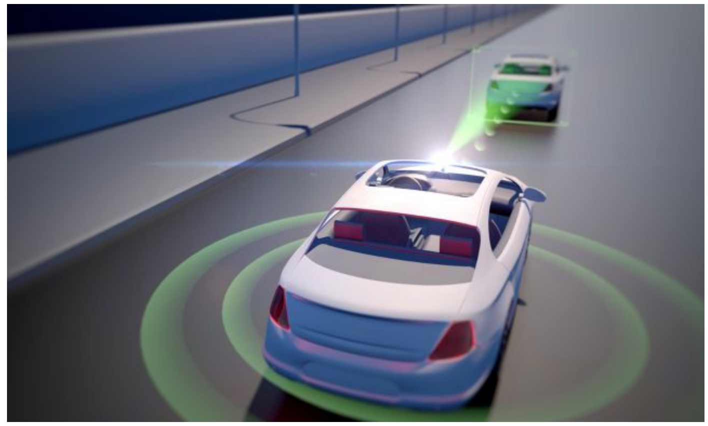
Public transportation modernization forms the backbone of this revolution. **Tokyo** operates one of the world’s most punctual metro systems, supported by precise scheduling technology, predictive maintenance, and human discipline. **Dubai** uses AI to optimize bus routing while maintaining one of the most advanced metro systems, largely automated. In **India,** cities like Delhi, Bangalore, and Mumbai increasingly deploy GPS-enabled buses, contactless ticketing, Metro networks, and integrated transport apps that help passengers track real-time movement. The Delhi Metro’s introduction of Women-Only coaches, information systems, and structured travel environments shows how human sensitivity meets technology in smart mobility.

Energy science supports smart mobility’s sustainability mission. The Dutch city of **Amsterdam** has created widespread EV charging infrastructure and renewable-powered mobility systems. In the United

ITS INDIA FORUM

Think Tank on Intelligent Transportation System

https://itsindiaforum.com/



India today stands on the brink of a remarkable mobility transformation. As our cities expand, our roads stretch further, and the movement of people and goods grows more complex, the nation faces a defining question: how do we build transportation systems that are not only larger, but smarter? This is where the story of **ITS India Forum** begins—an organization that has emerged as a national thought leader, guiding India toward an intelligent, technology-driven mobility future.

ITS India Forum is more than an institution; it is a collaborative force. It brings policymakers, government authorities, scientists, industry innovators, technology leaders, researchers, and transport professionals onto a single platform, united by a shared mission: to shape a future in which mobility is safer, more efficient, environmentally responsible, and deeply people-centric. In a country as vast and diverse as India, that mission is both ambitious and essential.

At its core, the Forum believes that transportation is not merely about moving vehicles; it is about empowering lives, strengthening economies, connecting communities, and safeguarding the planet. Intelligent Transport Systems—data-driven, digitally enabled mobility technologies—lie at the heart of this effort. Whether it is reducing congestion on crowded roads, improving traffic discipline, enhancing commuter comfort, enabling seamless public transport, or promoting clean mobility, the Forum works to ensure that innovation meets real-world needs.

What makes ITS India Forum truly impactful is its ability to bridge thought and action. It works closely with national ministries, state authorities, city governments, and industry partners to shape policy frameworks and technology standards that can support India's evolving mobility ecosystem. Through national conferences, expert roundtables, technical dialogues, and capacity-building initiatives, the Forum nurtures informed decision-making and builds the skills needed to deploy smart mobility at scale. Discussions on AI-enabled traffic management, digital tolling, connected vehicles, road safety innovations, logistics optimization, and smart infrastructure are not just academic exercises—they become actionable roadmaps for India's future.

India's smart mobility journey is also deeply connected with global innovation, and here too, ITS India Forum plays a crucial role. Its induction into the prestigious **ITS Asia-Pacific community** marks a milestone, placing India alongside leading nations shaping the next generation of mobility technologies. Through participation in international platforms such as the ITS World Congress, the Forum ensures that India's perspectives, innovations, and challenges contribute meaningfully to global mobility discourse. At the same time, it brings international best practices back home, adapting them to India's unique social, technological, and infrastructural realities.

Science and research are integral to the Forum's identity. By collaborating with premier national research institutions, it strengthens India's capabilities in emerging areas such as AI-based transport analytics, connected and autonomous mobility ecosystems, enforcement and safety technologies, and digital transport infrastructure. These partnerships help transform scientific insight into practical solutions, ensuring that innovation does not remain locked in laboratories but translates into safer streets, smarter cities, and better mobility experiences for citizens.

The importance of ITS India Forum becomes even clearer when viewed through the lens of India's long-term aspirations. As the nation advances toward Viksit Bharat 2047, mobility will determine how efficiently our economy grows, how sustainably our cities evolve, and how equitably opportunities reach every citizen. Intelligent transportation is not just a technological agenda—it is a developmental imperative. By guiding policy, enabling collaboration, nurturing innovation, and aligning India with global thought leadership, ITS India Forum is helping build the backbone of that future.

States, Tesla's Supercharger network and energy storage innovations support long-distance electric travel. Meanwhile, Japan's experimentation with hydrogen fuel-cell vehicles, especially in Tokyo, adds another scientific dimension to mobility's future energy story.

Cybersecurity and safety science remain essential. As transport becomes digital, countries like Israel have become global research centers in automotive cybersecurity. Their systems help prevent hacking of connected cars and ensure transport networks stay secure.

However, smart mobility is not purely about technology. It is also about planning cities more intelligently. **Vienna** and **Copenhagen** redesigned urban spaces to prioritize cycling and walking, making their cities healthier and more livable. **Bogotá** transformed travel culture with extensive bus rapid transit (BRT) lanes, providing affordable, fast urban travel. Behavioral science supports these shifts by studying why people prefer private vehicles and how to encourage eco-friendly habits through incentives, awareness, and better user experience.

One of the most compelling real-world stories of smart mobility lies in healthcare and emergency response. Cities such as **Bangalore** and **Chennai** in India experiment with "Green Corridors" for ambulances, where smart coordination clears traffic lights along emergency routes. This integration of data, traffic control, and human intent has saved countless lives. Similar ideas operate in London and Singapore, showcasing the humanitarian dimension of mobility technology.

Environmental science remains the heart of smart mobility. Cities like Paris and Madrid now restrict high-pollution vehicles from entering central areas. China has aggressively deployed electric two-wheelers and buses to combat pollution. In India, electric rickshaws and urban e-buses are gradually redefining public mobility, especially in Delhi and Kolkata. These developments are not just technological—they are public health investments.

Despite immense promise, challenges remain. Technology requires investment. Developing nations face budget limitations. Cybersecurity and data privacy demand constant vigilance. Infrastructure rollout takes time. Workforce training and public adaptability are essential. Yet, with determined leadership, innovation, and global collaboration, these challenges are being steadily addressed.

Even with these hurdles, there is no doubt where the world is headed. Artificial intelligence continues to advance. Batteries are becoming lighter, cheaper,

and more powerful. Communication systems grow faster. Renewable energy adoption increases. Cities are redesigning themselves with sustainability in mind. Smart mobility will only grow stronger.

Ultimately, smart mobility is not just about cars, buses, or infrastructure. It is about improving human lives. It is about reclaiming hours lost in traffic. It is about ensuring a child breathes cleaner air on their way to school. It is about safer roads, dignified travel, and equitable access to movement. It is about a world where mobility does not damage the planet, but harmonizes with it.

Smart mobility is not only a technological revolution—it is a social, scientific, and ethical evolution. It transforms transportation from chaos into intelligence, from pollution into sustainability, from isolation into connection. It builds cities that breathe easier, societies that move efficiently, and futures that are cleaner, safer, and beautifully interconnected.

In the simplest words, smart mobility is not just about moving faster—**it is about moving smarter, living better, and building a future where transportation serves humanity, not the other way around.**

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Women Nobel Laureate for Medicine 2009

Elizabeth Blackburn

From "Lab Rat" to Trailblazing Scientist

Elizabeth Blackburn's scientific journey reads like a portrait of curiosity made discipline: a childhood fascination with the natural world that matured into a lifetime of careful, often revolutionary, laboratory work. Born in Tasmania in 1948 to a family of doctors, Blackburn was the second of seven children and spent her early years enchanted by the small lives on the seashore—jellyfish, tadpoles and other miniature wonders that fed a childhood appetite for observation. While other children filled their bedrooms with posters of sports stars or movie icons, she filled hers with drawings of amino acids and re-read the biography of Marie Curie until it became part of her inner map of what a life in science might mean.

That map took her from the University of Melbourne, where she trained in biochemistry, to the Laboratory of Molecular Biology (LMB) in Cambridge—then the beating heart of molecular biology. Blackburn has often described her LMB years as "complete immersion." Under the guidance of luminaries such as Fred Sanger, she learned the exacting craft of DNA sequencing and inherited a professional ethic that prized methodological rigor above all. It was also in Cambridge that her personal and scientific lives intertwined: she met John Sedat, with whom she would later move to the United States and continue her research.

At Yale, in the laboratory of Joseph Gall, Blackburn found the ideal experimental organism for a daring question. She began to study *Tetrahymena,* a single-celled organism with many linear chromosomes—a biological advantage when hunting for the short repeated sequences that cap chromosome ends. These caps, later known as telomeres, had been proposed but not fully understood. Blackburn's meticulous sequencing work revealed that telomeres consist of short, repeated motifs of DNA—a discovery that reframed how scientists thought about chromosome stability.

The next conceptual leap required an explanation for how telomeres were maintained. As cells divide, the copying machinery cannot fully replicate the ends of linear chromosomes, so a gradual shortening should logically occur; unchecked, that shortening would eventually erode essential genetic information. Blackburn, then at Berkeley, and her collaborator Jack Szostak reasoned that an enzyme must exist to rebuild telomeric sequences. In 1984, with her graduate student Carol Greider, Blackburn co-discovered **telomerase,** an enzyme that extends telomeres and thus allows cells to divide without losing critical genetic material. This was a seminal finding: telomerase explained how cells maintain genomic integrity across countless divisions and suggested mechanisms by which cellular aging and unchecked proliferation (as in cancer) might arise.

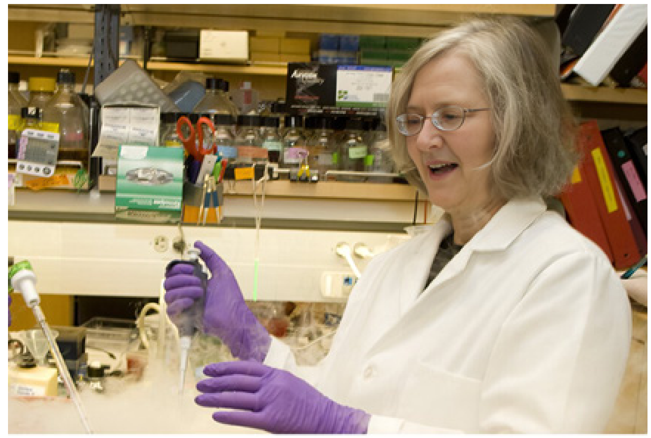
Telomeres, Blackburn later explained in accessible metaphors, act like the plastic tips on shoelaces: they prevent chromosome ends from fraying and protect the integrity of the genome. Telomerase is the repair crew that replenishes those tips. Together, these discoveries formed a conceptual framework with extraordinary reach. If telomerase activity can prevent telomere shortening, could it be harnessed to stave off degenerative conditions? Conversely, if telomerase activity becomes unregulated, might that promote cancer by enabling limitless cell division? Blackburn's laboratory probed precisely those dualities: the enzyme is both a guardian and, in certain contexts, an accomplice to disease.

In 1990 Blackburn moved her lab to the University of California, San Francisco (UCSF), where she and her team explored the molecular choreography of telomere maintenance—how protein and RNA components of telomerase unite, how they are regulated, and how balance is struck in healthy cells. Her work there blended rigorous molecular biology with a growing interest in the broader determinants of health. Blackburn did not remain confined to the petri dish; she reached across disciplines, asking what her cellular discoveries might mean for human lives shaped by stress, caregiving, trauma, and social circumstance.

This interdisciplinary turn is perhaps what most distinguishes Blackburn's later career. In collaboration with psychologist Elissa Epel and others, Blackburn began to measure telomere length in humans under different life circumstances. Their work on mothers caring for chronically ill children, spouses of dementia patients, and people exposed to early-life trauma revealed a troubling pattern: **chronic stress correlated with shorter telomeres.** The implication was powerful and unsettling—that life experience, especially persistent psychosocial stress, could imprint itself on biology in ways that accelerate cellular ageing.

Such findings shifted the conversation from molecules to morals. If telomere length is shaped in part by life circumstances, then public policy, social support, and community structures become part of the equation for health and longevity. Blackburn became an advocate for evidence-based thinking that spans laboratory science and public health interventions. Yet she remained an unrepentant empiricist: "You have to get the science right," she has insisted, cautious about overclaiming and keen to see hypotheses withstand rigorous testing.

Blackburn's research offered hope as well as caution. The telomere-telomerase axis provided a promising target in oncology: inhibiting telomerase in tumour cells could limit their ability to divide indefinitely. Conversely, fostering telomere maintenance in degenerative conditions might forestall cellular decline. Her questions also invited inquiry into lifestyle interventions—might exercise, improved diet, stress reduction, or meditation have measurable effects on telomere biology? Blackburn pursued these questions



Elizabeth Blackburn in her lab at the University of California, San Francisco.

with the same disciplined curiosity that marked her earliest days in the lab.

Beyond her technical accomplishments, Elizabeth Blackburn's career exemplifies a model of scientific citizenship: meticulous lab work, mentorship of students (Greider among them), and a readiness to translate molecular insights into broader social and ethical conversations. Her Nobel Prize in Physiology or Medicine in 2009, awarded for the discovery of telomerase and the role of telomeres in chromosome protection, recognised not only a breakthrough in molecular biology but a new lens through which to view ageing, disease, and human resilience.

Blackburn herself is characteristically reflective about the limits of any single discovery. "Ageing is so many different things," she has said—telomere dynamics are a part of the picture, but far from all of it. This humility underscores her broader posture toward science and society: curiosity married to caution, wonder tempered by method. Whether she is in the lab refining an assay, in a lecture hall explaining telomere dynamics to students, or in a policy forum discussing the health implications of social stress, Blackburn remains committed to one principle above all: **let the data lead the way.**

Her life—from Tamarian beaches and childhood jars of tadpoles to the halls of Cambridge, Berkeley, and UCSF—traces a path that is at once deeply personal and globally consequential. Through meticulous study of the smallest units of life, Blackburn has helped reveal a connection between circumstance and cell, between the public sphere and the private biology of ageing. In doing so, she has changed not only what scientists study but how society thinks about the relationship between our lives and our cells. ◆

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The Science of Happiness

Pushpa Singh

For centuries, happiness was mainly discussed by philosophers, spiritual thinkers, poets, and moral teachers. Today, however, happiness is also a serious subject of scientific study. Psychologists, neuroscientists, and economists now examine what happiness truly is, how it works in the brain, why some people seem happier than others, and which factors genuinely improve well-being. This growing field, often called positive psychology, shows that happiness is not simply a pleasant feeling or a privilege of the lucky. It is a measurable, observable, and deeply human condition that can be nurtured and strengthened with the right habits, environments, and relationships.

A remarkable long-term study from Harvard University followed hundreds of men for more than 80 years to find what truly leads to a happy, healthy life. Researchers expected wealth, intelligence, or status to be the strongest predictors. Instead, they discovered something profoundly human: the happiest and healthiest people were those who had strong, supportive, and trusting relationships. Across cultures and generations, research keeps returning to this essential truth—happiness is shaped not just by what we have, but by how we live, connect, think, and care.

Scientists do not treat happiness as a vague feeling. They usually define it as **subjective well-being,** which has three main components:

- frequent positive emotions such as joy, gratitude, calm, or interest
- lower levels of negative emotions like chronic anxiety or persistent sadness
- life satisfaction, meaning how people evaluate and judge their lives as a whole

This definition tells us that happiness is not about feeling good all the time. A person can experience stress or sadness and still be considered happy if they feel their life has meaning, direction, and fulfillment. Psychologists such as Ed Diener helped shape this structured understanding, moving happiness out of purely philosophical discussion into scientific measurement.

Consider two people: one lives comfortably but constantly compares themselves to others, feels dissatisfied, and complains. Another faces occasional challenges but feels grateful, engaged, and purposeful. Scientifically speaking, the second person is likely “happier,” because happiness is not only a mood; it is an overall emotional assessment of life.

Behind every joyful experience, there is a biological story unfolding in the brain. A teenage runner completing a race, a mother hugging her child, or a scientist achieving a breakthrough all experience similar processes.

Neuroscience shows that several key brain chemicals—known as neurotransmitters—play central roles in happiness:

- Dopamine helps us feel motivated and rewarded when we achieve goals
- Serotonin stabilizes mood and emotional balance
- Oxytocin strengthens trust, bonding, and connection
- Endorphins reduce pain and produce pleasure, especially during exercise

These chemicals do not activate randomly; they respond to daily behaviors. Exercise increases endorphins, meaningful conversations raise oxytocin, gratitude influences serotonin, and achieving small goals releases dopamine. Importantly, brain science shows that emotional patterns are not fixed. Through neuroplasticity, the brain can change with experience and practice. This means habits like mindfulness, gratitude, kindness, physical activity, and positive thinking can literally reshape emotional responses over time.

Many people believe some individuals are simply "born happier." Science partly agrees. Studies suggest about 40–50% of our baseline happiness is influenced by genetics—our natural emotional tendency, sometimes called the happiness "set point." Around 10% comes from life circumstances such as wealth, health, or where we live. Surprisingly, the remaining 40% is shaped by what psychologists call **intentional activities**—how we think, behave, and relate to others.

This finding is empowering. Two people may face the same hardship, yet respond differently. One may remain bitter and helpless, while another may gradually rebuild hope, seek connection, and help others. Their conditions are the same; their emotional strategies differ. Science shows that while happiness is partly influenced by birth and environment, a large portion is within our influence.

One of the most famous questions in happiness research is whether money truly makes people happier. Nobel laureate Daniel Kahneman and economist Angus Deaton found that money does improve happiness—mainly up to the point where basic needs and reasonable comfort are secured. Beyond that, emotional benefits of increasing income gradually flatten.

To understand this, imagine three families. A family struggling to afford food experiences deep stress, so extra income significantly improves their happiness. A comfortable middle-class family gains convenience but not necessarily deeper joy with more money. A wealthy family may still experience loneliness, anxiety, and emptiness despite luxury. More importantly, researchers now emphasize that how money is used may matter

even more than how much is earned. Spending on experiences, learning, contribution, and relationships often brings more lasting happiness than spending on possessions. Money can reduce suffering and improve security, but it cannot independently create meaning.

Perhaps the most powerful and consistent discovery in happiness research is that relationships matter more than almost anything else. Humans are deeply social beings. The Harvard Study of Adult Development found that warm friendships, supportive families, and healthy partnerships predict not only happiness but also physical health and longevity.

Everyday life offers countless examples. A retired teacher who spends evenings chatting with neighbors remains lively and positive. A successful executive without emotional connections may feel lonely despite achievement. Elderly individuals sharing laughter, meals, and companionship often show better health than isolated peers. On the other hand, loneliness is now widely recognized as a serious public health concern, linked to depression, weakened immunity, heart disease, and early mortality. Human beings are wired for connection, and we thrive when we belong.

Happiness is not only about pleasure—it is also about meaning. Psychologists distinguish two kinds of happiness: hedonic happiness (pleasure and comfort) and eudaimonic happiness (purpose, growth, and contribution). Research shows that long-term well-being is more closely linked to meaning than to pleasure alone. People who feel their lives have purpose—whether through work, creativity, helping others, or learning—often report deeper fulfillment and emotional strength.

Psychologist Mihaly Csikszentmihalyi introduced the concept of "flow," the state of being completely absorbed in an activity where time seems to disappear. A musician performing, a student deeply engaged in study, a sportsperson mid-game, or a researcher immersed in discovery all experience this. Flow is associated with creativity, competence, and satisfaction. It transforms effort into engagement and turns work into fulfillment.

The Happiness Index

Happiness is now measured globally through the World Happiness Report, which ranks countries not just by economic strength but by how satisfied people feel with their lives. The index considers factors such as income, social support, life expectancy, freedom to make life choices, trust in government and institutions, and generosity. Interestingly, the countries that frequently rank highest—such as Finland, Denmark, and Iceland—are not always the richest in the world, but they emphasize social equality, strong welfare systems, trust, and community well-being.

For many developing and emerging nations, including India and others, the Happiness Index reveals both strengths and challenges. While strong family bonds, cultural richness, and resilience contribute positively, issues like inequality, stress, urbanization pressures, and limited access to mental health support can pull scores downward. The index serves as an important reminder that happiness is both a personal experience and a societal responsibility. Policies, communities, and collective systems play just as important a role as individual choices. Encouragingly, more countries are now beginning to treat happiness and well-being as serious development goals alongside economic growth.

Scientific evidence strongly suggests that happiness is not fixed—it can be developed like a skill. Research identifies several practices that reliably enhance well-being: regular exercise improves mood and brain chemistry; good sleep stabilizes emotional regulation; mindfulness and meditation reduce anxiety and improve clarity; gratitude practices increase positive emotion and life satisfaction; kindness strengthens bonds and emotional warmth; and positive thinking strategies help people respond better to challenges.

These are not superficial techniques. They work because they shape brain chemistry, thinking patterns, and social connection. Countless personal stories show that small changes can transform emotional lives—a person who begins gratitude journaling feels calmer, a lonely individual joining a community group rediscovers

belonging, a stressed employee starting morning walks feels lighter and energized.

Across countries, ages, and generations, research leads to a deeply human truth: happiness is neither accidental nor a luxury reserved for a few. It is shaped by biology, relationships, habits, environment, purpose, and perspective. We cannot control everything life brings, but we can build emotional foundations that help us live well.

Happiness is not something we simply wait for. It is something we cultivate—through love, meaning, connection, gratitude, courage, and conscious living. ◆

Key Research and Foundational Studies

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Bio Tribology

Kamal Mukherjee

Initial application of tribology was on metals and their lubrication, automotive & other industries. Later on, it has manifested towards every aspect of the society & continuous research into field has led new areas on human such as dental science, ocular science, heart valves, orthopaedics, sports and many more, where knowledge of tribology is utilized to create new breakthroughs—bio tribology.

Biomedical (Bio-tribology)

The application of tribology in biological systems is a rapidly growing field and extends well beyond the conventional boundaries. Biomedical tribological systems involve an extensive range of synthetic materials and natural tissues, including cartilage, blood vessels, heart, tendons, ligaments, and skin (Fig.-1). These materials operate in complex interactive biological environments.

Bio-tribologists incorporate concepts of friction, wear, and lubrication on the design of joints and prosthetic devices, the wear of screws and plates in bone fracture repair, wear of denture and restorative materials, wear of replacement heart valves, and even the tribology of contact lenses for eyes.

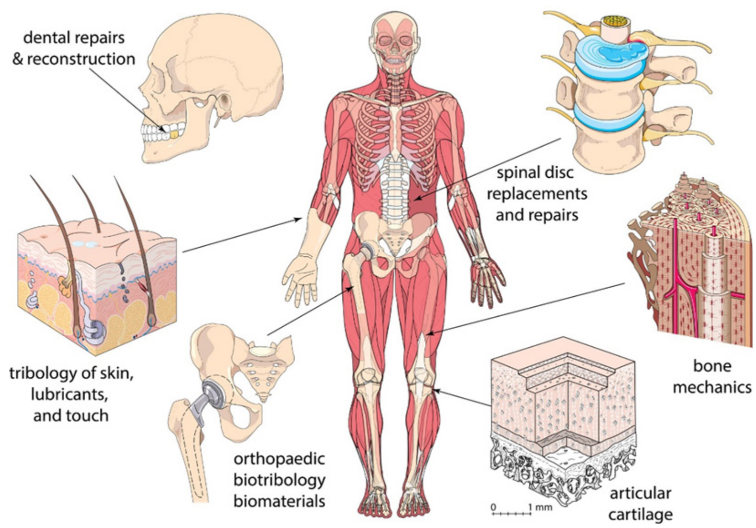
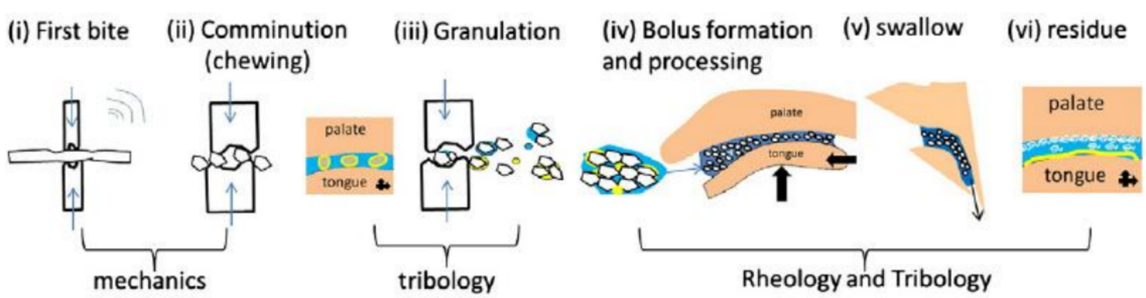


Fig.-1: Human related tribology

Oral/food tribology

The food which enters in the mouth is subjected to a series of mechanical processes by the lips, tongue, teeth and palate in order to facilitate digestion. Different types of feeling due to different size, shape etc. of food & its various process are shown in Fig-2. Thus, oral processing of food is a dynamic multistage process consisting of complex stages of biting, chewing, saliva incorporation, bolus formation, swallowing, and mouth coating.



Crispy	Crunchy	Rough	Sticky	Smooth	Firmness	Creaminess	Fattiness	Astringency

Fig-2: Visualisation of the six stages Stoke et al proposed occur during oral processing of solid food (ref. Fig 3. from Stokes et al. (2013))

Many macroscale pits and grooves are present in the tongue surface & they contain your taste buds, the things that help you taste everything from sour lemons to sweet peaches. The friction properties depend on many factors including the lubrication properties of saliva, the oral surfaces involved (which differ between individuals depending on age, sex, health etc.) and the food itself.

Role of tribology in food products

a) General problem related to soft drinks: Consumers generally prefer regular (sugary) soft drinks over diet (sugar free) soft drinks. Diet drinks are a healthier option than regular drinks but consumers often complain about the taste difference. This is achieved by two ways e.g. changing food texture and mouthfeel which are of huge interest to food tribologists; **b) Dairy products:** Ice-creams, milk bars with higher milk content will have higher lubrication effect and are soft and smooth. Ice-creams, milk bars with 50 percent milk content will have higher friction coefficient but using tribological and rheological solutions, the friction values are reduced to products containing 80 percent and 100 percent milk. The research is further extended to sports drinks and fruit juices.

So, tribology of real food samples is not to replace sensory analysis in food industries, but it helps to navigate product development in the right direction.

Tribology uses in cardiovascular devices

Stents and grafts: These are used either to correct by strengthening it or bypass a blockage or defect entirely by creating an alternate (new) pathway for your blood to flow through (Fig.-3, a & b).

1) Stents are cylindrical metallic frames (more of a coil) to strengthen it from clogging which are expanded at high pressure inside a blood artery to keep the passageway open.
2) Grafts are tubes that are shaped like blood vessels, used as a bypass path to the blockage—to make a continuity of blood flow.

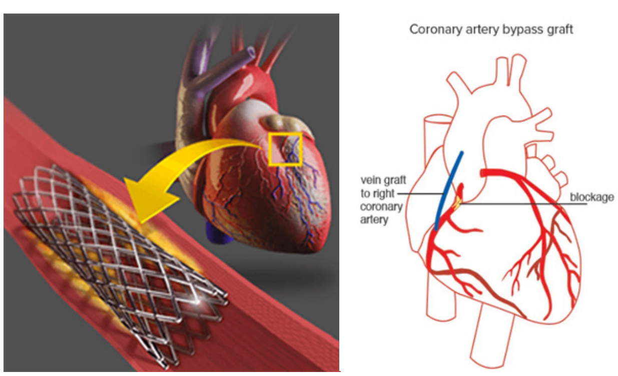


Fig-3: (a) Stent; (b) Coronary artery bypass graft surgery (CABG) is done mainly to relieve angina symptoms.

The material used for stents and grafts have low friction, wear and low corrosion characteristics as they are in continuous contact with the soft tissues in the region and the endothelial cell layer of the heart. Nitinol which is a Nickel Titanium alloys are generally used to manufacture stents. Characteristics such as super-elasticity, shape memory effect, corrosion resistant, low friction & wear makes it a prime choice. Stents are also coated with biocompatible coatings or polymer-free coatings which help achieve low friction & wear. UHMWPE (Ultra high molecular weight polyethylene) and ePTFE (Expanded PTFE) are the most preferred graft materials as both have low coefficient of friction and anti-wear capabilities.

Artificial heart valves: It is a device implanted in the heart of a patient to replace a malfunctioning natural valve. Mechanical heart valves (MHV) are commonly used as artificial heart valves. The material used for manufacturing of MHVs are strong, durable, low friction & wear resistant. Pyrolytic Carbon or PyC is a fatigue resistant, biocompatible, durable material which is normally used for manufacturing MHVs. Biocompatibility and excellent tribological properties of Diamond-like carbon DLC coating provide long durability to MHV's material.

Tribology of hair

Tribology is applicable to our own hairs where friction, wear and lubrication persist. The hair care product industry focuses on characterization of friction and wear properties of hair and their lubrication so that a high-quality product such as shampoo, conditioner, hair lotion, hair spray are developed.

The hair shaft consists of: **a) Cuticle:** it's the outermost layer of the hair and is responsible for creating the shine and smoothness, **b) Cortex:** It's the middle layer of the hair and contains melanin pigment responsible for providing elasticity and natural colour & **c) Medulla:** It's the innermost layer and is not involved in salon services (Fig-4).

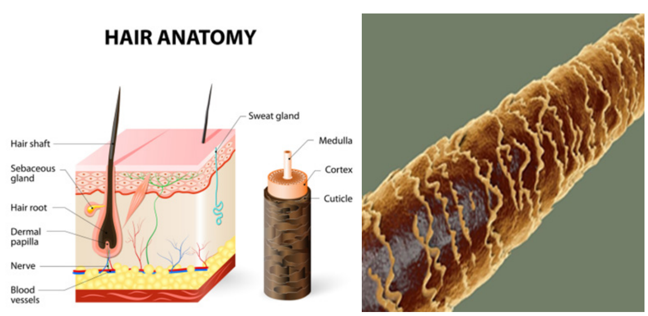


Fig.-4: Topology of hair

Let's talk about the three main processes present in hair:

- **Friction:** Processes like combing of hairs via thin spaced comb or plastic comb and environmental conditions like dust, dirt, humidity, sweat also contribute towards friction between hairs.
- **Wear:** Processes like blow-drying, excessive rubbing for drying it after taking bath, chemical hair dyes, hair colorants and hair straighteners leads to hair damage or wear of hairs.
- **Lubrication:** Hair shampoos and conditioners provide cleaning and lubricating functions.

Tribology of hair conditioners

Having healthy hair means having a smooth and unbroken outer layer called the cuticle, which protects the hair. This smoothness comes from a natural fatty acid layer on the cuticle's surface (Fig.-5).

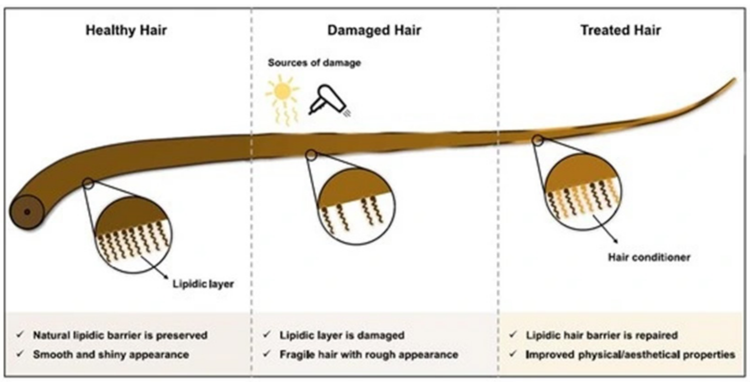


Fig.-5: Schematic representation of healthy, damaged and treated hair

Since hair is made up of cells that cannot repair themselves, people use hair conditioners to temporarily fix the cuticle by adding special molecules. Surfactants have multiple roles, such as being emulsifiers, wetting agents, foaming agents, and dispersants. Simply put, a surfactant is a molecule that has a water-loving part and a water-repelling part. To address the environmental concern, there is a push to enhance the biodegradability of conditioner ingredients. Bio-ingredients sourced from renewable, plant-based origins, such as biosurfactants and amino acid-based surfactants (AAS), offer a promising solution due to their biocompatibility and biodegradability. Cationic AAS, synthesized from natural amino acids, particularly stand out for their positive impact on hair.

Role of Tribology in hair: Particularly for rinse-off hair conditioners, the ultimate goal is to offer maximum wet lubrication by significantly reducing the coefficient of friction and enhance hair lubricity.

Dental tribology

The current world population is undergoing a transition towards becoming a geriatric society. According to the World Population Prospects 2019, the data suggest that the percentage of people aged 65 and over would rise from 1 in 11 in 2019 to 1 in 6 by 2050 (Lee, H., et al 2022) The tooth loss is the common feature of oral health among the elderly. Dental implants have the benefits over natural teeth e.g. safety & preservation of adjacent teeth and bones, improved speech and chewing, enhanced oral health and better quality of life. Typical materials used for dental implants are metal alloys, including stainless steel, cobalt–chromium alloy, and titanium-based alloy etc. Titanium alloys are mostly preferred implants due to their ability to strike a balance between mechanical performance and biological compatibility, ensuring the success and longevity of medical implants. The success rate of titanium dental implant surgery can exceed 90%, however, there is still a failure probability of approximately 10%. In order to reduce the failure rate, implant surface treatments play a crucial role in enhancing the healing process following implant placement, which is called "**osseointegration**" (Fig.-6). Osseointegration is defined as the direct structural and functional connection between the living bone and the surface of a load-bearing implant. Some of the latest surface modification techniques for dental implants on osteoblast and bone formation are—Titanium, Dental implants, Osteoblast, Anodization, Sandblasting, Acid etching, Laser radiation, HA coating, Chitosan etc.

In healthcare, nano-coatings serve as essential anti-bacterial agents to prevent infections & possess anti-abrasive qualities, providing strength to materials in scenarios where lubricants are not employed.

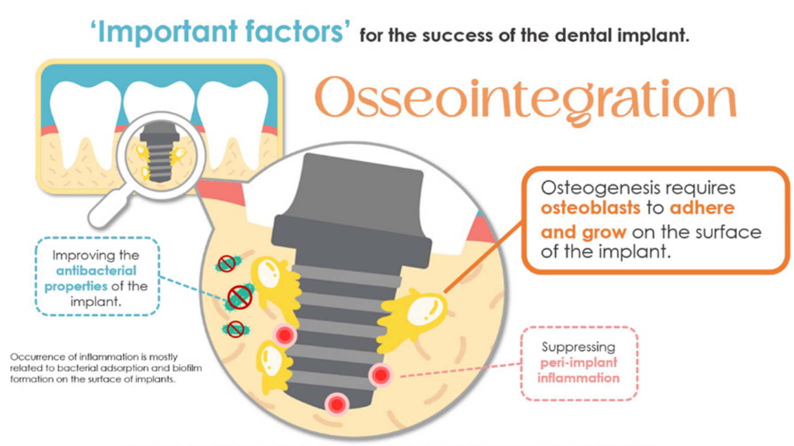


Fig.-6: Important factors for the successful osseointegration following dental implant placement

Tribology of bone joints

With the aging of the population, the incidence of orthopaedic diseases has increased, and the use of orthopaedic implants has increased rapidly.

Knee joint tribology

Many defects are seen in knee joint, particularly cartilage damage leading to Osteoarthritis (OA), due to changes in lifestyle. Total knee replacement surgery is a common solution offered. It involves the use of implants made from bio-compatible metals and ceramics. This procedure is commonly performed on individuals aged 45-65 who suffer from osteoarthritis. Lifespan of the implants can range from 15 to 20 years. Surgeons typically use materials such as stainless steel, titanium alloys, Co-Cr alloys, tantalum alloys, composites, ceramics, and polymers for these implants. An implant is surgically attached to the knee joint (Fig-7). While these implants provide relief to patients, daily activities can gradually lead to wear between the implants. As a result, wear debris affects the knee joint and causes pain for the patient. To address this problem, excellent results have been achieved in orthopaedic implants, promoting bone growth and reducing complications by nanotechnology i.e. applying a thin film or coating of bio-compatible material on the implant.

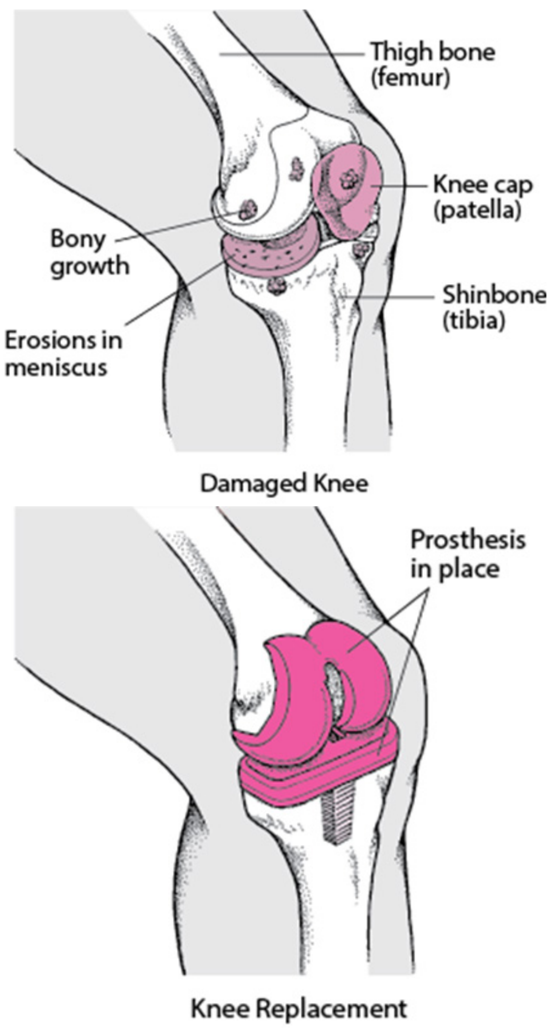
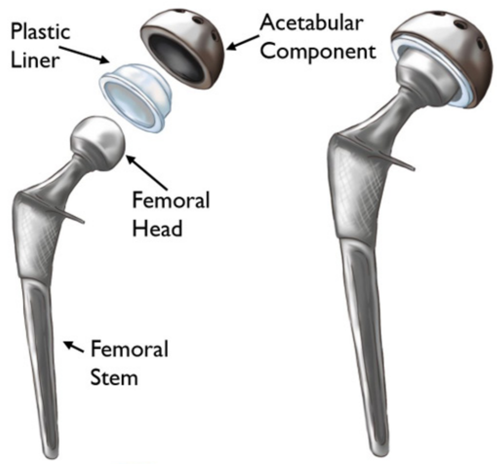
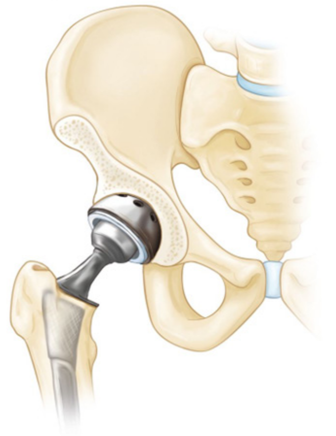


Fig-7: The figure showing the cartilage damage in the knee joint, and the implant (Prosthesis) replaced at that joint





ig-8: The components f a total hip eplacement (upper left). he components merged nto an implant (upper ight). The implant as it its into the hip (below)

The hip joint

It is a joint between femur and acetabulum of pelvis. The primary function of hip joint is to support weight of the body in both the static and walking postures. Excessive degradation of a hip joint often requires replacing it with an artificial joint, known as hip joint prosthesis. In such replacements, the 'femoral head' is replaced with a "metal ball", having a metal stem to be anchored into the hollow space inside the femur bone with bone cement; and the worn out 'acetabular (socket)' is replaced with "artificial socket" (Fig.-8 & 9). The majority of current hip implants utilize a material combination of ultrahigh molecular weight polyethylene UHMWPE articulating against either a metallic or ceramic component. These man-made bearings can sometimes last approx. 20 years in the body without failure.

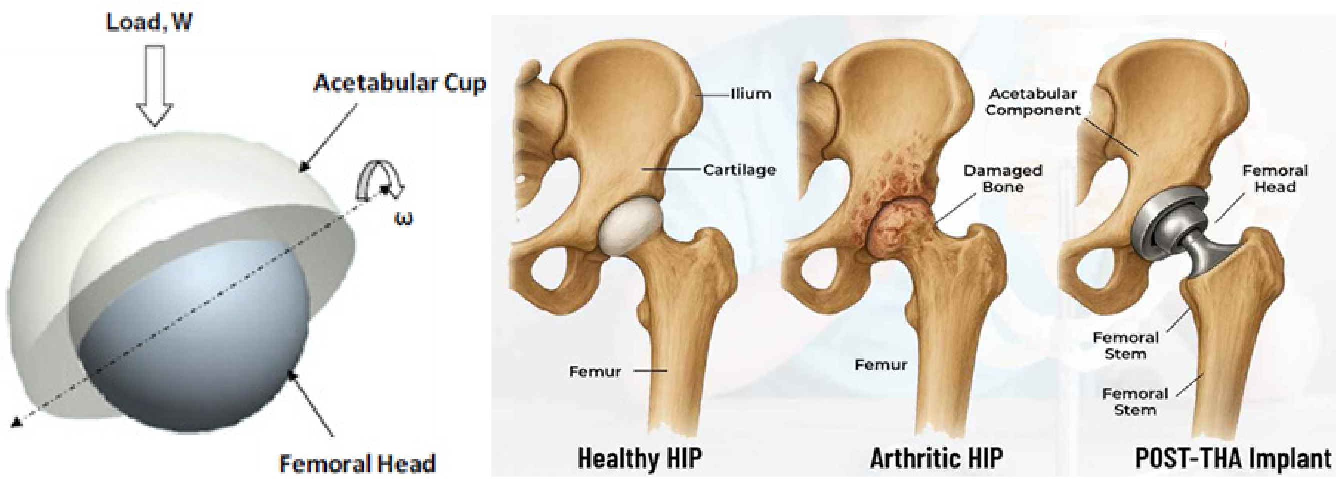


Fig-9: (a) 3-D view of Artificial Hip Joint; (b) A Closer Look at Total Hip Replacement (Total Hip Arthroplasty)

Various types of Hip prostheses are a) Metal-on-metal (MoM), THR. b) Metal-on-polymer (UHMWPE / XLPE), THR, c) MoM resurfacing THR & d) Ceramic-on-ceramic, THR

Various types of ACETABULAR CUP are: UHMWPE, Cross linked UHMWPE, Co Cr, Alumina, Polyurethane, Alumina Composite etc.

Various types of FEMORAL HEAD are: Stainless Steel, CoCr, Alumina, Alumina Composite Zirconia, etc.

How to overcome this challenge—Nano coatings

At the Nano level, materials exhibit unique properties that are impossible to achieve at the micro level. Nano coatings enhance material functionalities, including reducing friction, improving corrosion resistance, extending the lifespan of medical implants, and incorporating anti-bacterial properties.

Tribology for eyes

Eye blinking speed varies from zero speed (at rest) up to approximately 400 mm/s. Eye balling effect—the liquid around the eye is such that it keeps the eye boll rolling very freely in all directions. Even a very tiny dust particle (almost not visible to the eye) if it enters the eye—it is very irritating & have a painful rubbing sensation. Therefore, the IOL (Fig.-10) or contact lens are designed with precision so that one can have the eye-balling effect otherwise one can't move the eye balls freely. An intraocular lens (IOL) is a small, artificial lens implanted inside the eye to replace or supplement the natural lens. Designed to correct refractive errors and restore clarity These lenses are made from biocompatible materials, ensuring they remain functional and stable within the eye.

Bio-tribology—the study of friction, lubrication, and wear as it occurs in the body, is helpful in a product design and solve the related faults. ◆

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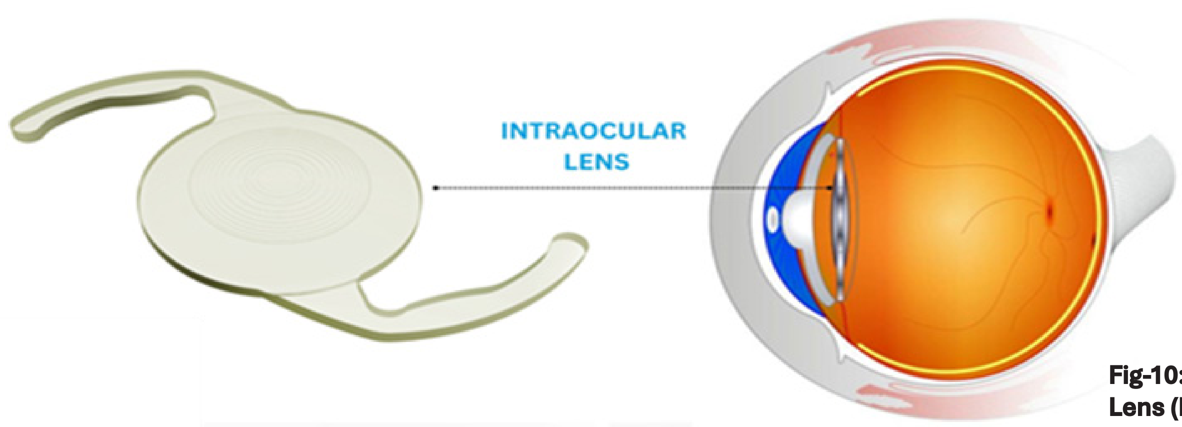

Fig-10: Intraocular Lens (IOL)

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National Science Day

Nakul Parashar

Every year, as 28 February dawns, India pauses for a moment of reflection and quiet pride. The date recalls a luminous instant in 1928 when C. V. Raman announced the discovery of the Raman Effect—a revelation that not only transformed our understanding of light and matter but also earned the nation its first Nobel Prize in Physics in 1930. Nearly a century later, National Science Day continues to remind us that science is not merely a collection of facts or technologies, but a way of seeing the world—anchored in curiosity, questioning, and disciplined inquiry. For Vigyan 2047, the day is far more than a ceremonial observance; it is an invitation to introspect on where Indian science has come from, where it stands today, and where it must journey as the nation moves steadily toward its centenary of independence.

Raman's discovery was not simply an individual triumph etched into the annals of global science; it was a moment of national awakening. It proclaimed, with quiet confidence, that world-class science could emerge from Indian laboratories guided by originality, intellectual courage, and rigorous experimentation—even in the absence of lavish resources. That message resonates as powerfully today as it did in 1928. The Raman Effect is no relic of history. It lies at the heart of modern Raman spectroscopy, a technique indispensable to materials science, nanotechnology, pharmaceuticals, environmental monitoring, forensic analysis, and biomedical diagnostics. Each time these tools are employed in contemporary laboratories, Raman's legacy is gently but firmly reaffirmed. National Science Day, therefore, celebrates a living, evolving science—one that continues to generate knowledge, applications, and innovation.

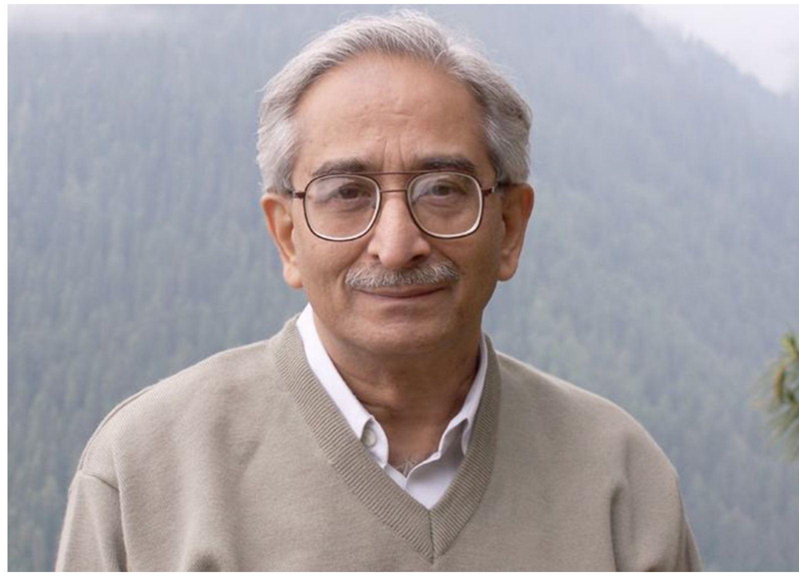
Yet the relevance of National Science Day in 2026 stretches far beyond a single discovery. We live in an era where science and technology shape almost every dimension of human life—from public health and climate action to energy transitions, digital systems, and national security—while paradoxically, scientific facts are increasingly challenged by misinformation, half-truths, and spectacle. In such times, National Science Day becomes an annual reaffirmation of rational inquiry, evidence-based reasoning, and scientific temper. It reminds us that science is not the preserve of a few institutions or experts, but a shared societal enterprise whose strength lies in public understanding and trust.

Over the decades, this spirit has been sustained and amplified by a vast ecosystem of science communication endeavours in India. Popular science magazines have played a particularly enduring role in shaping scientific consciousness. Science Reporter and Vigyan Pragati nurtured generations of young readers, translating complex ideas into lucid narratives and cultivating curiosity beyond classrooms. In more recent years, Dream 2047 emerged as a forward-looking platform that linked science with national aspiration. Its silence today—following the closure of Vigyan Prasar, the national body that anchored much of India's science communication effort for over three decades—marks a poignant pause in this tradition. Yet from this pause has arisen Vigyan 2047, carrying forward the same mission with renewed resolve, reminding us that while institutions may close, ideas and commitments endure.

Beyond print, India's science communication landscape expanded dramatically across media. In less than four years, the IndiaScience OTT Channel created a remarkable archive of nearly 4,000 science films, taking scientific stories far beyond academic spaces and into homes and classrooms across the country. Complementing this visual outreach, All India Radio sustained year-round science programming in 19 Indian languages, ensuring that scientific ideas travelled deep into linguistic and cultural terrains where textbooks often do not reach. Alongside this, more than 400 popular science books and monthly magazines in 18 Indian languages built one of the world's most diverse reservoirs of public science literature—explaining everything from atoms to astronomy, microbes to monsoons, and climate change to space missions.

Science also stepped out of pages and screens into lived, collective experiences. VIPNET science clubs transformed students into explorers through hands-on learning and peer engagement. State Councils for Science and Technology, despite uneven capacities, mounted localised efforts—science fairs, exhibitions, workshops, and outreach programmes—demonstrating that science communication has always been as much a grassroots movement as a national one. The iconic Science Express, carrying exhibitions across thousands of kilometres by train, turned railway platforms into classrooms. Public engagements around solar eclipses replaced fear with understanding and wonder. Large-scale initiatives such as the India International Science Festival and Vigyan Sarvatra Pujyate—with 75 cities celebrating science simultaneously for seven days—created rare nationwide moments when science entered public imagination with confidence and clarity, generating what could only be described as a national roar for science communication, popularisation, and its extension.

Any reflection on this movement would remain incomplete without acknowledging the seminal contributions of Dr Narender Kumar Sehgal, a distinguished physicist-turned-scientific administrator at the Department of Science and Technology (DST), who went on to head the National Council for Science & Technology Communication (NCSTC) and to found Vigyan Prasar. Dr. Sehgal was among the earliest visionaries to recognise that scientific advancement without public understanding was both fragile and incomplete. More importantly, he translated this conviction into sustained institutional action. Under his leadership, National Science Day itself was formally conceptualised and institutionalised—not as a symbolic observance, but as a nationwide platform for engaging citizens with science.



Dr Narender Kumar Sehgal (1940–2020)

Dr. Sehgal spearheaded mass outreach programmes that were unprecedented in scale and ambition. The Bharat Jan Vigyan Jatha took science to villages and small towns through performances, demonstrations, and dialogue, demystifying science for ordinary citizens. The National Children's Science Congress empowered students to pursue inquiry-based learning rooted in local problems, fostering early scientific thinking beyond rote education. Science radio and television programmes reached households across linguistic and social boundaries, while publications such as Dream-2047 provided sustained intellectual engagement with science, society, and policy. Through Vigyan Prasar, Dr. Sehgal also nurtured networks of science clubs, communicators, teachers, and voluntary organisations, effectively creating a national ecosystem for science popularisation. Awarded the UNESCO Kalinga Prize for the Popularization of Science in 1991, he legitimised science communication as a serious national priority rather than a peripheral activity. Remembering him on National Science Day is therefore not an exercise in nostalgia, but a recognition that much of India's science communication architecture rests on foundations he so thoughtfully laid.

And yet, at the heart of this celebration lies an uncomfortable paradox. Even as India has made undeniable strides in scientific research and technological capability, science communication, popularisation, and extension remain chronically under-resourced and undervalued. There is a visible and worrying shortage of high-quality, engaging learning aids capable of igniting curiosity—especially among school students, first-generation learners, and the wider public. Beyond a handful of institutions and

National Science Day: Theme Timeline (1987–2025)

1987 – Science & Technology for National Development
1988 – Science & Technology for Environmental Protection
1989 – Science & Technology for Development of Rural Areas
1990 – Science & Technology for Eradication of Poverty
1991 – Science & Technology for Women
1992 – Science & Technology for Development of New Materials
1993 – Science & Technology for Food, Nutrition & Environment
1994 – Science & Technology for Development of Human Resources
1995 – Science & Technology for Industrial Development
1996 – Science & Technology for National Prosperity
1997 – Science & Technology for Information & Communication
1998 – Science & Technology for Health Care

Turn of the Millennium

1999 – Our Changing Earth
2000 – Recreating Interest in Basic Science
2001 – Information Technology for Science Education
2002 – Wealth from Waste
2003 – 50 Years of DNA & 25 Years of IVF: The Blueprint of Life
2004 – Encouraging Scientific Awareness in Community
2005 – Celebrating Physics
2006 – Nurture Nature for Our Future
2007 – More Crop per Drop
2008 – Understanding the Planet Earth
2009 – Expanding Horizons of Science

Sustainability & Inclusion Era

2010 – Gender Equity, Science & Technology for Sustainable Development
2011 – Chemistry in Daily Life
2012 – Clean Energy Options & Nuclear Safety
2013 – Genetically Modified Crops & Food Security
2014 – Fostering Scientific Temper
2015 – Science for Nation Building
2016 – Scientific Issues for Development of the Nation
2017 – Science & Technology for Specially Abled Persons
2018 – Science & Technology for a Sustainable Future
2019 – Science for the People, and the People for Science

Future-Focused India@2047 Phase

2020 – Women in Science
2021 – Future of STI: Impact on Education, Skills & Work
2022 – Integrated Approach in Science & Technology for Sustainable Future
2023 – Global Science for Global Wellbeing
2024 – Indigenous Technologies for Viksit Bharat
2025 – Empowering Indian Youth for Global Leadership in Science & Innovation for Viksit Bharat

sporadic initiatives, meaningful outreach often depends on individual passion rather than sustained systemic support. As a result, science too often remains confined to textbooks, examinations, or elite spaces, instead of becoming a vibrant part of everyday cultural life.

The true strength of National Science Day lies precisely in its potential for extension—taking science beyond laboratories, universities, and metropolitan centres into classrooms, community halls, informal learning spaces, and digital platforms, in languages and forms people can relate to. Raman himself believed deeply that science must belong to society, not merely to specialists. To honour that belief in spirit rather than symbolism, we must acknowledge that without continuity, institutional stability, and serious investment in learning resources and communicators, we risk alienating not just future scientists but a scientifically informed citizenry.

As India looks toward India@2047, National Science Day must be seen not as a one-day ritual, but as a strategic and moral instrument—one that connects past excellence with present responsibility and future ambition. It reminds policymakers that investment in science cannot stop at laboratories and infrastructure; it must extend to communication, education, and outreach. It reminds educators that curiosity and imagination are as vital as curriculum and assessment. And it reminds all of us that a nation's scientific strength is ultimately measured by how deeply science is woven into its social fabric.

For Vigyan 2047, National Science Day is therefore both a celebration and a call: a celebration of Raman's light—first scattered in a Calcutta laboratory in 1928—and a call to ensure that this light travels far beyond journals and research papers, into classrooms, communities, and everyday conversations. Our quiet anguish over the present state of science communication is born not of despair, but of conviction: that India can, and must, do better. The truest tribute to Raman—and to pioneers like Dr. Narender Kumar Sehgal—lies not merely in remembrance, but in sustaining a culture of curiosity, communication, and public engagement that allows science to fulfil its highest purpose in service of society. ◆

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Living with Motor Neuron Disease

Nutrition, Food, and the Search for Comfort

A. K. Gupta

Motor Neuron Disease (MND), also known as Amyotrophic Lateral Sclerosis (ALS), is among the most unforgiving neurological conditions known to medicine. It slowly dismantles the body's capacity for voluntary movement—weakening limbs, silencing speech, impairing swallowing, and eventually compromising breathing—while often leaving cognition, memory, and awareness painfully intact. This stark contrast between a conscious mind and a failing body makes MND not only a clinical diagnosis, but a deeply human journey marked by adaptation, endurance, and quiet courage.

In the absence of a definitive cure, the philosophy of MND care rests on a single, compassionate principle: to preserve quality of life for as long as possible. Among the many supportive interventions that medicine offers—ventilatory support, physiotherapy, speech therapy, and palliative care—nutrition occupies a uniquely powerful place. Food, after all, is not merely fuel. It is comfort, culture, memory, and connection. For a person living with MND, nutrition becomes both a physiological necessity and an emotional anchor in an increasingly uncertain world.

One of the lesser-known but clinically significant features of MND is hypermetabolism. Many patients burn more energy than expected, even while resting. This elevated metabolic demand, combined with muscle wasting,

involuntary muscle activity, and fatigue, leads to unintended and often rapid weight loss. At the same time, progressive weakness of the jaw, tongue, and throat muscles causes dysphagia, making chewing and swallowing exhausting and sometimes unsafe.

Research consistently shows that weight loss in MND is associated with faster disease progression and reduced survival, whereas maintaining body weight—and in some cases achieving modest weight gain—correlates with improved outcomes. Nutrition, therefore, is not a secondary consideration. It is therapeutic in its own right, influencing strength, immunity, respiratory resilience, and overall well-being.

When Eating Becomes Effort

In the early stages of MND, eating may still resemble normal life, though subtle changes often appear. Meals take longer. Chewing becomes tiring. Appetite fluctuates. Fatigue sets in halfway through a plate of food. It is precisely during this phase that proactive nutritional planning can make the greatest long-term difference.

The central nutritional goal in MND is clear and consistent across clinical guidelines: high-calorie, high-protein nutrition with minimal effort.

Unlike dietary advice for metabolic disorders such as diabetes or cardiovascular disease, nutritional care in MND actively discourages calorie restriction. For people with MND, fat is not the enemy; it is an ally.

Healthy Fats as Energy Anchors

Fats provide more than twice the calories per gram compared to carbohydrates or proteins, making them invaluable when meal volumes must remain small. They allow patients to meet energy needs without exhausting chewing or prolonged eating.

Useful fat-rich foods include full-fat milk, yogurt, paneer, and cheese; butter, ghee, and cream (used judiciously but without fear); vegetable oils such as olive, mustard, groundnut, or sesame oil; avocados and avocado-based spreads; and nut butters made from peanuts, almonds, or cashews. These foods can be effortlessly incorporated into everyday meals—stirred into porridge, blended into soups, or mixed into purées—without increasing chewing burden.

Protein for Maintenance, Not Recovery
Protein cannot reverse the muscle loss caused by motor neuron degeneration, but it remains essential for maintaining tissue health, immune function, and slowing catabolic breakdown. Eggs (soft-boiled or scrambled), fish with soft flesh, minced or slow-cooked chicken, well-cooked lentils and dals, and dairy-based foods such as curd, yogurt, and milkshakes are reliable protein sources.

When intake becomes insufficient, dietitians may recommend medical-grade protein supplements. These are best used strategically, not indiscriminately, and always under professional guidance.

Carbohydrates for Readily Available Energy
Carbohydrates provide quick energy and are particularly important for patients who fatigue easily. Easily digestible options include rice, soft rotis soaked in dal or curry, oats and porridge, potatoes and sweet potatoes, bananas, mangoes, and stewed fruits. Combining carbohydrates with fats and proteins improves caloric density and stabilises energy levels throughout the day.

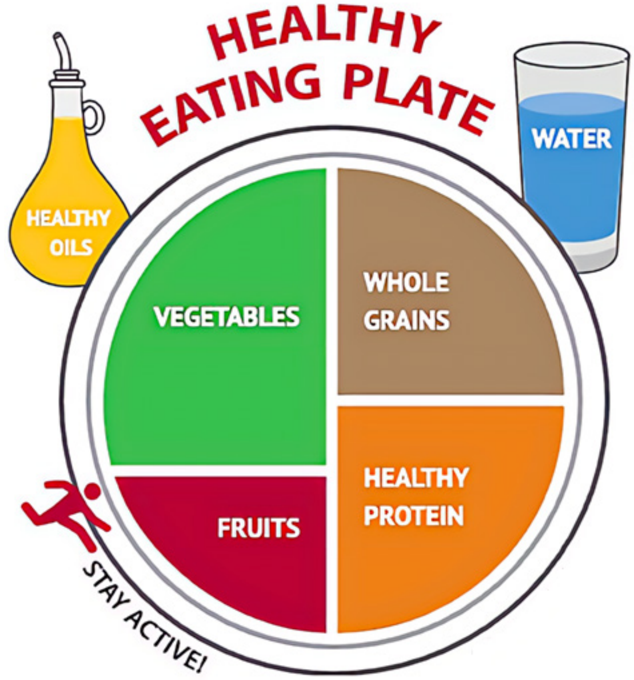
As MND progresses, swallowing difficulties become one of the most serious nutritional challenges. Food or liquid entering the airway can cause aspiration pneumonia—a potentially life-threatening complication. At this stage, texture modification becomes as critical as nutritional composition.

Hard, crumbly, or dry foods are replaced with soft, moist preparations. Puréed foods ensure smooth swallowing, while thickened liquids reduce choking risk. Though meals may look different, they need not be unappealing. Well-prepared purées, blended curries, thick soups, and nutrient-dense smoothies can be both safe and enjoyable.

Speech and swallowing therapists play a vital role in guiding families on safe consistencies, posture, pacing, and adaptive techniques during meals.

Few decisions in MND care are as emotionally charged as the consideration of a feeding tube, such as a PEG (Percutaneous Endoscopic Gastrostomy). It is essential to reframe this intervention. Feeding tubes are not a sign of surrender, nor do they strip patients of the pleasure of eating.

Instead, they reduce exhaustion during meals, ensure adequate nutrition and hydration, lower aspiration risk, and offer psychological relief to both patients and caregivers. Many individuals continue to eat small amounts orally for pleasure even after tube placement. Early discussion—before respiratory function declines—allows patients to exercise autonomy and make informed choices.



A balanced diet rich in carbohydrates, proteins, and healthy fats remains the foundation of nutritional care. Yet certain micronutrients and supplements are often prescribed to support general health, immunity, and metabolic balance.

Antioxidants such as Vitamin E support immune function and are found in almonds, sunflower seeds, spinach, avocados, and vegetable oils. B-complex vitamins—including B6, B12, and folic acid—support nerve health and metabolism and are present in dairy products, eggs, whole grains, legumes, bananas, and leafy vegetables. Zinc, important for immunity and taste perception, comes from seafood, legumes, nuts, and yogurt.

Other commonly discussed compounds include Vitamin D for bone and immune health; Coenzyme Q10, involved in cellular energy production; Creatine, which supports muscular energy metabolism; and antioxidants such as alpha-lipoic acid, glutathione, and N-acetyl cysteine (NAC). While some of these have shown promise in other neurodegenerative conditions, no supplement has conclusively been proven to halt or reverse MND.

As overwhelming as this list may appear, many nutrient levels can be supported through food alone. When chewing and swallowing become severely compromised, targeted supplementation under medical supervision becomes necessary.

In chronic and life-limiting illnesses such as MND, many patients explore complementary approaches, including homeopathy. The motivation is deeply

human—the desire to explore every possibility, to feel heard, and to regain a sense of control.

From a scientific perspective, there is no credible evidence that homeopathy alters the disease course of MND. However, some patients report subjective benefits such as improved sleep, reduced anxiety, or better appetite. These effects are best understood as supportive or placebo-mediated responses rather than biological modification of disease.

Ethical care requires honesty without dismissal. Homeopathy must never replace evidence-based medical or nutritional care, and claims of cure should be firmly challenged. Yet respectful dialogue preserves trust and supports emotional well-being.

Successful nutritional care in MND is often built on small, thoughtful adjustments. Energy-dense foods are prioritised while textures are adapted to tolerance. Hydration is maintained through water, juices, broths, and soups. Meals are small and frequent rather than large and exhausting.

Patients are positioned upright with head and neck support during meals. Ergonomic cups, spoons, and straws reduce effort. Soft, moist foods are fortified with milk powder, eggs, or cream. Smoothies and thick drinks are enriched with protein supplements. Above all, mealtimes are approached with patience and reassurance—failure is not defeat, only part of the process.

Nutrition in MND is rarely managed alone. Spouses, children, and family members become cooks, feeders, planners, and advocates. This responsibility is emotionally and physically taxing. Caregivers often struggle with guilt, fearing they are "not feeding enough." Education is essential: comfort feeding is not neglect. It is an act of respect for the patient's wishes and dignity.

Supporting caregivers through training, reassurance, and respite is as important as supporting patients themselves.

Motor Neuron Disease strips away many certainties, but nutrition remains a domain where care can still make a tangible difference. In maintaining weight, preventing complications, and preserving comfort, food becomes an act of resistance against the disease's relentless progression.

In the absence of a cure, nutrition is one of the most powerful tools we possess—not to defeat MND, but to humanise the journey through it. Thoughtful dietary choices, texture adaptation, timely interventions such as feeding tubes, and compassionate dialogue around complementary therapies together form the foundation of humane care.

In the end, nourishment is not only about sustaining the body. It is about sustaining identity, dignity, and connection—until the very last shared meal. ◆

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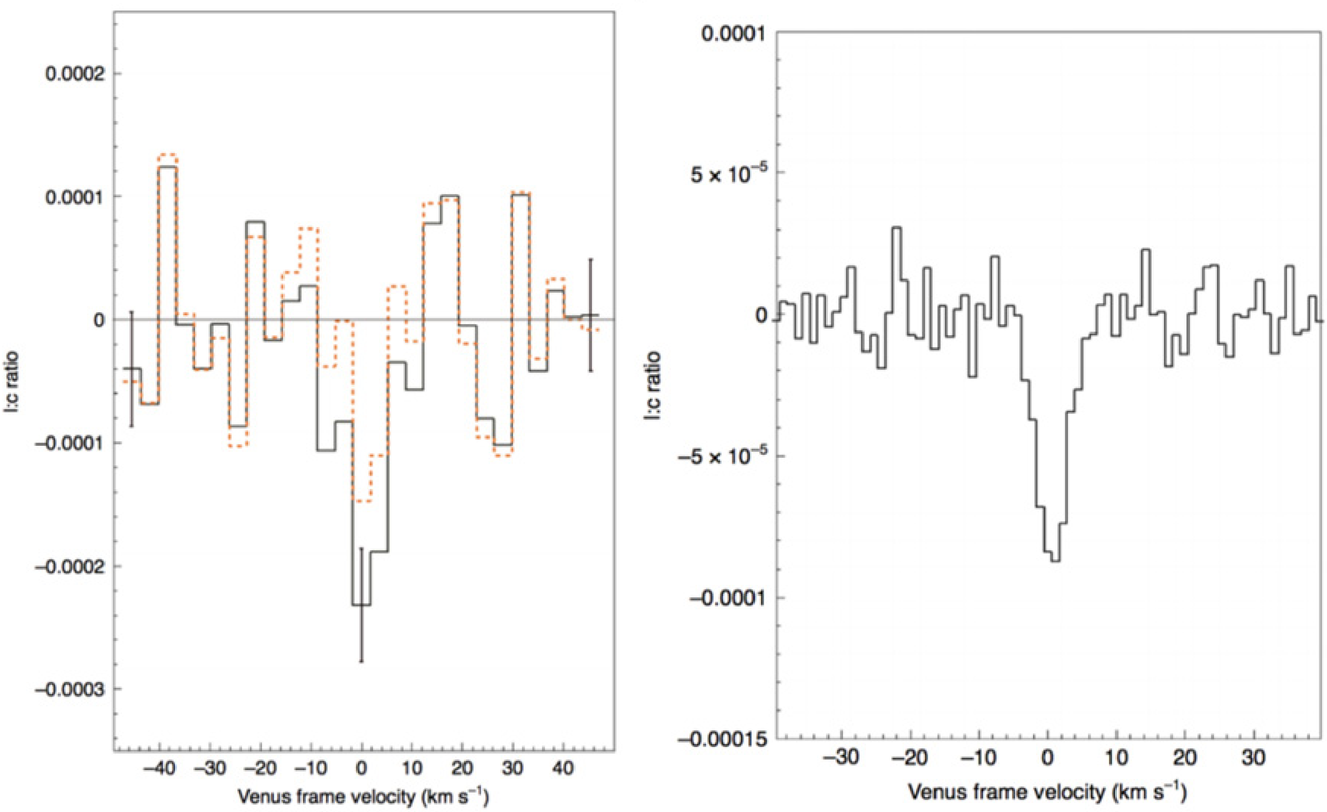
Beacon of Exoplanets—Light of Life?

Govind Bhattacharjee

In 1979, while writing about the possibility of balloon-like creatures existing in the clouds of Venus, Carl Sagan popularised the concept of ECREE—acronym for “Extraordinary Claims Require Extraordinary Evidence”. The aphorism is as old as the 18th Century and has been used by many thinkers—from English philosopher David Hume (1711–1776) in his essay “On Miracles” to the French Mathematician Pierre-Simon, marquis de Laplace (1749–1827). The principle states that “the weight of evidence for an extraordinary claim must be proportioned to its strangeness”. ECREE, which decrees that the more unlikely a scientific claim is against the existing evidence, the more stringent the standard of proof that is required to establish it, has remained a gold standard for the scientific method and critical thinking ever since. A piece of such an “extraordinary evidence” was obtained by scientists in September 2020 from the noxious clouds of Venus again, hinting at the possibility of life there.



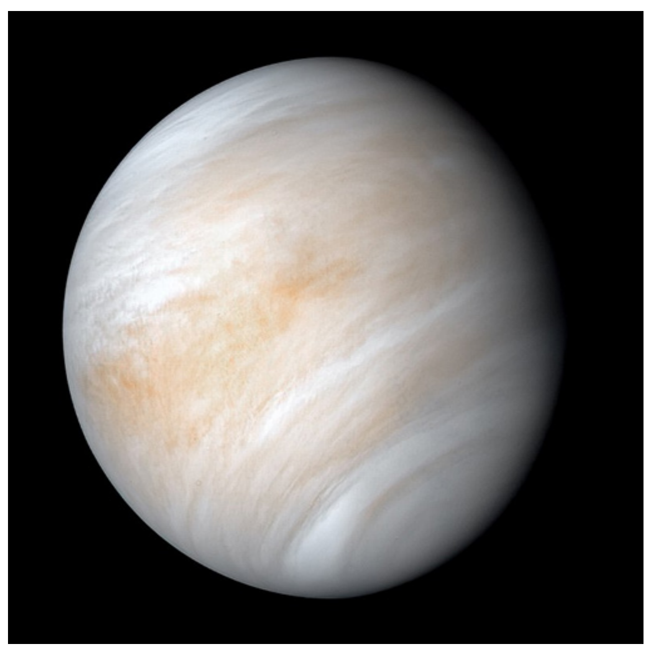
The detection of PH3 towards the entire planet of Venus. The left is the detection with JCMT and right is with ALMA. The x-axis is labelled ‘Venus frame velocity’ because the observed spectra need to be corrected for the velocity at which Venus is spinning. V=0 on the x-axis corresponds to the frequency at which PH3 emits. On the y-axis, l:c stands for line: continuum ratio. Continuum can be thought of as the background and the line corresponds to the PH3 detection. Any value away from zero means that there is flux at that frequency. Bumps and wiggles are normal and are called ‘noise’. The authors are able to determine the significance of the detection based on the depth of the line compared to the noise (plus some other fancy statistics).
Source: Nature Astronomy, https://astrobites.org/2020/09/21/phosphine-in-venus/, accessed 15/09/2020.

Though the brightest star in the night sky, Venus has always been overlooked as a possible candidate for the existence of extra-terrestrial life as life is thought to be impossible in a planet roasting at hundreds of degrees and surrounded by clouds of carbon-di-oxide and corrosive sulfuric acid. However, on September 14, an international team led by Jane Greaves of Cardiff University in Wales detected signs of phosphine (PH_3)—a molecule of phosphorus and oxygen, in Venus' clouds by using two different telescopes - the James Clerk Maxwell Telescope in Hawaii and the powerful ALMA Telescope Array in Chile. Instead of visible light, these telescopes work with millimetre-wave radiations lying between the infrared and the radio wavelengths. Molecules in Venus's toxic hot atmosphere give out quite a bit of radiation at these wavelengths which can be detected from their absorption spectra which is produced when the molecules in the cooler air above the atmosphere absorb some of these radiations while moving out into space. The specific wavelengths absorbed depend on the absorbing molecules, and the spectrum shows a dip at the corresponding wavelength, revealing a chemical present in the atmosphere of the planet. Phosphine showed up as a dip in Venus' spectrum at about 1.12 mm.

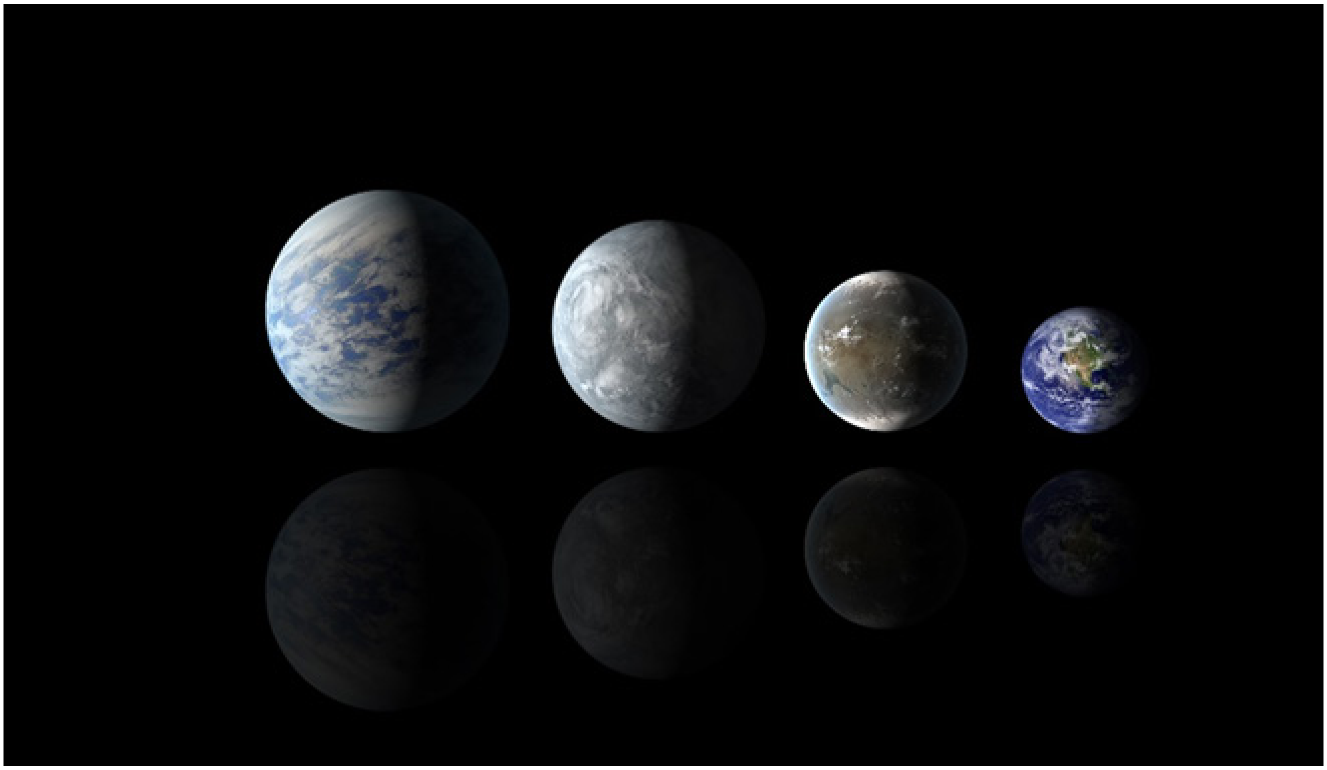
Bacteria on Earth make phosphine from the phosphate of minerals or biological material and hydrogen. Being a gas produced by non-oxygen-using life, it can therefore be used as a biomarker to indicate the possibility of existence of life on planets around other stars. But the discovery of phosphine in Venus's clouds indeed comes as a huge surprise, because such a molecule is thought unlikely to survive in the highly corrosive, carbonated and acidic atmosphere of Venus—because chemistry would destroy it as soon as it is formed. To account for its observed incidence of about 20 parts per billion in Venus's atmosphere, something else must be producing it at the same rate as atmospheric chemistry destroys it. That something could only be a living organism - a microbe.

It is always problematic to interpret scientific data from the space with any certainty, as we had learnt from our 2015 BICEP3 experiment that generated great excitement about the detection of the gravitational waves. Especially when trying to detect a tiny amount of gas in another planet's atmosphere, the observed dip attributed to phosphine could have been caused by other sources which could be anything—from the Earth's thick atmosphere to the inner workings of the telescope itself that produce wriggles that scientists call "noise". Any particular dip could just be a random, extra-large wiggle. The intrinsic brightness of Venus may also introduce such wriggles. The standard practice is to write an equation of the wriggle and subtract it from the observed data. The equation is generally expressed by a polynomial - the team used a twelfth-order polynomial, that is, an equation with twelve variables (the simplest second order polynomial is: ax -y + b = 0, where x, y are variables and a, b are constants) to describe the noise in their ALMA data, but other astrophysicists found "no statistically significant sign of phosphine" in the ALMA data. Obviously many more confirmations will be necessary before accepting or rejecting the possibility of life in Venus—an extraordinary claim. The next mission to Venus from the Earth should give us enough time to design an appropriate experiment for this, and it will be sent by none other than India: the Shukrayaan-1 orbiter is currently scheduled for launch in 2023.

For life to evolve and thrive anywhere, a set of conditions needs to be satisfied, the most important of which is the presence of water. Further, there has to be a 'habitable zone' conducive to life, the so-called Circumstellar Habitable Zone (CHZ), also known as the 'Goldilocks Zone'. This means that a candidate planet has to be at an appropriate distance from the parent star on which water can exist in liquid state under ordinary temperature and pressure. There also has to be an abundance of organic elements necessary for making the complex organic molecules to capture and reflect the complexity of life—99



Venus (Source: NASA/JPL-Caltech)



Artists' depictions of the newly discovered super habitable planets and Earth. Left to right: Kepler-69c, Kepler-62e, Kepler-62f and Earth (Source: NASA/Ames/JPL-Caltech)

percent of all living forms on Earth are composed only of six elements—carbon, hydrogen, nitrogen, oxygen, phosphorus and sulphur (CHNOPS). Organic molecules of these elements dispersed in water provide an ideal environment for chemical interaction between these molecules which forms the basis of all metabolising mechanisms on Earth.

Scientists have identified nine bodies inside the solar system where life might exist in subsurface oceans of water or other organic liquids like methane or ammonia: Mars, Ceres—the largest asteroid, Europa, Ganymede and Calisto—all moons of Jupiter, Enceladus and Titan, moons of Saturn, Triton, the largest moon of Neptune and Pluto. Mars once had free flowing water flowing on its surface—some of it may still be flowing underground. Life has so far been ruled out in Venus which once lay within the Goldilocks Zone. But the Goldilocks Zone also changes its boundaries due to the brightening of the Sun over the past billions of years. On Venus, it triggered a "runaway greenhouse effect" which boiled its seas away, driving any living microbes which existed on its surface waters into the Venus skies, where the temperature remains bearable and water even now remains liquid in droplets. Beyond our Solar System, scientists have discovered nearly 3400 Earth-like rocky planets within the Goldilocks Zone in other stellar systems within and outside our galaxy capable of nurturing life, though without any evidence of life so far. Such planets, called 'exoplanets' are detected indirectly from the stellar properties like brightness, position, etc. or by direct observations made by telescopes in space, like Hubble, Spitzer, Corot or Kepler Space Telescopes.

Once an exoplanet is discovered, scientists look for bio-signatures of life in it. The planet's visible or infrared spectrum may reveal the presence of oxygen or methane, two gases produced by life through photosynthetic or other biological processes. They may look for evidence of liquid water which is essential for life. Ozone will provide another bio-signature as also the compounds of organic sulphur or carbon-di-oxide. However, some of these gases and compounds may even be produced by abiotic processes; there also remains the possibility that even when no bio-signature is detected, some form of life can still be ebbing and flowing beneath the surface of the planets—in subsurface oceans of water or organic compounds like methane or ammonia, though less likely.

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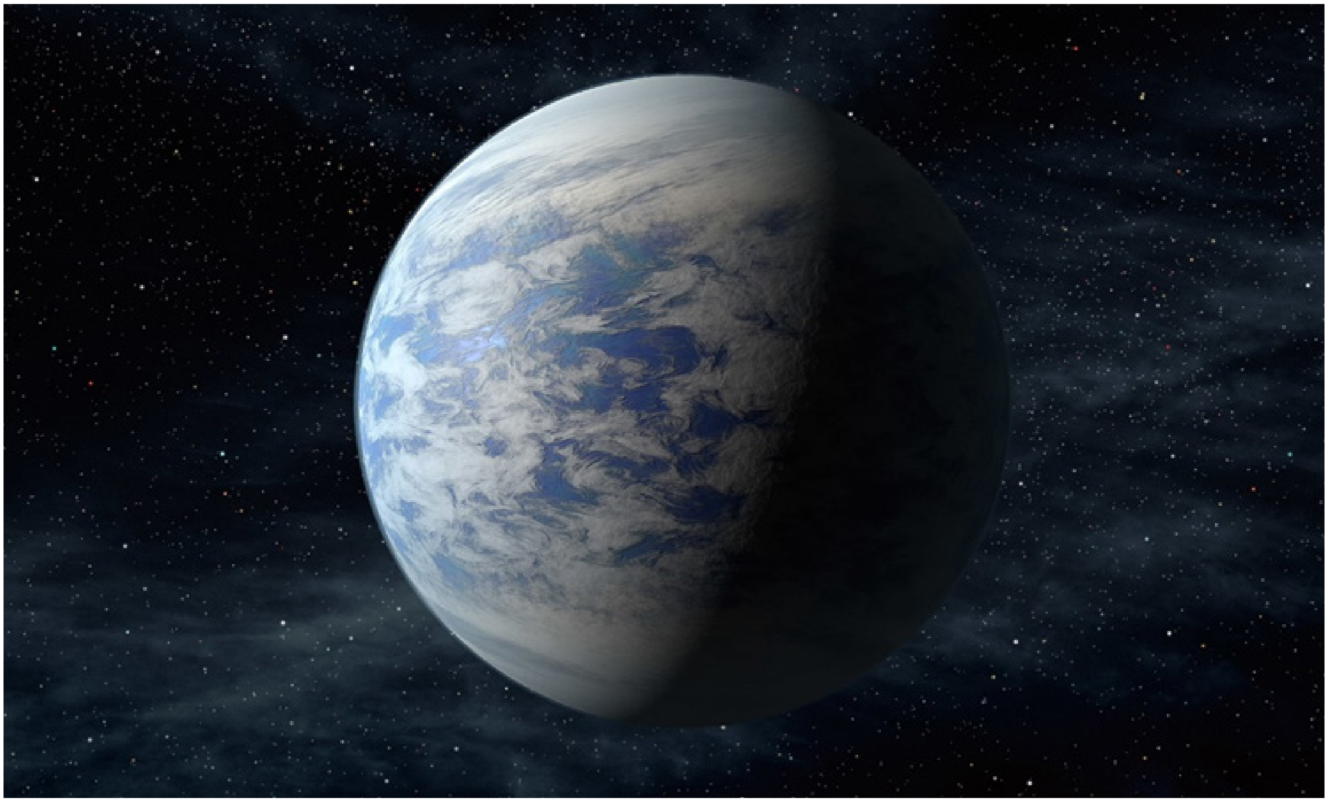
Given that vastness of the universe and the immensity of time through which it has evolved, it is unlikely that a single planet like our Earth in this Universe only



Kepler-69c: Super-Venus (Source: NASA Ames/JPL-Caltech)

harbours life, where in fact it has been proved to exist and proliferate under the most extreme conditions, in highly acidic, alkaline or radioactive environments, in hot springs and frigid lakes deep below the surface. In September 2020, in a research paper titled "In Search for a Planet Better than Earth: Top Contenders for a Super-habitable World"1 astrophysicists Dirk Schulze-Makuch, René Heller and Edward Guinan from Washington State University have identified the conditions that will make a exoplanet habitable—in fact more habitable than our Mother Earth. These demand that it should be about 5–8 billion years old and up to 1.5 times heavier and 10 percent larger than the Earth, with mean surface temperature about 5°C higher. It must also have a large moon with up to 10 percent of planetary mass at a moderate distance of 10–100 planetary radii, with plate tectonics or similar geological and geochemical recycling mechanism as well as a strong protective geomagnetic field. Further, it must be orbiting around a K-type dwarf star with surface temperature lower than the Sun which is a G-type dwarf star. The Sun, in fact, has a relatively short lifespan of 10 billion years. Since it took some 4 billion years for complex life to emerge on Earth since its formation, it is likely that many stars like the Sun would live out their lives before complex life—unlike simple microbial life—could evolve upon them. K-type dwarf stars, being smaller, cooler and less bright than the G-stars, can shine for 20 to 70 billion years—time enough for complex life to evolve. Further, planets tend to get cooled due to the exhaustion of their internal heat-generating mechanisms once they grow older which affect their environment and temperature, making them less suitable for life. Earth is about 4.5 billion years' old and from probabilistic calculations, researchers estimated between 5 billion and 8 billion years as the optimal age of a planet to harbour complex life.

Exoplanets can not only be habitable but 'super-habitable' if they are also larger, heavier, warmer, and wetter compared to Earth. Heavier planets with larger surface areas would feature stronger gravity to support and retain atmosphere, provide more space to support "more biomass and a higher biodiversity", besides adequate plate tectonics to form large landmasses like continents as on earth and strong protective geomagnetic shields. However, there is a fine trade-off—too large a planetary mass might make the planet evolve into a "gas giant or mini-Neptune retaining the light gases such as hydrogen or being an undifferentiated iron-rich body". A planet with sufficient water content in the form of moisture would guarantee sufficient humidity, clouds, rainfall and tropical forests; it should have oxygen content between 25 and 30 percent compared to Earth's 21 percent, and should be warmer than the Earth so that with the additional moisture it can generate vast tropical areas with fewer regions of extreme climate. A large moon at a moderate distance would impart stability to its orbital motion and ensure stable seasons like the Earth.

Based on the above criteria, the team identified some 24 super-habitable planets out of some 4500 candidate exoplanets that could support life better than on earth, even though none of course could be found to satisfy all the criteria; the most that any exoplanet could meet were three, as in the case of exoplanet designated KOI 5715.01. Our current technology is also unable to measure many of the parameters, like atmospheric oxygen, plate tectonics, geomagnetism and natural moons, etc., on extra-terrestrial planets. However, only two of them—Kepler 1126 b and Kepler-69c, have been designated as "statistically validated planets", the rest being only "unconfirmed Kepler Objects of Interest". The upcoming probe tools like NASA's James Webb Space Telescope, LUVIOR Space Observatory, ESA's space telescope and the other new generation telescopes and radio telescopes might help bring more clarity on this aspect. But time to pack our bags will be long as all these 24 exoplanets are more than 100 light years away, a distance we still do not know how to negotiate. Kepler-69c for example lies at a distance of 2000 light years—too far away even for a target to be investigated by telescopes. It also does not imply that we should pack our spaceship with deadly missiles to face any possible existential threats from creatures living there—being super-habitable does not automatically mean that intelligent life actually exists on these remote worlds.

But in the end, we may not have to leave the world and search for a new Earth after all. Old and exploited though the Earth is, it now looks as if she might just able to support her 8 billion human children. A study of population trends in 195 countries by the University of Washington's "Institute for Health Metrics and Evaluation" published in the reputed medical journal, The Lancet, in July 2020 projected the world population to reach its peak at 9.73 billion in 2064 and then gradually to decline to 8.79 billion in 2100, as against the current world population of around 8 billion. Stability of population is defined by the Total Fertility Rate (TFR) which is the average number of children per woman. A TFR of 2.1 just replaces the current population. The Lancet study estimated that

the TFR in 183 of the 195 countries will fall below the replacement level, with the global TFR declining from 2.37 in 2017 to 1.66 in 2100. Population will shrink by more than 50 per cent in 23 countries including Japan, Thailand, Italy and Spain. With lesser population, environment and climate will become sustainable and with appropriate global regulation on conspicuous consumption, the planetary carbon footprints can also be brought within manageable levels. Progress in technology will ensure adequate food production for the current level of population well into the future and even to meet their future energy demand. We won't have to explore other planets for energy or for setting up extra-terrestrial human colonies at immense expenditure and risk to human lives. After all, can there be another planet for us humans like the mother Earth, where we live and love, learn and grow, and help and harm each other, but which still remains to all humans as dear as life. ◆

Note

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1. https://doi.org/10.1089/ast.2019.2161

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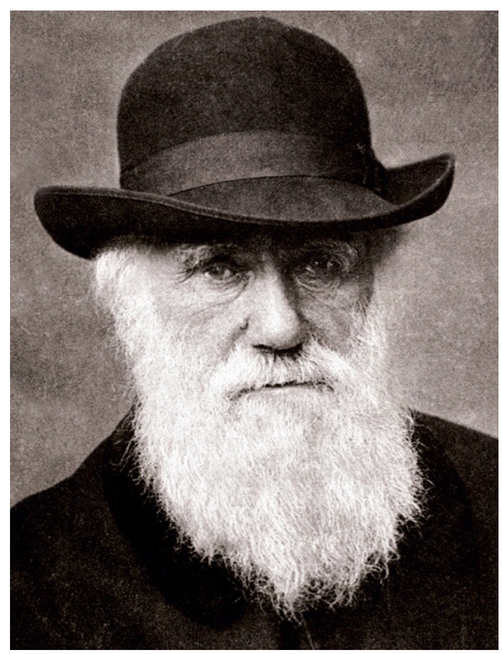
Celebrating the February Born Scientists

Bhupati Chakrabarti

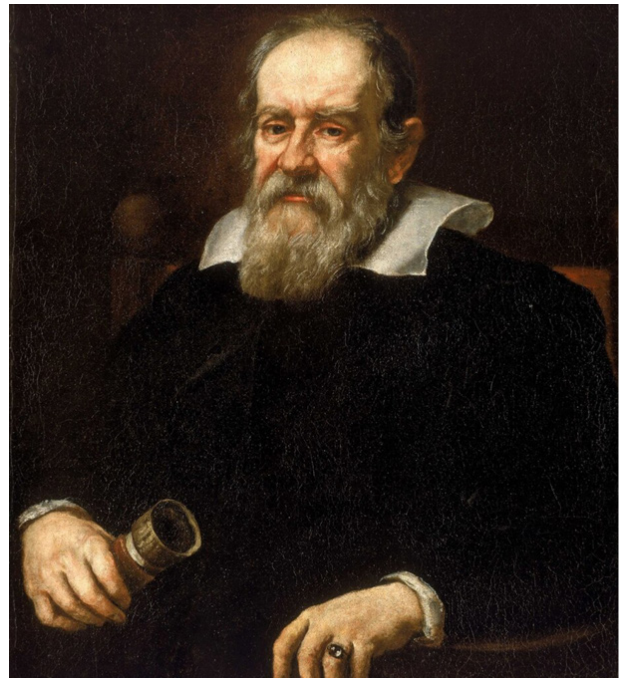
These luminaries, born in the month of February, have each illuminated the path of human progress in their own right. Their discoveries have transcended the bounds of their respective fields, shaping the world as we know it. As we reflect on their lives and legacies, we are reminded of the boundless 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.

Sambhunath De was born on 1 February 1915 and was an Indian medical scientist whose work transformed the understanding of cholera. He completed his MB from Calcutta Medical College in 1939 and a Diploma in Tropical Medicine in 1942. After earning a PhD in Pathology from University College Hospital, London, in 1949, he returned to India and devoted his career to studying the pathogenesis of cholera. De made his most significant contribution in 1959 with the discovery of cholera toxin, proving for the first time that Vibrio cholerae causes disease by secreting an enterotoxin rather than by directly invading tissues. He also developed the ligated intestinal loop and ileal loop models, which became essential tools for studying cholera and diarrhoeal diseases caused by E. coli. His work clarified the mechanism of secretory diarrhoea and laid the foundation for oral rehydration therapy, which has saved millions of lives. Despite working in modest laboratory conditions, De published over 30 influential papers. He retired in 1973 and continued research until his death on 15 April 1985. His discoveries remain central to modern microbiology and medicine.

Charles Darwin was born on 12 February 1809 and was an English naturalist, geologist, and biologist best known for founding evolutionary biology. He proposed that all species descend from common ancestors through natural selection, a process in which individuals with advantageous traits are more likely to survive and reproduce. This idea, presented jointly with Alfred Russel Wallace in 1858, transformed scientific thinking. Darwin's early interest in nature led him away from medical studies at the University of Edinburgh. At Christ's College, Cambridge, he developed a strong interest in natural science. His five-year voyage aboard HMS Beagle from 1831 to 1836 proved crucial, allowing him to study geology, fossils, and living organisms around the world. These observations supported gradual geological change and inspired his evolutionary ideas. Darwin published influential works, including On the Origin of Species (1859), The Descent of Man (1871), and studies on orchids, emotions, and earthworms. By the late nineteenth century, evolution was widely accepted. Darwin's theory remains the unifying foundation of modern life sciences. It continues to influence biology, medicine, genetics, ecology, and scientific research worldwide today.



Galileo Galilei was born on 15 February 1564 and was an Italian astronomer, physicist, and engineer of the Renaissance. He is often called the father of observational astronomy, modern classical physics, the scientific method, and modern science. Galileo studied motion, gravity, inertia, projectile motion, and the principle of relativity, laying foundations for later scientists. He also worked in applied science, describing the motion of pendulums, inventing the hydrostatic balance, and developing early scientific instruments such as the thermoscope and military compasses. Using an improved telescope he built himself, Galileo made groundbreaking astronomical observations. He studied the Milky Way, the phases of Venus, Jupiter's four largest moons, Saturn's rings, sunspots, and the uneven surface of the Moon. These discoveries supported the Copernican theory that the Earth moves around the Sun. Galileo's support of heliocentrism brought him into conflict with the Catholic Church. In 1633 he was tried by the Roman Inquisition, forced to recant his views, and placed under house arrest. During this time, he wrote Two New Sciences, which became a cornerstone of modern physics and influenced scientific thinking worldwide.



Sir Shanti Swarup Bhatnagar was born on 21 February 1894 and was a distinguished Indian colloid chemist, academic, and scientific administrator. He is widely regarded as the Father of Research Laboratories in India. Bhatnagar was the first Director-General of the Council of Scientific and Industrial Research (CSIR) and the first Chairman of the University Grants Commission (UGC). In his honour, the Shanti Swarup Bhatnagar Prize for Science and Technology was instituted in 1958. Bhatnagar earned his Doctorate in Science from University College London in 1921 and began his academic career at Banaras Hindu University, where he also composed the university anthem. He later worked at Punjab University, Lahore, where his most important scientific contributions were made, especially in magnetochemistry.

He co-developed the Bhatnagar–Mathur Magnetic Interference Balance, a highly sensitive scientific instrument. He played a central role in establishing India's scientific infrastructure by founding national laboratories under CSIR after independence. Bhatnagar strongly believed in applying science to industry and nation-building. He constituted the one-man Commission in 1951 to negotiate with oil companies for starting refineries and this ultimately led to the establishment of many oil refineries in different parts of the country. He induced many individuals and organisations to donate liberally for the cause of science and education. He died on 1 January 1955 at the age of 60, leaving a lasting legacy in Indian science and research administration.

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Nazarbayev University School of Medicine (NUSOM)

Building Physicians for a Global Future

Established in 2015 as an integral part of Nazarbayev University, NUSOM was conceived to address both national and international healthcare needs by preparing physicians, researchers, and public health professionals capable of working across borders and systems. The Nazarbayev University School of Medicine (NUSOM), located in Astana, Kazakhstan, represents one such forward-looking effort—designed from the outset to align medical training with global standards, strong scientific foundations, and real-world clinical relevance.From its inception, the School has adopted an explicitly international academic model, with English as the medium of instruction and curricula benchmarked against leading global medical education frameworks.

A **Curriculum Anchored in International Standards**

The flagship Doctor of Medicine (MD) programme at NUSOM follows a U.S.-style graduate-entry medical curriculum, developed in close academic collaboration with the University of Pittsburgh School of Medicine. This partnership has shaped not only the structure of the programme, but also its pedagogical philosophy—integrating basic medical sciences with early clinical exposure, problem-based learning, and continuous assessment.

A **Strategic Choice for Aspiring Medical Professionals**

For students seeking a globally benchmarked medical education, delivered in English, within a modern research university, the Nazarbayev University School of Medicine offers a distinctive and credible pathway. Its combination of international collaboration, accredited programmes, integrated clinical exposure, and commitment to research-driven education positions NUSOM as an important contributor to the future of medical training—not only in Kazakhstan, but across the broader region and beyond.

Accreditation and Global Recognition

NUSOM places strong emphasis on academic quality assurance and international recognition. The MD programme is fully accredited by the Eurasian Accreditation Centre (ECAQA), an agency recognised by the World Federation for Medical Education (WFME). This alignment with WFME standards is particularly significant, as it positions graduates for mobility within an increasingly interconnected global medical workforce. In addition to medical training, NUSOM offers programmes in Public Health, including a Master of Public Health (MPH) degree that has received accreditation from the Agency for Public Health Education Accreditation (APHEA) in Europe. The School also supports doctoral (PhD) programmes, fostering research capacity in biomedical and health sciences.

A Truly International Academic Environment

NUSOM attracts students and faculty from multiple countries, creating a diverse academic community that reflects global healthcare realities. English-medium instruction, international faculty recruitment, and collaborative research links help expose students to different clinical perspectives and cultural approaches to medicine. As part of Nazarbayev University, which has gained recognition as a leading research-intensive university in Central Asia, NUSOM benefits from a wider interdisciplinary environment encompassing engineering, natural sciences, social sciences, and public policy. This proximity encourages cross-disciplinary dialogue—an increasingly important factor in addressing complex health challenges such as pandemics, climate-related health risks, and health system reform.

Preparing Graduates for a Changing World

NUSOM's educational philosophy recognises that modern physicians operate in complex systems shaped by technology, policy, and society. Accordingly, the curriculum incorporates themes of public health, health systems, leadership, and professionalism, preparing graduates not only for clinical practice but also for roles in research, academia, administration, and global health.

NAZARBAYEV UNIVERSITY