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Women's Day Special

Grace Murray Hopper

The Woman Who Taught Computers to Speak

Serials: Light | Tribology | MND

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Women's Day Special

Science, Leadership, and the Power of Continuity

Scientific progress has always been cumulative, shaped by countless minds working across generations. The contribution of women to this advancement is vast and deeply embedded across disciplines—so extensive that capturing it in a single editorial would be neither possible nor just. What follows, therefore, is not an exhaustive account, but a reflection on a few scientists whose work and influence have personally inspired my own engagement with science and technology.

The foundations of modern science were strengthened by pioneers whose ideas continue to shape contemporary research. Marie Curie, through her groundbreaking work on radioactivity, transformed both physics and chemistry while setting enduring standards for scientific rigor. Ada Lovelace, working in the nineteenth century, articulated concepts central to algorithmic thinking long before computing became a reality. In India, Anna Mani's contributions to meteorology and atmospheric instrumentation laid critical groundwork for climate and weather research. In molecular biology, Rosalind Franklin's work remains foundational to genetics, biotechnology, and medicine.

These scientists represent only a fraction of the contributions made across time and geography. Their stories endure not because they were rare, but because they exemplify intellectual persistence in environments that were often slow to recognize their value.

That legacy continues in the present generation. Across strategic research, defence technology, space science, and institutional leadership, professionals today are building on these foundations through sustained excellence. Figures such as Dr. Tessy Thomas in defence research and Prof. Annapurni Subramaniam in astrophysics reflect this continuity—not as symbols, but as practitioners whose work combines technical depth with long-term responsibility for scientific systems and institutions.

Equally influential are mentors whose impact extends beyond formal achievements. My personal interaction with the late Prof. Rohini Godbole, a distinguished theoretical physicist and educator, remains a defining experience. Her clarity of thought, commitment to scientific integrity, and dedication to nurturing young researchers illustrated how leadership in science is expressed not only through discovery, but through guidance and example. Her influence continues through the many scholars and institutions she shaped.

As science addresses increasingly complex global challenges—climate change, emerging technologies, public health, and sustainable development—the need for broad, merit-driven leadership becomes ever more evident. Progress depends on enabling talent wherever it exists and sustaining environments where excellence, mentorship, and responsibility are valued.

This Women's Day, the focus need not rest on isolated achievements alone. The more meaningful narrative is one of continuity—of countless contributions, many unrecorded, that collectively advance knowledge and capability. Acknowledging this continuum strengthens not only our understanding of science, but our commitment to ensuring that future generations inherit institutions where opportunity and excellence are inseparable.

Nakul Parashar, PhD
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Letter to the Editor

I would like to place on record my deep appreciation for Vigyan 2047, a magazine that stands out as a refreshing and much-needed platform for contemporary science communication in India. Each issue reflects a rare blend of creativity, originality, and intellectual depth, presented with excellent print quality, a thoughtfully designed layout, and visually appealing aesthetics that make reading both engaging and enjoyable. What is particularly commendable is the magazine's ability to communicate complex scientific ideas with clarity and elegance, without compromising on accuracy or substance. The passion, dedication, and sustained hard work of the Editor, ably supported by a visionary and committed Advisory Committee, are clearly visible in the magazine's content, structure, and overall direction.

In a time when genuinely creative, lucid, and high-quality science communication magazines are increasingly scarce in the country, Vigyan 2047 assumes even greater significance. It has very effectively filled a long-felt gap by offering a platform that nurtures scientific temper, curiosity, and informed thinking among readers from diverse backgrounds. Given its quality and relevance, Vigyan 2047 deserves wide circulation and visibility. It would be highly desirable for the magazine to reach higher secondary colleges, universities, and research institutions across the country, and to find a place of pride in all libraries. Such outreach would greatly enhance its impact, especially among young learners and emerging scientists.

As a constructive suggestion, and subject to resource and funding availability, your team may consider introducing a Hindi edition of Vigyan 2047, which would further strengthen inclusive, nationwide science communication.

I wish Vigyan 2047 continued success and growing influence in the years ahead, and congratulate the entire team for setting such high standards.

Thanking you with best regards,

Dr Ankkur Goel
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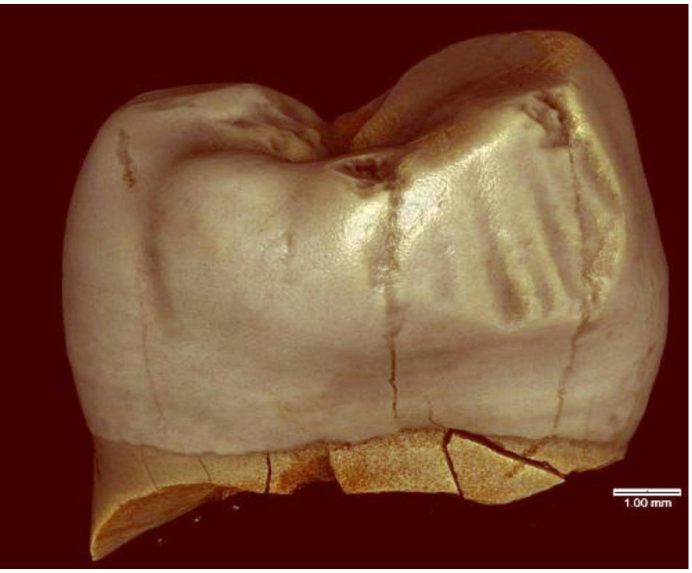
In The News

What primate teeth say about human evolution

For decades, narrow grooves on ancient human teeth were interpreted as evidence of deliberate behaviors such as tooth cleaning with sticks or fibers, often described as the earliest known human habit. New research challenges this view. In a study published in the *American Journal of Biological Anthropology,* scientists examined more than 500 teeth from 27 living and fossil wild primate species and found that similar grooves occur naturally, without any involvement of tools or dental hygiene. Using microscopes, 3D scans, and detailed measurements, they identified non-carious cervical lesions in about 4% of individuals. Some closely resembled classic "toothpick grooves" seen in fossil humans, while others were likely caused by acidic diets rich in fruit or by abrasive particles during chewing. These findings suggest such grooves do not reliably indicate intentional toothpicking. Strikingly, researchers found no evidence of abfraction lesions—deep, wedge-shaped defects common in modern humans—despite studying primates with powerful chewing forces and tough diets. This absence strongly suggests that abfraction is linked to modern human behaviors, such as forceful brushing, processed foods, and acidic drinks. Together, these results highlight the need for caution when interpreting dental marks in fossils and suggest that some common human dental problems are uniquely tied to modern lifestyles rather than deep evolutionary history. ◆



Snow monkeys' hot spring baths

Japanese macaques, or snow monkeys, are famous for bathing in natural hot springs during winter, a behavior often seen as a simple response to cold. New research from Kyoto University shows this habit has deeper biological effects. Studying wild macaques at Jigokudani Snow Monkey Park over two winters, researchers compared females that regularly bathed with those that did not. They combined behavioral observations with parasite assessments and gut microbiome analyses to examine effects on the macaque holobiont—the host and its associated microbes and parasites. The results revealed subtle but meaningful differences. Bathing macaques showed changes in where lice were distributed on their bodies, suggesting warm water may disrupt parasite behavior or egg-laying patterns. Gut microbiome diversity was broadly similar between groups, but several bacterial genera were more abundant in non-bathers, indicating that bathing selectively alters microbial communities. Importantly, bathing did not increase intestinal parasite infection rates, despite shared water use. These findings demonstrate that behavior can shape host–parasite and host–microbe relationships without uniformly affecting all components of the holobiont. The study highlights how natural behaviors influence animal health and challenges assumptions that shared bathing environments necessarily increase disease risk, offering insights relevant to both evolutionary biology and human health. ◆

Crystals that spin, twist, and heal themselves

Crystals made of spinning components may sound improbable, but new research shows they are real and exhibit remarkable properties. Scientists from Aachen, Düsseldorf, Mainz, and Wayne State University report in *PNAS* that systems governed by so-called transverse interactions can form rotating crystals with unusual behaviors. Unlike conventional forces such as gravity, transverse forces act perpendicular to the line between objects, causing them to rotate around one another. At high concentrations, many interacting rotors form solid-like crystals with "odd" material properties. One striking example is odd elasticity: instead of stretching when pulled, these materials twist. They can also spontaneously fracture into smaller rotating pieces without external forces and later reassemble into a crystal. Using a unified theoretical framework and computer simulations, the researchers showed that large rotating crystals tend to split, while smaller ones grow only up to a characteristic size determined by their rotation speed—contrary to normal crystal growth. The theory also predicts dynamic defects whose formation can be externally controlled, allowing material properties to be tuned. Because transverse interactions occur in engineered materials and even biological systems, such as swimming embryos, the findings may inspire applications ranging from soft matter physics to novel mechanical or switching devices. ◆

Ocean that no longer exists

Geologists from the University of Adelaide report that mountain building in Central Asia during the age of dinosaurs may have been driven by forces originating far from the region itself. By compiling hundreds of previously published thermal history models from nearly 30 years of research, the team identified large-scale geological patterns that individual studies could not reveal. Their analysis suggests that the ancient Tethys Ocean played a key role in shaping Central Asia's landscape during the Cretaceous period. Contrary to long-standing assumptions, the researchers found that climate change and mantle convection had only limited influence on Central Asia's topography, which remained largely arid over the past 250 million years. Instead, short-lived episodes of mountain uplift closely correlated with tectonic processes linked to the gradual closure of the distant Tethys Ocean. Extension caused by rollback of subducting oceanic slabs likely reactivated ancient suture zones, forming parallel mountain ridges thousands of kilometers from the future Himalayas. Although today's relief is dominated by the India–Eurasia collision, dinosaurs would have inhabited a similarly mountainous landscape. The study highlights the power of large, integrated datasets and suggests this approach could clarify the origins of mountain building in other poorly understood regions worldwide. ◆

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COVER STORY

Grace Murray Hopper

The Woman Who Taught Computers to Speak

Prerna Gaur

Grace Brewster Murray Hopper (1906–1992) stands among the most consequential figures in the history of computing—not because she designed the fastest machine or derived the most abstract equations, but because she fundamentally transformed how humans communicate with computers. A mathematician by training, a naval officer by service, and a visionary by temperament, Hopper reshaped computing from an arcane, machine-bound activity into a human-centred enterprise. Her insistence that computers should adapt to people, rather than the reverse, helped define the philosophy of modern software.

Born in New York City on December 9, 1906, Hopper grew up in a household that quietly challenged the conventions of its time. Her father, a Yale alumnus, believed strongly that daughters deserved the same educational opportunities as sons—an unusual conviction in the early twentieth century. Intellectual curiosity was not only encouraged but expected. As a child, Grace famously dismantled alarm clocks to understand their inner workings, once taking apart seven before her mother intervened. This instinct to question systems rather than accept them at face value would remain a defining trait throughout her life.

Her formal education reflected both brilliance and perseverance. After preparatory schooling in New Jersey, she entered Vassar College, graduating Phi Beta Kappa in 1928 with degrees in mathematics and physics. She went on to Yale University, earning a master's degree in 1930 and a Ph.D. in mathematics in 1934 under the supervision of the noted mathematician Øystein Ore. Her doctoral work, *New Types of Irreducibility Criteria,* placed her firmly within the mathematical research community. Hopper returned to Vassar as a faculty member, where she taught mathematics and rose to the rank of associate professor. Teaching, for her, was never secondary; it was a lifelong vocation.

World War II altered Hopper's trajectory decisively. Following the

Why COBOL Still Matters in Today's Digital Economy

More than six decades after its creation, COBOL (Common Business-Oriented Language) remains a silent backbone of the global digital economy. Designed under the leadership and vision of Grace Murray Hopper, COBOL was built for clarity, reliability, and large-scale data processing—qualities that continue to define mission-critical systems today.

COBOL programs still run core operations in banking, insurance, government finance, social security, airline reservations, and taxation systems across the world. Trillions of dollars in daily transactions depend on COBOL-based infrastructure, particularly in legacy mainframe environments that prioritize accuracy, stability, and security over rapid change.

Hopper's insistence on English-like, readable code proved remarkably future-proof. COBOL programs written decades ago can still be understood, audited, and maintained—an essential feature in regulated industries where transparency and accountability matter. In an era of AI and automation, this human-readability is once again a strategic advantage.

Modern digital transformation does not replace COBOL; it builds around it. APIs, cloud services, and AI-driven analytics increasingly interface with COBOL systems, allowing organizations to modernize without disrupting trusted cores. The global shortage of COBOL programmers has further highlighted the language's continued relevance and economic value.

COBOL endures because Grace Hopper designed it not as a temporary technology, but as a bridge between human intent and machine execution. In a digital economy driven by scale, trust, and continuity, that bridge remains indispensable.

attack on Pearl Harbor, she sought to join the U.S. Navy. Initially rejected due to age, weight, and the argument that her work as a mathematics professor was already valuable to the war effort, she persisted. In 1943, she obtained a waiver and was commissioned into the U.S. Naval Reserve (WAVES). She graduated first in her class from the Naval Reserve Midshipmen's School at Smith College and was assigned to the Bureau of Ships Computation Project at Harvard University.

At Harvard, Hopper joined the team working on the IBM Automatic Sequence Controlled Calculator—the Harvard Mark I—under the leadership of Howard H. Aiken. Beginning in 1944, she became one of the earliest computer programmers in history. Her work involved complex wartime calculations, including ballistic trajectories and naval engineering problems. She also authored what is widely regarded as the first comprehensive computer manual, *A Manual of Operation for the Automatic Sequence Controlled Calculator*. Even at this early stage, Hopper revealed a defining impulse: she was as concerned with explaining machines as with operating them.

After the war, Hopper faced a pivotal decision. Offered a full professorship at Vassar, she chose instead to remain at the frontier of computing. She stayed at Harvard as a research fellow under Navy contract

(Yale University)

Grace Hopper & IEEE

Professional Affiliation and Rank

IEEE Fellow: Hopper was elected a Fellow of the IEEE in 1962 for her contributions to automatic programming.

IEEE Life Fellow: In 1980, she was named an IEEE Life Fellow, a high-distinction honor for long-term members.

IRE Membership: Before the merger that created the IEEE, she joined the Institute of Radio Engineers (IRE) in 1954 and was named an IRE Fellow in 1962.

Awards and Recognition

W. Wallace McDowell Award: The IEEE Computer Society awarded her this honor in 1979 for her leadership and technical skill in developing and standardizing high-level programming languages.

Harry Goode Memorial Award: In 1970, she received this award from the IEEE Computer Society for her pioneering work in software and mathematical compilers.

Grace Hopper Achievement Award: In 2021, the IEEE Philadelphia Section created this local award in her honor, sponsored by the IEEE Computer Society and IEEE Women in Engineering.

Posthumous Honors

IEEE Milestone (2024): In May 2024, the IEEE dedicated a permanent Milestone marker at the University of Pennsylvania to honor Hopper's invention of the A-0 compiler.

Plaque Dedication: The plaque is located in the Moore Building, next to the ENIAC computer, making her the first woman to be named individually on an IEEE Milestone plaque in a decade.

(Vassar College)

and, in 1949, joined the Eckert–Mauchly Computer Corporation, which was developing the UNIVAC I—the world's first commercial electronic computer. At a time when computing was transitioning from experimental machines to industrial systems, Hopper found her intellectual home.

It was here that she articulated her most radical idea: machine-independent programming languages. Hopper believed that computers should not require humans to think in binary or symbolic code. Instead, machines should translate human-readable instructions into executable operations. In 1952, she completed the A-0 system—initially called a compiler and later described as a linker—the first working system to convert symbolic instructions into machine code. This achievement marked the birth of modern compilers and fundamentally altered software development.

Her vision extended further. Hopper openly rejected the assumption that programming had to resemble mathematics. "Very few people are really symbol manipulators," she later observed. "It's much easier for most people to write an English statement than it is to use symbols." Acting on this conviction, she led the development of FLOW-MATIC, the first programming language to use English-like commands. In 1954, she

(New England Historical Society)

Grace Hopper and the Birth of UNIVAC & COBOL

Grace Murray Hopper played a decisive role in transforming early computers from experimental machines into practical systems for governments and industry. After joining the Eckert–Mauchly Computer Corporation in 1949, she became part of the team that developed UNIVAC I, the world's first commercial electronic computer. At UNIVAC, Hopper led efforts to move beyond hand-coded machine instructions, laying the groundwork for modern software systems.

Her most enduring contribution was the concept of automatic programming—the idea that computers could translate human-readable instructions into machine code. In 1952, Hopper developed the A-0 system, the world's first operational compiler, enabling symbolic and word-based commands to be converted into executable programs. This breakthrough fundamentally changed how software was written and maintained.

Building on this insight, Hopper led the creation of FLOW-MATIC, the first programming language to use English-like statements. FLOW-MATIC directly influenced the design of COBOL (Common Business-Oriented Language), developed in 1959 under the CODASYL initiative, where Hopper served as a key technical architect and advocate.

COBOL revolutionized business and government computing by making programs readable, standardized, and portable across machines. By the 1970s, it had become the most widely used programming language in the world—a testament to Hopper's vision that computers should serve human understanding rather than demand technical abstraction.

Today, decades later, COBOL systems still underpin critical global infrastructure, reflecting the lasting impact of Grace Hopper's insistence on clarity, accessibility, and machine-independent programming.

(Brittanica Kids)

became the company's first director of automatic programming, overseeing the release of some of the earliest compiler-based languages.

This work culminated in one of the most influential developments in computing history: COBOL (Common Business-Oriented Language). In 1959, Hopper served as a key technical consultant to the CODASYL committee, which designed a standardized, machine-independent language for business data processing. COBOL embodied Hopper's core belief that programs should be readable by humans. Its impact was profound. By the 1970s, COBOL had become the dominant language for government and commercial computing—and, remarkably, it remains in use today.

Throughout these civilian achievements, Hopper remained deeply connected to the U.S. Navy. Although forced into retirement in 1966 by age regulations, she was recalled to active duty repeatedly to help standardize the Navy's increasingly fragmented computing systems. From 1967 onward, she served as a leading advocate for programming language standards, distributed computing, and system interoperability. Promoted eventually to the rank of rear admiral, she retired in 1986 at the age of 79, the oldest serving commissioned officer in U.S. naval history.

Hopper was also a gifted communicator and a legendary teacher. She lectured relentlessly, addressing audiences ranging from senior military leaders to schoolchildren. Her teaching style was vivid and unconventional. To explain the speed of light, she handed out short lengths of wire—about 11.8 inches long—calling them "nanoseconds." She kept a clock that ran backwards on her wall, explaining that it was a reminder that "humans are allergic to change." These gestures were not gimmicks; they were expressions of a deeply held belief that understanding must be tangible.

Her later years were marked by widespread recognition. Hopper received more than forty honorary degrees, the National Medal of Technology in 1991, and posthumously the Presidential Medal of Freedom in 2016. Institutions, ships, supercomputers, and even microarchitectures—from the USS *Hopper* to NVIDIA's "Hopper" GPU architecture—bear her name. Yet she consistently insisted that her greatest accomplishment was not a compiler or a language, but the people she mentored. "The most important thing I've accomplished," she once said, "is training young people ... and backing them up when they take chances."

Grace Murray Hopper died peacefully on January 1, 1992, and was buried with full military honors at Arlington National Cemetery. Her legacy endures in every line of readable code, every programming language designed for clarity, and every effort to make technology more humane.

Grace Hopper did more than invent tools. She reshaped the philosophy of computing itself—teaching machines to speak human language, and ensuring that the digital future would be intelligible, inclusive, and shared. ◆

Prof Prerna Gaur *is the Director of NSUT's West Campus and Chair-IEEE India Council. A prolific writer and proponent of popularizing science and technology, Prof Gaur can be reached at prernagaur@yahoo.com*

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Women, Science and Public Policy in India
From Inclusion to Influence

Aruba Rais & Mohammad Rais

India is living through a defining moment in its development journey. From space missions and digital public infrastructure to biotechnology and climate technologies, the nation increasingly speaks the language of science and innovation. Yet, within this inspiring national narrative lies a quieter, unresolved question: who gets to participate in science—and who gets to shape it? This is not merely a matter of representation. It is a matter of national capacity. A country cannot build a durable innovation ecosystem when a large portion of its talent does not remain engaged in scientific careers or is excluded from scientific decision-making. In that sense, the relationship between women, science, and public policy is not an optional social debate; it is a critical development agenda for India@2047.

Science and the Indian woman: an unfinished journey

India has made visible progress in bringing girls and young women into education. Across many parts of the country, women now enter science education in substantial numbers, and in some disciplines—particularly life sciences and medical fields—they form a strong presence in classrooms. However, the optimism of this progress begins to fade when one follows the trajectory beyond graduation. The number of women declines as academic levels rise, and further reduces as careers become more competitive. By the time one reaches the leadership layers of science—principal investigators, heads of institutions, grant committees, expert panels, advisory councils, and science-policy platforms—the representation of women is far thinner.

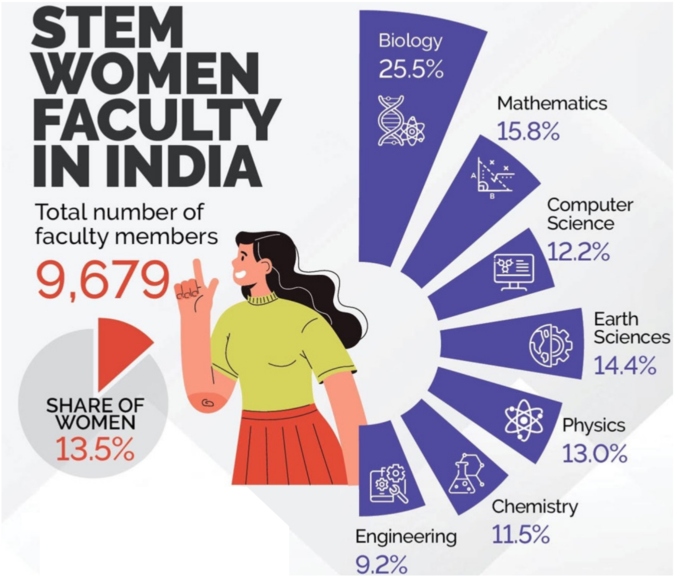
This drop is often called the "leaky pipeline," but the phrase should not make the problem sound inevitable. The decline is not natural. It is structured. It reflects the ways in which society and institutions distribute opportunity and burden. The issue is not about whether women can do science; it is about whether women are enabled to do science continuously, safely, and with recognition.

For decades, women's participation in science was framed largely as a question of empowerment or equality, often addressed through scholarships or awareness programmes. While these interventions are important, they are not sufficient. Women in science must be understood as a public policy issue because it shapes outcomes that affect all citizens. Public policy depends heavily on scientific understanding and scientific capability, whether the subject is public health, climate change, food systems, water management, emerging technologies, or national innovation missions.

When women are absent from research careers, India loses trained talent in which it has already invested public resources through schooling and higher education. When women are underrepresented in research leadership, the national research agenda risks becoming narrower. When women are missing from science-policy bodies, the policy process itself becomes less diverse, often less humane, and less sensitive to the lived realities of half the population. In short, women in science is not only about inclusion; it is about increasing the quality and relevance of India's scientific and policy ecosystem.

The real problem is not entry into STEM, but retention and progression

India's primary barrier today is not the absence of women at the point of entry into science education. The bigger challenge lies in retention and progression. Many young women complete their degrees but do not move into long-term research. Others begin research careers but discontinue due to personal and structural



pressures. Still others remain in the system but face slow career growth because of institutional biases and unequal access to opportunity.

The points of dropout are predictable. After graduation, family expectations regarding marriage, location, caregiving, or "acceptable work environments" begin to influence career options. During the PhD stage, the uncertainty and financial limitations of research often collide with cultural pressure for stability. Post-PhD and early career years become even more difficult because they coincide with the period when many women are expected to take on the largest share of domestic and caregiving responsibility. Even after surviving these stages, women often encounter invisible barriers—limited access to networks, fewer high-value collaborations, fewer nominations, fewer opportunities to lead, and weaker visibility within academic and research ecosystems.

These realities confirm a simple truth: the issue is not about women lacking ambition. The issue is about institutions and social structures failing to support continuous scientific careers for women.

India has not ignored this issue. Over the years, the country has built multiple frameworks to support women in science. The National Education Policy 2020 strengthened the national emphasis on equity and inclusion, and created a policy climate that recognizes gender responsiveness as integral to educational reform. Such direction matters because education policy is the root of the pipeline; it shapes confidence, aspiration, and access.

In the science ecosystem, the Department of Science and Technology (DST) has contributed significantly through programmes designed to support women scientists, including return-to-work opportunities for those who take breaks due to caregiving responsibilities. These schemes reflect a modern understanding: scientific talent should not be treated as disposable merely because a researcher's life includes pauses. Career interruptions, particularly for maternity or caregiving, are not evidence of incompetence; they are evidence of social responsibility. A nation benefits when its policy systems allow women to re-enter scientific work without stigma.

Equally important is India's movement towards institutional reform. Instead of merely offering individual support, institutional transformation initiatives signal a shift in philosophy—from correcting women to correcting the systems around them. Such reforms are essential because discrimination in science rarely occurs openly. It often occurs through subtle gatekeeping: recruitment committees, unequal lab space allocation, informal networks, biased evaluation practices, and leadership cultures that are not inclusive.

Even with such initiatives, the challenge remains large because the problem is complex. Policy has opened some doors, but the structure of scientific careers still continues to reward uninterrupted, mobility-heavy life patterns. Unless the career design itself changes, support schemes will only partially solve the problem.

The barriers that remain: safety, caregiving, bias, and visibility

A critical obstacle for women in science, especially in India, remains the larger environment in which careers are pursued. Scientific work does not always take place in safe and predictable settings. Fieldwork, travel, lab schedules that extend late into the evening, and male-dominated professional cultures can create real constraints. Safety is not just a social issue; it is a participation issue. Where women do not feel safe, they naturally self-limit their career options. This includes choosing disciplines that require less travel or avoiding leadership roles that demand greater mobility and visibility.

Another barrier is the motherhood and caregiving penalty. Scientific careers rely heavily on publications, continuity of research, conference participation, and networking. Even a short break can weaken competitiveness. The system often fails to account for the realities of motherhood and family responsibility. Without childcare support, flexible work structures, and fair evaluation mechanisms, women pay a disproportionate professional cost for social responsibilities.

Bias also persists in allocation of grants and recognition. Research careers advance not only through competence but through opportunity. The ability to lead large projects, gain high-impact collaborations, and secure leadership-level grants is influenced by networks, mentorship, and institutional culture. Women frequently receive fewer such opportunities. This limits their visibility and later limits their inclusion in policy-making and high-level scientific boards.

There is another dimension that is often overlooked. India is beginning to include women in science education and in research participation, but it is still struggling to ensure women become science-policy leaders. This difference is important. Science has power because it shapes policy, and policy has power because it decides what science gets funded, what research priorities are considered urgent, and what knowledge is taken seriously.

If women remain absent from scientific advisory bodies and regulatory systems, then women are not participating in the creation of national futures; they are merely consuming futures designed by others. India needs women not only in laboratories, but also in committees that design technology regulation, public health communication systems, climate adaptation planning, biotech ethics frameworks, and AI governance.

For India's long-term national development, it is essential to treat women scientists as future policy actors. Their role must evolve from participant to influencer, from contributor to decision-maker.

Science communication: India's powerful opportunity to build scientific citizenship among women

The COVID-19 pandemic taught the world a significant lesson: science is not effective unless it is communicated well. Knowledge must travel from journals to society. Trust must be built. Misinformation must be addressed. Public understanding must be strengthened. In this domain, women can play a transformative role in India.

Women as teachers, science communicators, editors, educators, health communicators, and creators can strengthen scientific citizenship in society. When science is explained in culturally relevant ways, and when women lead that explanation, it has a multiplier effect. It strengthens public understanding, reduces fear, and builds aspiration among young girls who begin imagining themselves as scientists. Science communication is thus not only about spreading information; it becomes a policy tool to expand participation and build a long-term culture of scientific temper.

India's ambition for 2047 requires a science ecosystem that is inclusive by design and resilient by function. This means policy must move beyond broad intentions to measurable reforms. The first

step must be to track retention and progression, not just enrolment. India should systematically measure how many women continue from STEM education into research, how many reach senior scientific ranks, how many lead funded projects, how many enter deep-tech entrepreneurship, and how many participate in national advisory platforms. Without such monitoring, leakage remains invisible and therefore uncorrected.

The second step must be to treat childcare and caregiving support as research infrastructure. A modern science ecosystem cannot rely on unpaid domestic labour by women. Funding structures and institutional arrangements must incorporate support systems that allow career continuity without penalty.

The third step is to make institutional transformation mandatory, not optional. Institutions receiving public research funding should be expected to demonstrate equity systems, transparent recruitment and promotion metrics, functional harassment prevention and redressal mechanisms, and mentorship structures that produce leadership pathways for women.

Finally, women must be made visible and powerful in frontier science missions. India's future is being shaped in domains such as quantum technology, artificial intelligence, genomics, clean energy, space systems, and climate technology. Women must not merely be staff in such missions; they must lead them. National scientific leadership must reflect national society.

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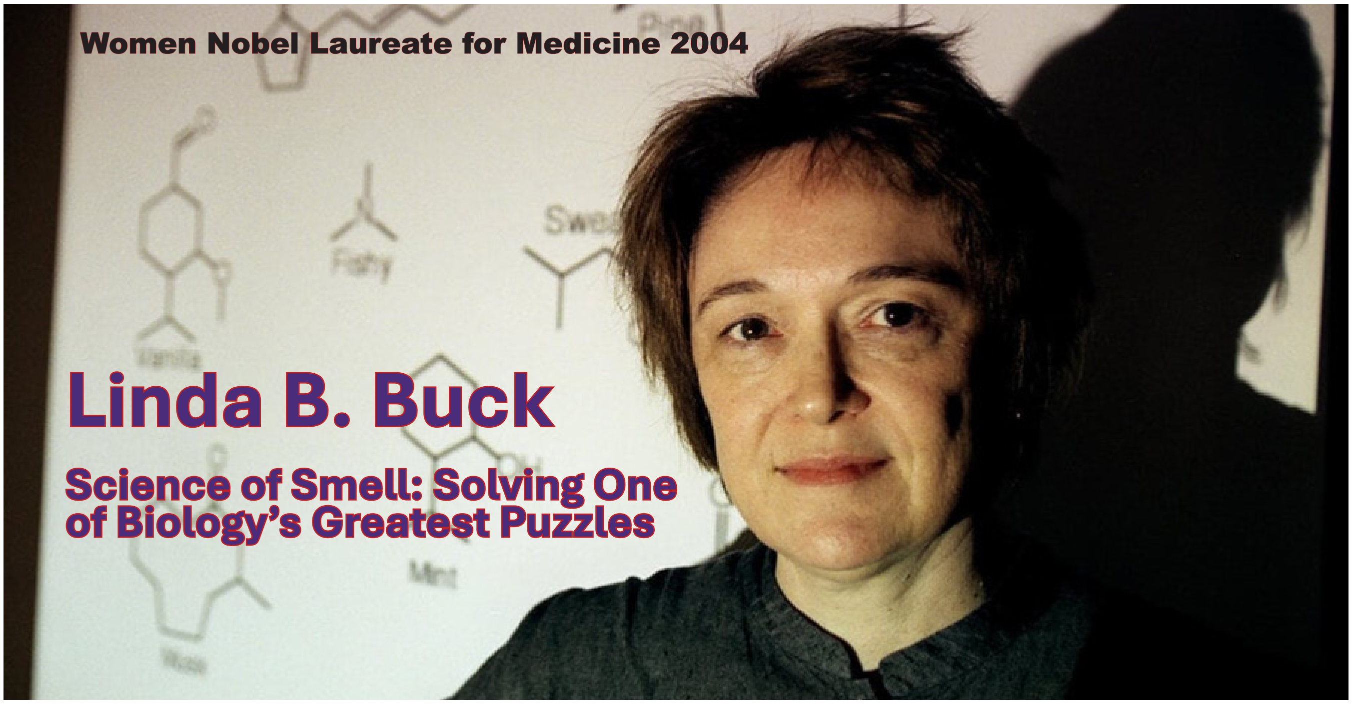
Women Nobel Laureate for Medicine 2004

Linda B. Buck

Science of Smell: Solving One of Biology's Greatest Puzzles



Linda Buck at the Fred Hutchinson Cancer Research Center in Seattle, May 2002. Behind her are molecules representing different scents. Photo: Meryl Schenker/SeattlePI.com/Polaris

In 2004, the Nobel Prize in Physiology or Medicine was awarded to Linda B. Buck, jointly with Richard Axel, for discoveries that transformed scientific understanding of one of the most mysterious human senses: olfaction, or the sense of smell. What began as a simple question—how do we smell?—became a lifelong intellectual pursuit that revealed deep connections between biology, perception, memory, and emotion. Buck's work not only uncovered the molecular and neural mechanisms underlying smell but also reshaped how scientists understand sensory perception itself.

Linda Brown Buck was born in Seattle, Washington, in 1947. Unlike many future scientists, Buck did not grow up with a clear ambition to pursue science as a career. Instead, she possessed something more fundamental: curiosity. Her father, an electrical engineer, and her mother, a homemaker, shared a love for puzzles, inventions, and problem-solving. This environment fostered a mindset that Buck would later recognize as central to scientific inquiry. As she would come to describe it, science is, at its core, "really puzzle-solving."

Her parents encouraged exploration, independent thinking, and the expectation that she would ultimately do something meaningful with her life. Yet Buck's path toward science was far from linear. After enrolling at the University of Washington, she initially studied psychology, considering a future as a psychotherapist. Uncertain about this direction, she left university to travel and explore other possibilities, returning intermittently to take classes.

In 1975, at the age of 28—ten years after she first began her undergraduate education—Buck graduated with a Bachelor of Science degree in both microbiology and psychology. The combination would later prove uniquely valuable, bridging molecular biology with questions of perception and behavior.

Buck went on to earn a PhD in immunology at the University of Texas Southwestern Medical Center in Dallas. There, she learned the craft of research under the mentorship of Ellen Vitetta, whom Buck credits with teaching her not just experimental techniques, but how to think like a scientist: how to ask the right questions, design rigorous experiments, and persevere through uncertainty.

After completing her doctorate, Buck joined Columbia University, where she entered the laboratory of Richard Axel, a neuroscientist known for applying molecular biology techniques to the nervous system. Axel's lab was studying the molecular basis of neural signaling, including work on the nervous system of a sea snail. For Buck, this environment opened a new intellectual landscape.

She became fascinated by the extraordinary diversity of cell types in the brain and by the question of how molecular differences translate into complex sensory experiences. While reading a scientific paper on possible mechanisms of odor detection, Buck experienced what she later described as a life-changing moment. For the first time, she confronted the mystery of olfaction—an everyday human experience that science had barely begun to explain.

In 1988, Buck embarked on what would become one of the most important investigations in sensory biology: the search for odour receptors. At the time, scientists did not know how the nose recognized and differentiated between thousands of distinct smells. The prevailing theories were speculative, and no molecular mechanism had been firmly established.

Buck worked intensely for three years, applying molecular genetics techniques to identify the receptors responsible for odor detection. In 1991, she and Axel published a landmark paper revealing the existence of a large family of olfactory receptor genes.

Their discovery showed that mice possess around 1,000 different olfactory receptors, located in the olfactory epithelium at the back of the nose. These receptors are proteins embedded in the membranes of sensory neurons. Each receptor binds to specific odorant molecules, initiating a signal that travels to the brain. Humans, it turned out, have fewer receptors—around 350—but the basic mechanism is the same.

Solving the problem of odor detection only raised a deeper question: how does the brain interpret these signals to create the rich world of smells we experience? With only 350 receptors, how can humans distinguish among 10,000 or more different odors, many of which are chemically similar?

To answer this, Buck moved to Harvard University, where she continued her research as an assistant professor and later as a full professor. Her focus shifted from the nose to the brain—from reception to perception.

In 1999, Buck uncovered the solution: the olfactory system uses a combinatorial coding strategy. Rather than each receptor corresponding to a single smell, each receptor can respond to multiple odorants, and each odorant can activate multiple receptors. Together, these patterns of activation form a unique "odorant code" for each smell.

Buck's research did not stop at decoding odor patterns. She wanted to understand how these signals are processed in the brain to influence memory, emotion, attraction, and aversion. Unlike other senses, smell has a direct and powerful connection to the brain regions involved in emotion and memory.

"As a woman in science, I sincerely hope that my receiving a Nobel Prize will send a message to young women everywhere that the doors are open to them and that they should follow their dreams."

—Linda Buck

In 2001, Buck published studies showing how olfactory neurons are organized and mapped in the olfactory cortex. These findings revealed that the brain maintains spatial representations of odor information, transforming molecular signals into meaningful perceptions.

This work illuminated why smells can evoke vivid memories, trigger emotional responses, and influence behavior in profound ways. From the comforting scent of home to the warning signal of smoke, olfaction plays a crucial role in survival and identity.

(Fred Hutchinson Cancer Research Center | Science News Releases)

In 2004, Linda Buck and Richard Axel were awarded the Nobel Prize in Physiology or Medicine for their discoveries of odorant receptors and the organization of the olfactory system. The Nobel Committee recognized their work as a foundational contribution to neuroscience and molecular biology.

Two years earlier, in 2002, Buck had returned to her hometown of Seattle, where she established a laboratory at the Fred Hutchinson Cancer Research Center. There, she continued exploring the olfactory system, expanding her research into how smell influences physiology and behavior across species.

For Buck, the Nobel Prize was not an endpoint but a platform. She hoped that her recognition would send a message—particularly to young women—that science is open to them.

"As a woman in science," she said, "I sincerely hope that my receiving a Nobel Prize will send a message to young women everywhere that the doors are open to them and that they should follow their dreams."

Linda B. Buck's work fundamentally changed how scientists understand the sense of smell, transforming it from a poorly understood phenomenon into a well-defined molecular and neural system. Her discoveries revealed how biology translates chemical signals into perception, memory, and emotion—processes that lie at the heart of what it means to be human. ◆

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Illuminating Asia

The Science of Light Across Civilisations

Zahid H Khan

This ten-part series in VIGYAN 2047 traces the journey of light from Indian and Asian civilisational thought to modern scientific understanding, advanced technologies, and future possibilities. Bridging heritage with optics and photonics, it highlights light as a unifying force of knowledge and innovation. ***VIGYAN 2047*** *is honoured to present this series on the science of light and its vast applications.*

— Editor

The human quest to understand light is among the oldest and most universal scientific endeavours. Yet this quest has never progressed along a single, linear path, nor has it belonged to one civilisation alone. Instead, the science of light evolved through a long continuum of observation, experimentation, and conceptual refinement across Asia—shaped by land routes and maritime networks that connected distant cultures of the world, especially Egypt in Africa, Greece in Europe, and West Asia, Central Asia ana South-East Asia in the Asian continent. From the Indian subcontinent to Central Asia, China, Southeast Asia, and the Islamic world, light was studied as illumination, perception, energy, and cosmic regulator. Together, these traditions laid much of the intellectual and practical groundwork for modern optics.

In early Indian thought, light (*jyoti, tejas, prakāśa*) occupied a foundational position in understanding nature. The Vedic worldview placed light at the heart of *rta*, the cosmic order governing regularity and balance. The daily motion of the Sun structured time, while seasonal changes in solar illumination regulated agriculture, ritual calendars, and social rhythms. The Sun (*Sūrya*) was repeatedly described as the "eye of the universe," an expression that fused symbolism with physiological insight—vision depends on illumination. Fire (*Agni*), the terrestrial form of light, revealed another crucial property: transformation. Through controlled fire, early observers encountered melting, combustion, and chemical change, making light inseparable from material processes. These experiences ensured that light was not merely revered but consistently observed and manipulated.

While similar solar-centred cosmologies existed in Mesopotamia and Egypt, Indian thought distinguished itself by encouraging inquiry. Light was not confined to divine agency; it became an object of questioning. This intellectual shift became clearer in the Upanishadic period, when reflection turned toward perception itself. Texts such as the *Brhadāraryaka Upanishad* ask what enables sight when external sources of illumination are absent. Though expressed philosophically, such questions reveal a proto-scientific concern with the conditions of visibility—an issue that would later lie at the heart of optical science.

As Indian philosophy matured, schools such as *Nyāya* and *Vaiśeṣika* approached vision analytically. They asked how the eye perceives distant objects, why reflection occurs, and why light is indispensable for sight. Some thinkers proposed that subtle rays emanate from the eye, while others stressed the necessity of external illumination. Comparable debates took place in ancient Greece, where Euclid and Plato supported emission theories and Aristotle favoured intromission. The significance of these Indian discussions lies not in their eventual resolution but in their framing of vision as a natural, law-governed process, subject to geometry and interaction rather than mysticism.

A decisive transition toward classical optics occurred with the rise of mathematical astronomy. Light now became central to explanation rather than metaphor. This shift is most clearly embodied in the work of Aryabhata (476–550 CE). In the *Āryabhatīya,* Aryabhata explained solar and lunar eclipses as shadow phenomena produced by precise geometric alignments of the Sun, Earth, and Moon. Such explanations presuppose rectilinear propagation of light, predictable shadow formation, and spatial geometry—principles fundamental to geometrical optics. His assertion that the apparent motion of celestial bodies arises from the Earth's rotation further refined the relationship between light, motion, and perception, anticipating later discussions in global astronomy.

Simultaneously, Central Asia—particularly regions such as Bactria, Sogdia, and Transoxiana—emerged as dynamic intellectual crossroads. These areas synthesised Indian astronomical models, Greek geometry, and Persian observational traditions. Scholars refined calendrical calculations, observational instruments, and eclipse predictions, transforming inherited ideas into more precise tools. The Silk Road thus functioned not only as a commercial artery but also as a scientific corridor, transmitting optical concepts across continents.

Parallel developments unfolded in China, where light was understood through the complementary forces of *yin* and *yang*. Unlike purely speculative cosmologies, Chinese science emphasised long-term empirical observation. Chinese scholars maintained some of the world's longest continuous astronomical records, documenting eclipses, comets, halos, and atmospheric optical effects over millennia. Light in the sky was measured, dated, and correlated with seasonal and terrestrial changes, forming a systematic observational science.

One of the most remarkable early contributions to optics comes from Mozi (5th century BCE), whose writings describe the camera obscura. Mozi observed that light passing through a small aperture produces an inverted image—demonstrating an implicit understanding of rectilinear propagation. Similar ideas would later appear in Greek optics and, centuries afterward, in Ibn al-Haytham's experiments, suggesting independent yet convergent discovery of optical principles.

By the Han dynasty, Chinese scholars employed gnomons and shadow-measuring devices to determine solstices, equinoxes, and the length of the year. These methods closely parallel those used in India and the Mediterranean world, reflecting convergent evolution driven by shared practical needs—timekeeping, agriculture, and navigation. Chinese bronze mirrors further demonstrate mastery of reflective optics. Some were engineered to project patterns when sunlight reflected from them, revealing sophisticated control of surface geometry and light behaviour.

As Chinese knowledge moved southward, it encountered the maritime cultures of Southeast Asia. Here, light became central to navigation and environmental understanding. Seafarers relied on

solar altitude, star paths, sky brightness, and water reflections to traverse open seas shaped by monsoons. Such practices demanded acute awareness of atmospheric optics—glare, scattering, and horizon illumination—acquired through cumulative experience rather than formal theory.

Monumental architecture across Southeast Asia reveals another applied dimension of optical knowledge. Structures such as Angkor Wat were designed with precise solar alignments, allowing sunlight to illuminate specific architectural features on solstices and equinoxes. Similar alignments appear in temples across Java and mainland Southeast Asia, embedding optical understanding into sacred space and ritual practice.

The maritime routes linking China, Southeast Asia, India, and the Middle East became powerful corridors of scientific exchange. Astronomical instruments, star charts, calendrical systems, and observational techniques travelled alongside spices, silk, and ceramics. These routes ensured continuity of optical knowledge even during periods when land routes were politically unstable.

This vast body of Asian knowledge entered a transformative phase in the medieval Islamic world during the 8th and 13th centuries during the Abbasid

Civilisation / Region	Time Period	Core View of Light	Understanding of Vision	Key Optical Phenomena Studied	Methods & Instruments	Notable Contributors / Texts
Early Egyptian Mythology	c. 2600 BCE	Light resulting from the eyes of the sun god "Ra".	Light due to opening of the eyes of sun god "Ra", and darkness when "Ra" closes its eyes	It is simply based on the Egyptian mythology	—	Egyptian Mythology books
Early Indian (Vedic–Upanishadic)	c. 1500–500 BCE	Light (*jyoti, tejas*) as cosmic order and life-giving energy	Vision dependent on illumination; early perception awareness	Day–night cycles, solar motion, fire, illumination	Naked-eye observation, fire, ritual instruments	Rigveda, Upanishads
Classical Indian (Astronomical–Philosophical)	c. 500 BCE–600 CE	Light as a physical phenomenon governed by geometry	Mixed emission–interaction ideas; vision requires light	Eclipses, shadows, reflection, atmospheric effects	Gnomons, shadow measurement, geometry	Aryabhata (*Āryabhatīya*), Varahamihira (*Brhat Samhitā*)
Ancient Greek	c. 500 BCE–300 CE	Light as rays or emanations	Strong emission theories (eye emits rays); later intromission	Reflection, perspective, basic geometry	Geometrical reasoning, mirrors	Euclid (*Optics*), Plato, Aristotle
Chinese (Early to Classical)	c. 500 BCE–1000 CE	Light–dark balance (*yin–yang*); natural process	Vision via light entering the eye (implicit)	Image inversion, shadows, atmospheric optics	Camera obscura, gnomons, mirrors	Mozi (*Mo Jing*), Han astronomers
Central Asian (Silk Road Regions)	c. 300 BCE–800 CE	Synthesis of Indian, Greek, Persian ideas	Practical vision models	Eclipse prediction, celestial illumination	Observatories, instruments, computation	Sogdian, Persian intermediaries
Southeast Asian (Maritime Cultures)	c. 500–1500 CE	Light as navigational and ritual guide	Practical perception-based understanding	Solar alignment, glare, sky brightness	Solar navigation, architecture	Angkor Wat planners, maritime traditions
Islamic Golden Age	c. 800–1300 CE	Light as a physical entity governed by laws	Vision occurs when light enters the eye	Reflection, refraction, lenses, image formation	Controlled experiments, camera obscura	Ibn al-Haytham (*Kitāb al-Manāzir*)
Early Modern Europe	c. 1300–1700 CE	Light as wave/ray phenomenon	Intromission fully accepted	Refraction, lenses, telescopes	Optics instruments, mathematics	Kepler, Descartes, Newton
Modern Europe	(17th – 19th Century CE)	Electromagnetic Spectrum; Blackbody Radiation Experiment; Photoelectric Effect	Failure of Wave Theory in explaining Blackbody Radiation Experiment and Photoelectric Effect	Emission Spectrum of Blackbody Radiation; Experiments on Photoelectric Effect	Sophisticated experimental observations	Heinrich Hertz and other scientists
Modern Europe	(1900 CE onwards)	Quantum Nature of Light; Development of Quantum Mechanics from 1925 CE onwards	Light having dual nature – wavelike and particle-like properties	Theoretical developments in Quantum Mechanics	—	Max Planck; Albert Einstein; Niels Bohr; Erwin Schrödinger; Werner Heisenberg; PAM Dirac; Richard Feynman
Modern India (Quantum Era)	20th century	Light as quantum (photon) + wave	Vision understood physically and biologically	Light–matter interaction, scattering	Spectroscopy, experiments	Bose, C. V. Raman

Aryabhata (476–550 CE)

Geometry, Shadows, and the Birth of Classical Optical Reasoning

(IUCAA, Pune)

Aryabhata marks one of the earliest moments when light was treated as a geometrically predictable physical phenomenon. In his seminal work, the Āryabhaṭīya, he explained solar and lunar eclipses as shadow effects arising from precise alignments of the Sun, Earth, and Moon—rejecting mythological explanations.

This explanation implicitly assumes:

- Rectilinear propagation of light
- Predictable shadow formation
- Spatial geometry governing illumination

Aryabhata's assertion that the apparent motion of the heavens results from the rotation of the Earth further refined the relationship between light, motion, and perception. Though he did not write a formal treatise on optics, his eclipse theory represents one of the earliest correct applications of geometrical optics in global science.

Mozi (5th century BCE)

The Camera Obscura and Early Geometrical Optics in China

(Wikipedia)

Mozi stands out as one of the earliest thinkers to describe a phenomenon central to modern optics—the camera obscura. In the Mo Jing (Canon of Mozi), he observed that light passing through a small aperture projects an inverted image of an external scene.

This observation demonstrates:

- Understanding of straight-line propagation of light
- Recognition of image formation without lenses
- Empirical reasoning grounded in everyday observation

Mozi's description predates similar accounts in Greek optics and anticipates later experimental work by Ibn al-Haytham. It shows that core principles of geometrical optics emerged independently in different civilisations through observation rather than abstract theory.

Ibn al-Haytham (965–1040 CE)

(Father of Modern Optics; Father of Applied Psychology)

From Observation to Experimental Optics; Scientific Method

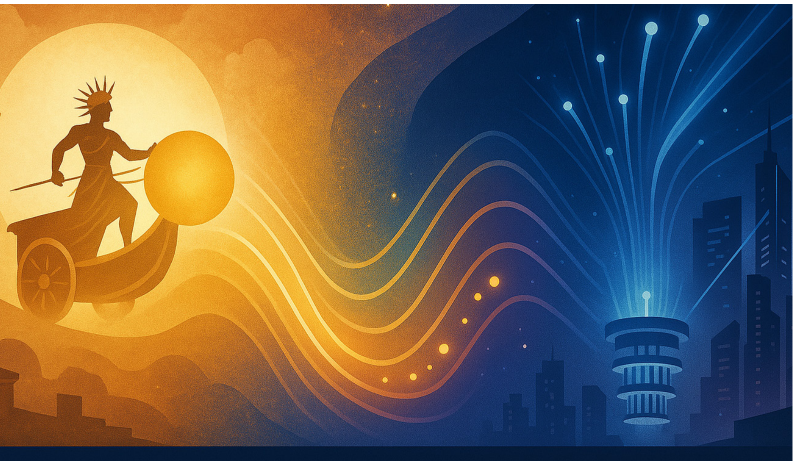
(UNESCO)

Ibn al-Haytham represents a decisive methodological shift in the history of light. In his Kitāb al-Manāzir (Book of Optics), he demonstrated experimentally that vision occurs when light travels from objects to the eye, decisively rejecting emission theories.

His contributions include:

- Systematic experiments on reflection and refraction
- Study of lenses and image formation
- Use of the camera obscura as an experimental device
- Introduction of controlled experimentation in optics

While revolutionary in method, Ibn al-Haytham's work synthesised earlier Indian geometrical reasoning, Central Asian instrumentation, Chinese observational insights, and Greek geometry—transforming optics into a rigorous experimental science.



Caliphate which covered the entire Arab & West Asian countries and Central Asia, with Baghdad as the Centre. Al-Mamun, the Caliph started a research university, "Bait-ul Hikma" in Baghdad, where philosophers and scientists from all enlightened nations of that time, namely Egypt, Greece, Europe, Persia, India etc. were invited to translate the books ion philosophy and science into Arabic. Such philosophers and scientists included included Christians, Jews, Muslims, Hindus and Buddhists. Thus the vast knowledge available throughout the world was made available in Arabic. The knowledge was not confined to mere translated work, but it was further expanded through research for almost six centuries. At the same time the Fatimid rulers in Egypt set up a "Dar-ul Hikma" in Egypt with the same objectives. This gave rise new centres of learning in Persia, Samarkand, and Bukhara. The period from 8th century CE to 13th century CE is referred to as the "Islamic Golden Age Science", during which the entire Europe was in the dark and hence call it as the "Dark Age". It was how all the available knowledge in philosophy and science available from the Indian astronomical computation, Central Asian instrumentation, Chinese observational traditions, and Greek geometry was synthesised. It was within this synthesis that Ibn al-Haytham, who was born in Basra (in the present day Iraq) moved to Cairo in Egypt on the invitation of its Fatimid Caliph, and transformed optics into an experimental science during 1011–1040 CE. During this period, he he wrote the famous book, "Kitab al-Manazir" (Book of Optics) in Arabic in six volumes. By systematically investigated reflection and refraction of light, lenses, and vision and demonstrated that light travels from objects to the eye—resolving centuries-old debates. He also for the first time gave the "Scientific Method" which is almost similar to the method that is adopted for scientific studies. Ibn al-Haytham is considered to be the greatest scientist in 2000 years in between Archimedes and Newton and is called the "Father of Modern Optics". He explained for the first time the large size of the rising moon (Moon Illusion"), explaining that that this is not due to refraction, but it causes due to psychological effect, where the human brain plays an important role. He is therefore also known as the "Father of Applied Psychology".

Through Latin translations, Islamic optics profoundly shaped European science, influencing figures such as Roger Bacon and Kepler. By the time optics entered early modern Europe, it had already passed through Indian, Central Asian, Chinese, Southeast Asian, and Middle Eastern intellectual traditions.

In India, the colonial period disrupted this continuity, marginalising indigenous scientific lineages. The early twentieth century therefore marked not merely India's entry into modern optics but its re-engagement with a long-standing tradition. Satyendra Nath Bose redefined radiation through quantum statistics, while C. V. Raman revealed new modes of light–matter interaction through optical scattering. Their work represents the culmination of a civilisational arc—from shadows and mirrors to photons and quanta.

The story of light is thus not a linear narrative of progress from East to West or ancient to modern. It is a shared human endeavour, sustained by observation, experimentation, and exchange across cultures. As Asia and the world move toward futures shaped by photonics, satellite navigation, and space-based observation, this history reminds us that scientific knowledge often travels quietly—reflected in mirrors, traced in shadows, and guided by the Sun across open seas.

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Tribology as Energy Saver

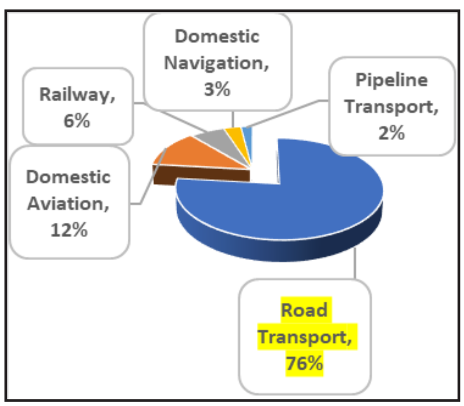
A Case Study of Indian Road Transport Industry

Kamal Mukherjee

Of late importance of limiting the use of energy from fossil source have been felt because of the environmental protection & conditional availability globally. Crude oil has been the main source of primary energy supply globally & it contributes 25% of India's primary energy supply and is the second largest after coal, which contributed 44% of the primary energy supply (IEA, 2021). Currently, India is the world's 3rd largest consumer of oil, 3rd largest LPG consumer, 4th largest LNG importer, 4th largest refiner and 4th largest automobile market. The ultimate thermal energy efficiency is observed as ~1/3rd only. Wear and friction issues are very detrimental as it reduces the machine's efficiency. Dr Jost proposed the potential savings of 515 million UK pounds (1.36% of UK's GNP) in this area through tribology in 1966. We knew from the textbooks of 25 years ago, that the lowest coefficient of friction between two sliding solid surfaces through PTFE (polytetrafluoroethylene) contacts was ~0.08. But with the technology advancement today, it has gone down to the far lower i.e. 0.0005 levels. By applying a thin layer of only a few micrometres (called microns) does not change the component geometry much but improves its both friction and wear (Holmberg & Matthews 2009).

Status on energy usage in—Road Transportation Industry in India

The maximum consumption of energy in transport is i.e. 76% through road transport among railways, aviation, navigation & pipeline etc. in 2023-24 (Fig-1a). High speed diesel (38%) accounted for the largest share of growth in the petroleum products followed by petrol (16%), LPG (13%) and others (Fig-1b) as per BEE India Energy Scenario Report-2024. Thus, efficient use of the fuel oil is of paramount priority.



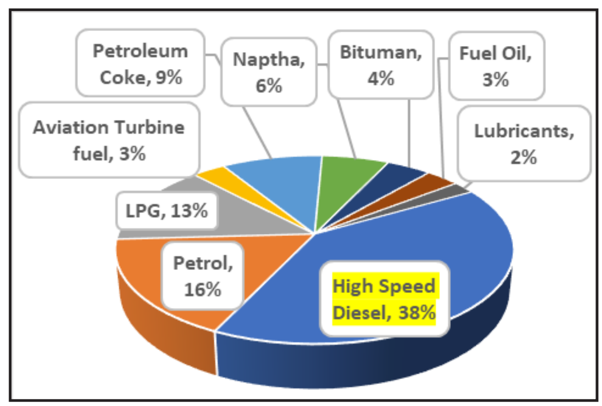


Fig-1a: Sector wise Energy Consumption in Transport in India (2023-24E)
Fig-1b: Consumption of Petroleum products in India (2023-24E)

Frictions and wear status on energy usage, in internal combustion engine (ICE) passengers—Car, Jeep, SUV

As per VAHAN data (MORT&H) of 2022, there are ~ 50 million cars, jeeps, SUVs, taxis in India (world's 1/28th). Inside the ICE the fuel is broken down from liquid hydrocarbons having chemical structure & burnt which releases the gas pressure (Fig-2). Partly it moves the piston to give power to run the car by overcoming both air drag and frictional losses & part of it goes into exhaust gases, mainly CO_2, H_2O, and NO_x. In a typical passenger car, only 20% of the fuel is used to

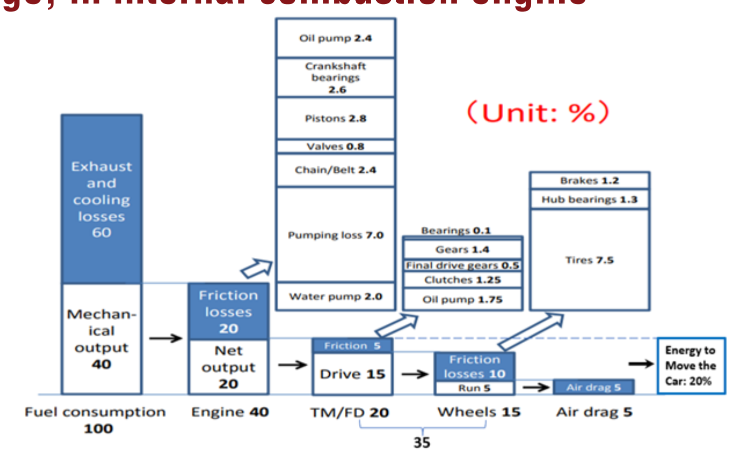


Fig-2: Distribution of energy in ICE driven passenger cars, tank-to-wheel calculations

move the car, and the remaining 80% accounts for the energy losses. To move a car, about 60% energy goes for its cooling & exhaust, 35% is converted to overcome friction loss & 5% to overcome air drag (Fig-2) (Takashi Nakamura, 2017).

Methods for reduction of friction losses in cars of 2020

a) For engine oil pumps—Low viscosity Oil (LVO), b) for main & big end bearings of crankshaft—narrow bearing, texture, surface treatment with low friction coatings, c) for piston & its rings-narrow piston skirt, low ring tension, surface treatment, d) for pumping loss—exhaust gas recirculation, Miller cycle, e) for water pump-seal improvement, electric drive, f) for transmission bearings—downsize, LVO, ball bearing, g) for final drive & gearbox-gears of high accuracy, LVO, h) for wheels—seal improvement, grease for wheel hub bearings, i) tyres of material molecular design, tread etc.

Fuel Consumption of car 2020 in a practical running condition

The fuel consumption of Car 2020 is calculated by using the predicted friction loss reduction rates while considering the threefold improvement and the retroactive effect. The calculated result shows that the fuel consumption for constant velocity running on a 0% slope is 3.09 L/100 km, which is a 49% less from that of Car 2010. i.e. 6.04 L/100 km of Car 2010.

Retroactive effect

As the tire rolling loss is reduced by 10%—the gears or bearings, the motive power that is transmitted by these elements' decreases, and thus, the friction losses of

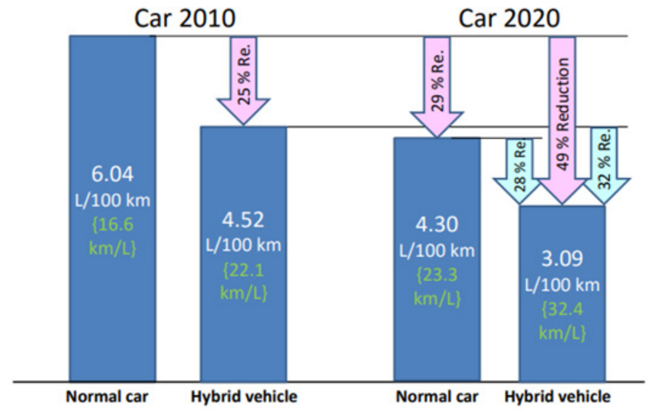


Fig-3: Comparison of fuel savings in a practical running with retroactive effect (Source: T. Nakamura, 2014)

these elements decrease. The calculated result shows that the fuel consumption is reduced by 2.77%, and this means that the contribution rate of the tire is 27.7% (T. Nakamura, 2014)

Impact of a Hybrid Electric Vehicle (HEV)

The main reason for the worldwide popularity of hybrid electric vehicle (HEV) is because it's a typical eco-friendly car. The comparison of performance as shown in Fig-3: a) The fuel consumption of HEV 2010 is lower by 25% with normal 'Car 2010', b) The fuel consumption of normal 'Car 2020' is less by 29% as compared to 'Car 2010' with the friction loss reductions as per tribology, c) The fuel consumption of HEV 2020 is lower by 28% as compared to normal 'Car of 2020' & d) By adopting the tribology, the researchers of Japan found the reduction of 32% in the fuel consumption of the HEV of 2020 (HEV 2020) as compared to that of (HEV 2010), (10-year-old) as shown

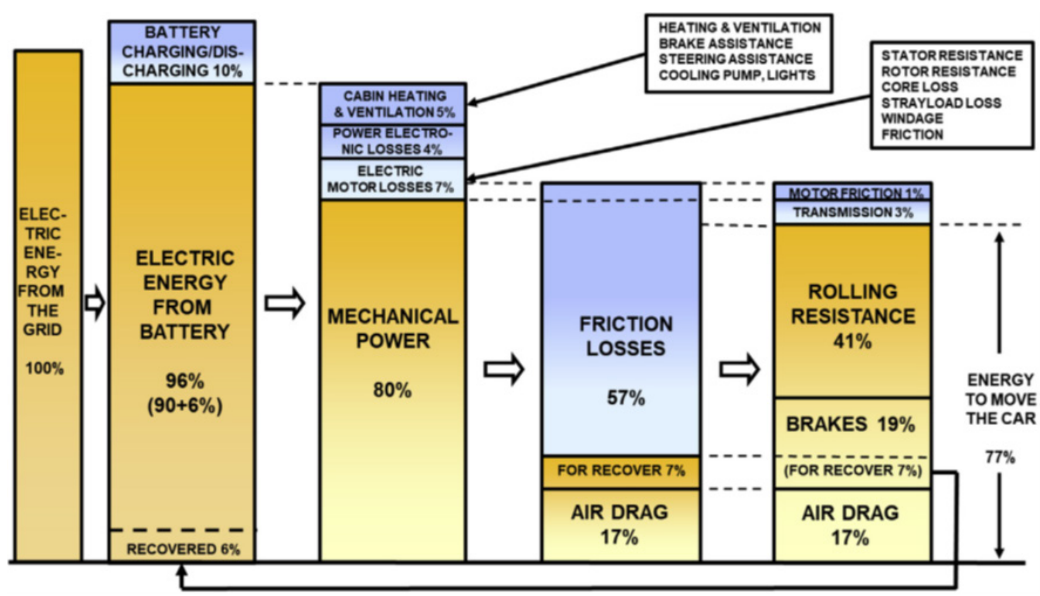


Fig. 4. Breakdown of the energy use in a battery electric (BEC) passenger car, of 2017 grid-to-wheel calculations (ref. K. Holmberg, Ali Erdemir et al.)

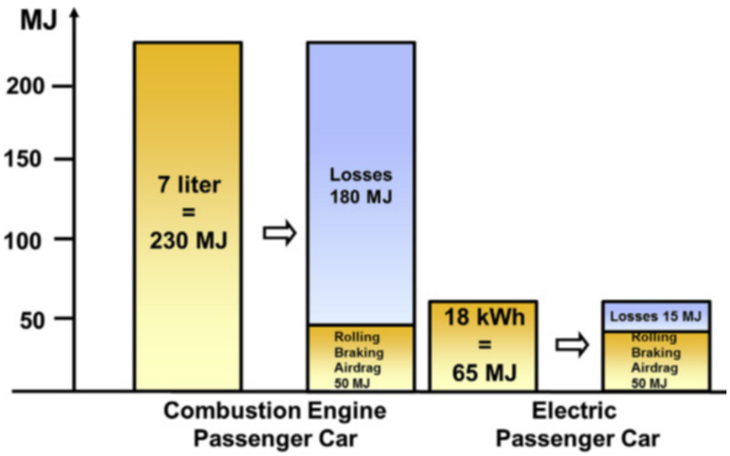


Fig-5. Energy consumption of global average internal combustion engine (ICE) and battery electric passenger cars (BEC) for 100 km driving, tank/grid-to-wheel calculations (ref. K. Holmberg, Ali Erdemir et al.)

in Fig-3 (T. Nakamura, 2014). This is indicative of the future of HEV & its performance in fuel consumption with that of a normal car.

Popularity of E-mobility

The battery electric car (BEC) need about 77% of energy to move and the remaining 23% of energy is used to overcome various energy losses (Fig-4). BEC differ from ICE vehicles in that the combustion engine is replaced by an electric motor, the mechanical transmission system is simplified, electricity storing, charging, and control systems are added and brake energy recovery systems are used. Due to regenerative braking, the kinetic energy is transformed back into electrochemical energy. This is shown as an extra 6% energy input in addition to the 100% electric energy coming from the grid and resulting in 106% energy to be consumed by the car, as shown in the second column from left in Fig-4. The number of e-vehicles will grow to 300 million worldwide by 2040, while at the same time, the number of vehicles with a combustion engine will rise from 1.3 billion to 2.1 billion vehicles (International Energy Agency estimate).

The energy efficiency for the BEC car is 77% which is 3.8 times higher, than 20% for the ICE car (Fig-4). For driving the same distance, the BEC uses only 18 kWh electricity. The rolling resistance is higher for the electric car due to its higher weight (considering additional weight of ~200 kg due to the heavy batteries), but the braking losses are smaller due to the energy recovery system. Finally, both cars require about 50 MJ (Fig-5) for running over 100 km but BEC incurs only 1/12th of ICE losses (Björnsson & Karlsson 2016, Jungmeier et al. 2015).

The whole impact of BEC is very challenging to the development of battery technology, smart charging stations and changes from fossil dominated fuels to renewable fuels.

Global energy consumption due to friction in Trucks, Trailers, Buses & Coaches

As per VAHAN data (MORT&H) of 2020, there are ~71 lakh such heavy-duty vehicles in India (1/50th of world). A comparison of the distribution of energy losses in these four vehicle categories is shown in Fig-6. In heavy duty vehicles ~1/3rd of the fuel energy is used to overcome friction in the engine, transmission, tires,

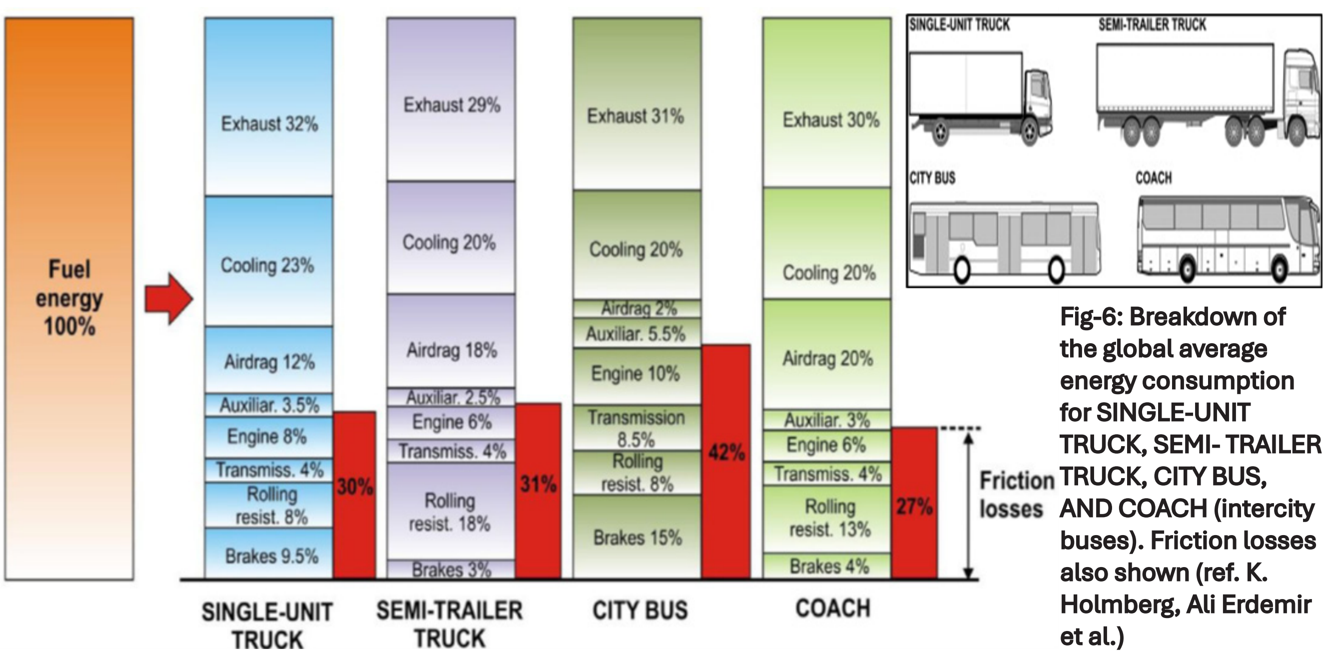


Fig-6: Breakdown of the global average energy consumption for SINGLE-UNIT TRUCK, SEMI- TRAILER TRUCK, CITY BUS, AND COACH (intercity buses). Friction losses also shown (ref. K. Holmberg, Ali Erdemir et al.)

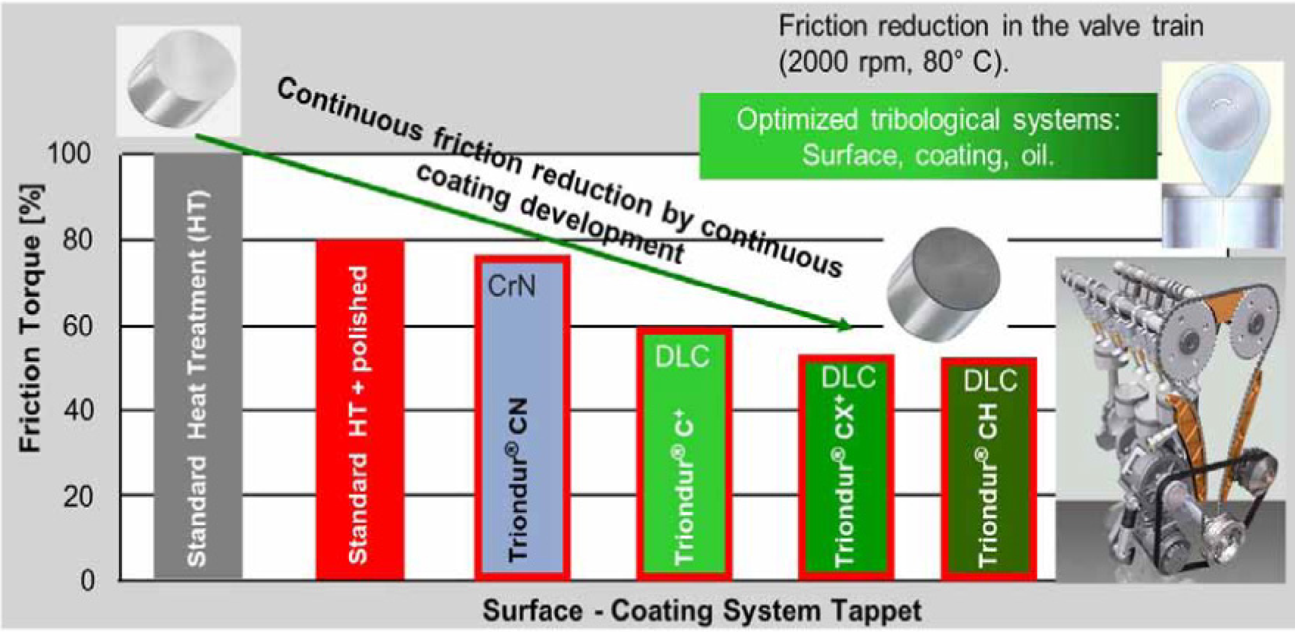


Fig-6: Measures reducing valve train friction (photo: SCHAEFFLER AG)

auxiliary equipment, and braking. The parasitic frictional losses, with braking friction excluded, are 26% of the fuel energy. In total, ~34% of the fuel energy is used to move the vehicle. Reductions in friction losses provide additional advantages in fuel economy and exhaust and cooling losses are reduced as well. Electrification is best suited for city buses and delivery trucks.

Replacement of the traditional dual-tyre installations with wide-base to single tires leads to reduction of energy loss of several percent. The tyre pressure has a considerable effect on the rolling resistance. For truck tyres a 20% reduction in the pressure causes an increase of 5–8% in the rolling resistance and a 2–3% increase in the energy consumption. Battery electric buses are best suited for urban service. For commercial vehicles, the most common applications are city buses and delivery trucks. Interest in electric city buses is currently very high. Coaches and heavy long-haul trucks are not suitable for electrification unless systems are developed for continuous power supply (e.g., catenary or inductive).

New technologies to reduce friction and wear

Low friction coating: The coating applied on the components acts as a safety layer. The advantage of surface coatings has reported a 10-fold increase of fatigue lifetime in rolling contacts, a 7-fold reduction in bearing wear, and a 3-fold increase in gear lifetime (K. Holmberg et al). Most fuel injector plungers used in fuel delivery systems of modern diesel engines are now coated with a durable coating. The change from traditional engineering materials like steel or cast iron to some polymeric, ceramic, or composite materials has been one solution to achieve low friction performance. Thin diamond-like carbon (DLC) and ceramic coatings are good examples of successful friction control technologies that can help to reduce friction coefficients to 0.001 level (Fig-7). **Super lubricity** is a sliding state with nearly zero friction, by definition with coefficients of friction below 0.01. Extremely low friction coefficients (even down to 0.0005) have been measured on nano and microscale with sliding surfaces involving highly hydrogenated and polymerlike DLC films, graphite, graphene and other 2D materials ((Kovalchenko et al. 2004, Klingerman et al. 2005, Ryk & Etsion 2006, Etsion 2012, Etsion & Sher 2009, Ishida et al. 2009, Vlădescu et al 2017).

Changing the surface topography of gears by superfinishing has reduced friction by typically 30%. Fine particle peening of the contacting surface that produces a surface with micro dimples was also found to reduce friction in lubricated conditions by up to 50%. Tungsten carbide (WC, "hard metal") has dominated wear protection for decades and is the standard material of choice for machining applications. Thus, tribology has impacted in reducing the friction & wear which contributed to energy saving in road transport industry. ◆

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Homeopathy and Neurological Disorders

A. K. Gupta

Neurological disorders represent some of the most complex and challenging conditions in medicine. They involve not only structural damage or biochemical imbalance, but also disruptions of coordination, communication, cognition, emotion, and identity itself. Diseases such as Parkinson's disease, multiple sclerosis, epilepsy, stroke sequelae, and motor neurone disease (MND) often progress over years, imposing cumulative physical disability alongside profound psychological and social consequences.

Conventional neurology has achieved remarkable advances in diagnosis, imaging, and acute intervention. Yet in chronic, degenerative, and incurable neurological diseases, therapeutic options frequently remain limited. Disease-modifying treatments may slow progression modestly; symptomatic therapies alleviate selected manifestations; supportive care sustains life and comfort. Still, for many patients, a significant gap remains between what medicine can offer and what they continue to experience.

It is within this therapeutic and experiential gap that **homeopathy has historically found relevance.** Not as a replacement for neurology, but as a system of medicine oriented toward **individualisation, functional balance, symptom coherence, and quality of life.** In neurological disorders—where cure is often elusive and suffering multidimensional—this orientation acquires particular significance.

Modern neurology is grounded in structural localisation and pathophysiology. Lesions are mapped, neurotransmitters quantified, and genetic mutations identified. This framework has brought clarity and precision, particularly in acute and focal neurological conditions.

However, many neurological diseases—especially degenerative ones—cannot be fully explained by lesion location alone. Patients with similar MRI findings may experience vastly different symptom burdens, progression rates, and responses to treatment. Emotional stress, constitutional vulnerability, adaptive capacity, and resilience all influence how disease manifests and evolves.

Homeopathy approaches neurological illness from this broader perspective. Rather than focusing exclusively on the anatomical lesion, it considers **the individual's total response to neurological disruption**—physical,

emotional, cognitive, and behavioural. This does not negate neurobiology; rather, it reframes disease as a dynamic interaction between pathology and the organism's adaptive capacity.

Homeopathy is fundamentally individualised. Two patients with the same neurological diagnosis may receive entirely different remedies, based not on the disease name but on the **pattern of symptoms, modalities, emotional responses, and constitutional tendencies.**

In neurology, where heterogeneity is the norm rather than the exception, this principle has particular relevance. For example, two patients with Parkinson's disease may share tremor and rigidity, yet differ profoundly in anxiety, sleep patterns, thermoregulation, appetite, emotional expression, and disease trajectory. Homeopathy treats these differences as clinically meaningful rather than incidental.

Homeopathic prescribing is guided by the "totality of symptoms"—the coherent pattern formed by physical complaints, mental states, emotional responses, and functional disturbances.

In neurological disorders, this totality often includes:

- Motor dysfunction
- Sensory experiences (even when clinically "normal")
- Emotional changes such as fear, frustration, or apathy
- Sleep disturbances
- Cognitive and behavioural shifts
- Response to stress and environment

This totality provides a therapeutic map that extends beyond neurological examination findings.

Central to homeopathic philosophy is the concept of the **vital force**—the organising principle that maintains physiological balance and adaptive responsiveness. In neurological disease, the vital force is understood as compromised, struggling to maintain coordination between brain, nerves, and muscles.

From this perspective, degeneration is not merely cell death but a progressive failure of regulatory harmony.

Patients with neurological diseases often seek homeopathy for reasons that extend beyond symptom relief. These include:

- Dissatisfaction with limited conventional options
- Desire for holistic, person-centred care
- Need for emotional and psychological support
- Fear of medication side effects
- Hope for slowing progression or improving quality of life

Patient Motivation	Underlying Need
Chronic progression	Desire to slow decline
Incurability	Search for hope and agency
Polypharmacy	Need to reduce side-effect burden
Emotional distress	Holistic psychological support
Loss of control	Individualised care and listening

Homeopathy has historically been applied in a wide range of neurological conditions, particularly those that are chronic, functional, or degenerative. These include:

- Parkinson's disease
- Multiple sclerosis
- Epilepsy (adjunctive)
- Stroke rehabilitation
- Neuropathic pain syndromes
- Motor neurone disease

In these contexts, homeopathy does not claim cure but seeks to:

- Reduce symptom intensity
- Improve functional coordination
- Stabilise fluctuations
- Enhance sleep and energy
- Support emotional well-being

MND represents one of the most challenging frontiers for any therapeutic system. Progressive, incurable, and ultimately fatal, it tests the limits of medicine's capacity to heal.

From a homeopathic standpoint, MND is understood as a profound disturbance of neuromuscular regulation, often reflecting deep constitutional vulnerability. Treatment is therefore cautious, individualised, and focused on **slowing deterioration, alleviating suffering, and preserving quality of life** rather than reversal.

Clinical attention is given to:

- Pattern and pace of progression
- Predominant motor features (spasticity vs flaccidity)
- Bulbar involvement
- Emotional response to illness
- Stress reactivity and coping mechanisms

Clinical Domain	Homeopathic Aim
Motor symptoms	Reduce severity, slow decline
Fasciculations/cramps	Improve comfort
Bulbar symptoms	Support coordination
Emotional distress	Enhance resilience
Sleep/fatigue	Improve restorative capacity

Critics often question the relevance of homeopathy in neurology due to lack of conventional biomarkers. However, several considerations support its exploratory and adjunctive role:

1. **Neurological diseases are multifactorial,** involving genetics, inflammation, oxidative stress, excitotoxicity, and psychosocial stress.
2. **Functional symptoms often precede structural damage,** offering a window for intervention.
3. **Quality-of-life outcomes** are clinically meaningful, even in the absence of structural change.

Emerging research in neuroimmunology and psychoneurobiology increasingly recognises the bidirectional influence between emotional state, stress physiology, and neurological function—an area long emphasised in homeopathic practice.

Aspect	Conventional Neurology	Homeopathy
Primary target	Lesion/pathway	Individual response
Outcome measure	Function, survival	Quality of life, adaptability
Treatment model	Protocol-driven	Individualised
Time horizon	Disease stage–specific	Longitudinal

Homeopathy in neurological disease must function **alongside,** not against, conventional care. Safe integration requires:

- Clear communication between practitioners
- Respect for essential medications (e.g., antiepileptics, ventilatory support)
- Monitoring for disease progression
- Avoidance of unrealistic promises

Homeopathy can be particularly valuable in addressing:

- Fatigue
- Anxiety and depression
- Sleep disturbance
- Appetite and digestion
- Stress-induced symptom exacerbation

Integrative Neurological Care Model

Diagnosis established

▼

Conventional disease-modifying and supportive care initiated

▼

Assess unmet needs (emotional, functional, quality of life)

▼

Introduce individualised homeopathic treatment

▼

Regular reassessment and coordination with neurology team

As neurology increasingly acknowledges complexity, individuality, and patient-centred outcomes, space opens for integrative approaches. Homeopathy's emphasis on totality, constitutional assessment, and long-term observation aligns with this evolution.

Future research—particularly in observational studies, case series, and quality-of-life outcomes—may further clarify where homeopathy fits within neurological care, especially in conditions like MND where therapeutic options remain limited.

Homeopathy and neurology are often portrayed as incompatible systems. In reality, they address different dimensions of the same human experience of disease. Neurology excels in diagnosis, acute intervention, and structural understanding. Homeopathy offers a framework for individualised, holistic care in chronic and degenerative conditions where cure is not possible. When integrated ethically and responsibly, homeopathy does not compete with neurology—it **complements it,** addressing suffering where pathology alone cannot.. ◆

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RESEARCH ARTICLE

The Ubiquitous Revolution: Diving into the World of Plastics

Ankkur Goel

The term "plastic" was derived, during early 1500s, from the Greek word *plastikos* which indicated "to mold" or "form" and was used in while sculpting figures made of wax or clay, reflecting the material's property to be shaped. Another theory mentions that this word comes from Latin word *plasticus* (meaning: capable of moulding). It has been reported that the ancient Meso Americans (Olmec & Mayan civilizations, 1500 BCE) used to mix sap from the rubber tree with juice of morning glory vine to make containers and clothes water-resistant.

Only about a century ago, the word "plastics" became a common term for man-made or synthetic organic, high molecular weight, polymer materials that are moldable at high temperatures and solidify upon being cooled.

Every aspect of our human life is interwoven with the occurrence of some or other kind of plastic material. These highly versatile materials have predominantly restructured our very existence and living style by offering an inexpensive, safe, sanitary, convenient, durable product whose enchanting myriad of applications were nearly unthinkable, till a few decades ago. The advent of plastics, with their endless applications and opportunities, gave the philosophers a utopian vision of the future with abundant material wealth owing to man's capability to shape almost anything and everything as per their whim and fancy.

Even then, this radically innovative material casts an appalling eclipse, posing serious environmental and health concerns. This article is an attempt to dive into the fascinating world of plastics—right from their serendipitous invention to their unescapable existence and the complex trap they have created. This story tries to explore the intricacies of the *toxic love story* between material marvel named 'plastics' and hyperconsumerism.

The genesis: From imitation to innovation

The story of plastics commenced not with any short- or long-term planned research activity, instead, with a pressing need and a dash of ingenuity. In the mid-19th century, a New York based firm by the name Phelan & Collender offered a US $10,000 reward for anyone who could offer a substitute for ivory, the then material of choice for production of billiard balls. Since, the availability of ivory was becoming sparce and highly expensive, due to the rampant slaughter of elephants, therefore, this challenge sparked the curiosity of John Wesley Hyatt, an American printer and inventor. In 1869, Hyatt, experimenting with cellulose nitrate (which was derived from cotton fibers treated with nitric acid), camphor, and alcohol, created a semi-synthetic material which he called "celluloid". While not initially successful for billiard balls (as the early versions sometimes exploded upon impact!), celluloid soon found its niche in

Source: Internet

other applications, like photographic films, detachable collars, dentures etc. thereby, marking dawn of the '*plastic era*'.

However, celluloid was flammable and its properties were fairly limited. The true revolution came in 1907, with the invention of Bakelite by Leo Baekeland, a Belgian-born American chemist. Baekeland had been trying hard to create a non-flammable electrical insulator. By reacting phenol and formaldehyde, under controlled heat and pressure, he produced the first fully synthetic plastic which he termed "Bakelite". Bakelite was found to be moldable, heat-resistant, and an exceptional electrical insulator. The arrival of Bakelite leapfrogged mankind into a new and fantabulous era of human creativity where man could design and produce materials with custom-made properties. Bakelite rapidly pierced the consumer market due to its extensive applications in in diverse sectors and products—right from jewellery to electrical parts and radio casings to kitchenware thereby demonstrating the colossal potential of this synthetic polymer.

This pioneering work ushered mankind into the new world of polymer chemistry, and even before the start of World War-II (around 1930's), several new versatile products like Polyvinyl Chloride (PVC), Polystyrene (PS), Polyethylene (PE) and Nylon were available on the shelf. These new plastics offered a diverse range of properties—right from flexibility and transparency to strength and chemical resistance, thereby, paving way for their amalgamation into innumerable aspects of everyday life.

The revolution: Reshaping our lives

The discovery of this marvel product—plastics—was revolutionary in every possible sense, and truly so because for the very first time, human manufacturing was not constrained by the limits of nature. The era after World War-II witnessed a disruptive increase in the production, regular use and exploring diverse applications of plastics. The grandeur success of US military may be significantly owed to their country's booming plastic industry. For example, Nylon, invented by Wallace Carothers in 1935, was widely used for making parachutes, ropes, armours, helmet liners etc. Similarly, Plexiglas, a shatter resistant plastic, invented in Germany by Otto Röhm, provided an alternative to glass for aircraft windows.

Being lightweight, durable, adaptable, multi-purpose and most importantly the low production cost made plastics an ideal replacement for traditionally used items such as metal, glass and wood. This proliferation of plastics prompted a gigantic alteration in our lifestyle, offering unprecedented convenience, accessibility and seminal change in consumerism.

Healthcare: The advent of disposable syringes, blood bags, catheters, and other medical devices transformed the healthcare sector. These single-use and durable plastics shrunk the risk of infections contributing to improved patient safety and hygiene standards at fairly manageable costs. Even the advanced medical equipment, prosthetics, and implants, needed for enhancing the quality of life of the masses, became highly dependent on plastics. Silicone, an advanced type of plastic (made of molecular chains of silicon and oxygen), is used in breast implants and silicone hydrogels are used for making optical lenses.

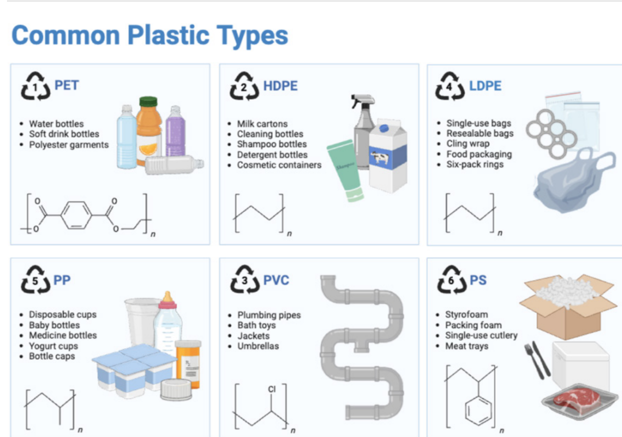
Farm equipment: Agriculture, too, has encapsulated plastics for applications like greenhouse films, irrigation pipes, mulch films, and storage containers. These applications have helped improve crop yields, conserve water, and reduce post-harvest and post-production losses, contributing to food security and availability.

Devices: Electronics became more affordable and accessible due to the use of plastics in casings, insulation, and components. The lustrous and diverse designs of our smartphones, laptops, and televisions have been possible due to the moldability and insulating properties of various polymers. Use of highly cost-effective and durable plastic components in electronic devices has led to their rapid market acceptability.

Packaging: Plastics revolutionized how products were stored, transported and sold. The aspects related to food preservation, transportation of fragile items, shelf life, spoilage & wastage and transportation costs all became exceedingly, both, producer and consumer-friendly, thereby, making a wider variety of products accessible to a larger population. The ubiquitous plastic bag, while now a symbol of environmental concern, initially represented a convenient and hygienic substitute to cloth or paper made bags.

Transportation: The automotive and aerospace industries benefited immensely from the lightweight nature of plastics. Replacing heavier metal components with plastic parts led to improved fuel efficiency in vehicles and reduced weight in aircraft, contributing to energy savings and better performance. From dashboards and bumpers to interiors and structural elements in some advanced applications, plastics have become imperative to modern transportation.

Beyond these major segments, plastics have permeated almost every facet of our lives, from clothing and furniture to toys and construction materials. Their affordability and adaptability has drastically improved the quality of life for communities. Globally, affordable plastic household items have become conventional, nearly replacing the more expensive and less durable alternatives.



Source/Credit: Biorender, Free version

Source/Credit: Biorender, Free version

A kaleidoscope of polymers: The diverse world of plastic types and their uses

The term ‘plastics’ embraces a vast family of synthetic or semi-synthetic materials with a diverse chemical structures and physical properties. Some of the common types include:

- **Polyethylene (PE):** These are the most widely produced plastics, available in numerous densities (HDPE, LDPE, LLDPE) and used in diverse range of products, right from packaging films and grocery bags (LDPE) to bottles and containers (HDPE) and flexible tubing (LLDPE). PE is extensively used in agriculture for irrigation and mulching purposes.
- **Polypropylene (PP):** Known for its strength, durability, hardness and heat resistance, PP is used in reusable food containers, car parts and medical devices. Packaging and automobile sectors have greatly benefited from the diverse applications of PP.
- **Polyvinyl Chloride (PVC):** Versatile and significantly low cost, PVC can be made either rigid (for example in pipes, window frames) or flexible (when used in films, cables, synthetic leather), depending on the additives used during their production process. PVC pipes are common in construction and agriculture, while flexible PVC is an integral part of almost all consumer goods.
- **Polystyrene (PS):** These may either be rigid and brittle (cutlery, electronics casings) or foamed (Styrofoam for packaging and insulation). The uniqueness of PS lies in their being lightweight and insulating thereby, making it properties make it popular for protective packaging and disposable containers.
- **Polyethylene Terephthalate (PET):** The application of PET is mostly in beverage bottles and food containers due to strength, transparency, insulation, wide temperature use range (from –60ºC to 130ºC) and impermeability properties. PET is also used for making light weight, tear resistant textiles and in electrical and electronic industry.

The immense adaptability, customization and personalization properties are the main factors for widespread acceptance of plastics. Research has been ongoing to develop new polymers and refine the existing ones so that even more applications of plastics may be explored.

The manufacturing mosaic: From fossil fuels to finished products

The expedition of every plastic item commences with raw materials, primarily derived from fossil fuels such as crude oil and natural gas. These hydrocarbons (or complex mixtures of organic compounds made entirely of carbon and hydrogen atoms) are processed through refining to produce different kinds of monomers (simple, low molecular weight hydrocarbons), which are the building blocks of polymers. Some of the fairly well-known monomers include ethylene (for polyethylene), propylene (for polypropylene), and vinyl chloride (for PVC). By using the polymerization process, monomers are linked together into long chains, forming the plastic polymer resin. Different catalysts and reaction conditions are used to control the length and structure of the polymer chains, thereby determining the properties of the resulting plastic.

The polymer resins are most often produced in the form of pellets or powders, which is converted into finished products using a variety of techniques, such as injection molding, blow molding, extrusion and thermoforming. Additives, like colorants, stabilizers, plasticizers and flame retardants, are often incorporated into the plastic resins during processing to enhance their properties, appearance, or processability.

The dark side of durability: Environmental and health hazards

The very properties that make plastics so useful—their durability and resistance to degradation—are also the root of their most significant environmental problems. Unlike natural materials that decompose over time, most conventional plastics persist in the environment for thousands of years.

Plastic pollution: Vast quantities of plastic waste end up in landfills, where they not only occupy space but also leach harmful chemicals into the soil and groundwater. These leachates and other plastic wastes enter our water

Source: Internet

Source/Credit: https://www.savehandloom.org/

bodies ultimately millions of tonnes finally invade the ocean each year, thereby polluting and threatening the coastal ecosystems.

Impact on wildlife: Plastic pollution poses a direct threat to wildlife. Marine animals become entangled in plastic debris like discarded fishing nets and plastic bags, leading to injury, suffocation, and drowning. They often mistake plastic items as food, leading to choking, internal injuries and starvation due to the digestive systems getting blocked.

Emission of Greenhouse Gases (GHGs): The entire lifecycle of plastics, right from the extraction of fossil fuels to their production, transportation, and disposal (particularly of through the incineration route), contributes significantly to emission of GHGs, thereby exacerbating climate change. While plastics are often touted as lightweight alternatives that can reduce transportation emissions, the sheer volume of plastic produced and its miserable end-of-life management contribute significantly to their overall carbon footprint. As per 2019 estimates, plastics are responsible for around 3.3% of global GHG emissions (*Hannah Ritchie, Our World in Data, October 2023*).

Toxicity: Several chemicals used during the production of plastics like phthalates, bisphenol A (BPA), nonylphenols (NPs), dioxins, furans, heavy metals and flame retardants, have high potential to leach out of plastic products and spread into food, water and environment. These chemicals are notorious endocrine disruptors, thereby having the potential to play havoc with the body's hormonal system, leading to a range of adverse health effects. Microplastics and the leachates from chemical additives are known causative agents for developmental arrests, neurotoxicity, reproductive issues and even several types of cancers. Research has already proven that leachates from plastics are causative agents for increased mortality in marine organisms, induce cell damage (cytotoxicity), inhibit photosynthesis & bioluminescence and cause oxidative stress.

Micro- & Nano-Plastics (MNPs): Gradually as the plastic products break down due to sunlight, wind, and wave action, they fragment into smaller and still smaller pieces called microplastics (less than 5 mm in size). These persistent MNPs are omnipresent and found in the air we inhale, the water we quench our thirst with, and soil that grows our food. They are ingested by marine organisms, from plankton to fish and seabirds, leading to physical harm, bioaccumulation of toxins and disruption of the food chain. Studies have also shown the presence of microplastics in human tissues and organs, raising concerns about serious health impacts.

The prestigious journal *Nature Medicine* reported in their April 2025 issue about the increasing MNP bioaccumulation overtime (from autopsy specimen samples of 2016 and 2024, collected retrospectively) in human brain, kidney and liver tissues. These researchers have also reported notable deposition of micro- and nano-plastics in cerebrovascular walls and immune cells (*Nat Med 31, 1114–1119 (2025)*). Another study conducted by Hu C. *et al.*, which was published in the Journal of Toxicological Sciences, reported the presence of microplastics in male reproductive system (testis) of canines and humans and ascertained that the total microplastics were nearly 3 times greater in human testes than in canine tissues, predominated by Polyethylene (PE). Other studies have established that microplastics translocate across the blood-brain barrier and have been detected in human blood.

The Indian scenario: A unique set of challenges and innovations

India faces a unique set of challenges in managing plastic waste due to its large population, rapid urbanization, and complex unorganized, frail informal waste management sector. Our Nation generates colossal quantities of plastic waste, and while recycling rates are relatively high compared to some developed nations, a substantial portion still ends up uncollected and utterly mismanaged, contributing to environmental hazards and degradation.

The informal sector, mostly ragpickers (waste pickers), play the imperative role in collecting and sorting recyclable plastics in India. This labour-intensive system, while providing

Source: Internet

livelihoods for millions, often operates under perilous conditions and lacks adequate infrastructure and social safety nets. However, there are growing efforts to integrate the informal sector into formal waste management systems and improve their working conditions.

Indian government has implemented various regulations and initiatives to address the plastic waste problem, including ban on single-use plastics in several states, as well as Plastic Waste Management Rules (2016 and the amendments thereafter) that mandate producers' responsibility for the collection and processing of plastic waste (Extended Producer Responsibility or EPR). The effectiveness of these measures might have been limited with significant challenges still lingering in their effective implementation and enforcement.

The solitary silver lining that remains in such grim conditions is that our Nation is investing heavily on finding innovative R&D solutions to tackle the menace created by plastics, and these efforts are equally complemented through expansive grassroot level initiatives. Public and Private sector organizations, hand-in-hand with progressive mindset individuals and philanthropists, alike, are bidding hard to evolve alternative materials, promoting waste segregation, reduction and reuse practices, and finding creative ways to upcycle (refine, deploy, reuse) plastic waste into useful products, such as furniture, handicrafts, construction materials and laying of bituminous roads.

Charting a sustainable course: The future of plastics

Addressing the crucial threats posed by plastics requires a multi-pronged approach involving extensive technological innovation, policy changes, consumer behavioural shifts, industry alliances, and trans-boundary collaborations.

Reducing consumption and promoting reuse: Though easier said than done, the prime and most efficient way to curb plastic pollution shall be to reduce our dependence on single-use plastics and instead embark upon and promote reusable alternatives. For example, encouraging and incentivizing the use of reusable bags, glass bottles, containers and cutlery shall significantly shrink the amount of plastic waste generated. In India, traditional practices of carrying reusable containers and net baskets (often made from cane or straw) for shopping and food need to be revived, socially accepted and promoted.

Developing & enhancing waste management and recycling infrastructure: There is a prudent need to invest profoundly in robust and dependable waste collection system, comprehensive sorting techniques (including semi-automation), and greener recovery-cum-recycling processes. Our government and private sector need to work hand-in-hand towards enormously enhancing the present meagre capacity and efficiency of the recycling facilities (including their decentralization), and developing innovative eco-friendly recycling processes & technologies that have the potential to handle diverse categories of plastic wastes. Formalizing, encouraging, incentivizing and capacity building of the informal waste management sector shall certainly create greener footprints by improving recycling rates.

Developing biodegradable and compostable alternatives: There is a pressing need and clarion call to substantially commit our resources (funds, focus, time and innovation) into development and deployment of environmentally acceptable, biodegradable and compostable plastics, and its alternatives, which should be originate and be derived from renewable resources. Exploring and promoting the development and use of such alternatives is the ultimate call of the hour.

Harnessing greener chemical recycling processes: Chemical recycling, which breaks down plastics into their its building blocks that can then be used to produce either fresh usable plastics or associated chemicals, holds a promising potential for dealing with plastic waste that is otherwise difficult to recycle through mechanical routes. S&T and engineering advancements in filling the knowledge-gaps related to this field might offer promising ways to effectively close the loop on plastic production and subside our dependence on the non-renewable fossil fuels.

Strengthening regulations and enforcement: Our esteemed Parliament and the pillars of our democracy, in unison, need to work towards development of stringent norms and policies to implement and enforce stricter legal frameworks and regulations on the production, use and disposal of plastics. Proper and expansive implementation of the Extended Producer Responsibility (EPR) schemes that hold producers accountable for the end-of-life management of their products are equally decisive in the achieving long term sustainable and replicable success stories. Synchronizing all-inclusive agreements, cooperation and collaborations at local, regional and international levels shall be equally mandatory to address the menace of plastic pollution.

Raising social awareness, public participation and fostering behavioural transformation: Educating the public about the environmental and health impacts of plastic pollution and promoting sustainable consumption habits are of utmost essence. Empowering individuals and involving local communities for capacity building shall certainly facilitate the public in making informed choices. Raising social awareness amongst the masses and enabling them to showcase participative decision-making roles shall surely inculcate transformative responsible behaviour patterns, thereby enabling reduction of single-use plastic consumption and proper waste disposal thereby embossing a noteworthy difference.

Conclusion: Navigating the plastic paradox

Without an iota of doubt, it can be stated that plastics revolutionized our lives, bringing unprecedented convenience and innovation across a multitude of sectors. However, their persistent nature, sheer scale of production, and more importantly, the irrational, imprudent and impulsive consumption have created significant environmental and health catastrophe. Addressing this challenge requires a phenomenal shift in how the society produces, uses, and disposes of plastics. By embracing a circular economy model, investing in sustainable, eco-friendly alternatives, robust greener waste management systems, fostering responsible consumer behaviour, and implementing effective policies, the world can navigate the plastic paradox and work towards a future where the benefits of these versatile materials are realized without compromising the health of our planet and ourselves.

The journey from the accidental invention of celluloid to the ubiquitous presence of plastics is a testament to human ingenuity. Now, we must apply that same ingenuity to create a more sustainable relationship with this material marvel. ◆

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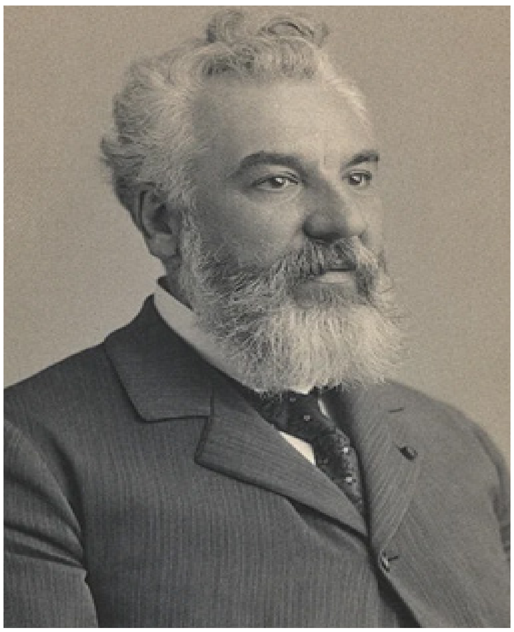
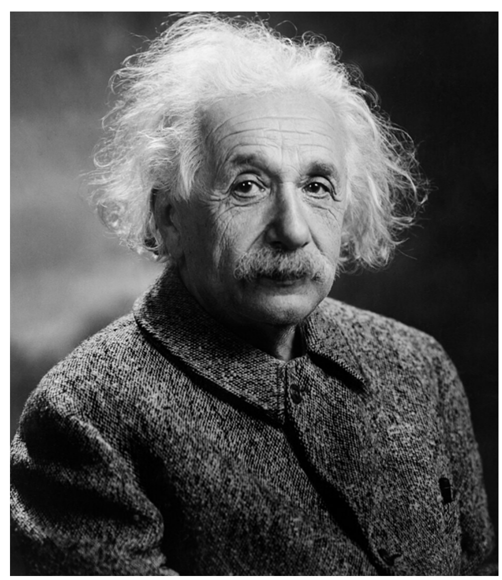
Celebrating the March Born Scientists

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.



Alexander Graham Bell was born on March 3, 1847 and was a Scottish-born Canadian-American inventor, scientist, and engineer who is credited with patenting the first practical telephone. He also co-founded the American Telephone and Telegraph Company (AT&T) in 1885. His research on hearing and speech further led him to experiment with hearing devices, which eventually culminated in his being awarded the first U.S. patent for the telephone, on March 7, 1876. Bell considered his invention an intrusion on his real work as a scientist and refused to have a telephone in his study. Many other inventions marked Bell's later life, including ground-breaking work in optical telecommunications, hydrofoils, and aeronautics. Bell also had a strong influence on the National Geographic Society and its magazine while serving as its second president from 1898 to 1903. Beyond his work in engineering, Bell had a deep interest in the emerging science of heredity. His work in this area has been called "the soundest, and most useful study of human heredity proposed in nineteenth-century America ... Bell's most notable contribution to basic science, as distinct from invention."



Albert Einstein was born on March 14, 1879 and was a German-born theoretical physicist widely regarded as one of the most influential scientists of all time. He is best known for developing the theory of relativity, which transformed our understanding of space, time, and gravity. Einstein also made major contributions to quantum theory. His mass–energy equivalence formula, $E = mc^2$, derived from special relativity, is often described as the world's most famous equation. In 1905, Einstein published four groundbreaking papers. These works explained the photoelectric effect, described Brownian motion, introduced special relativity, and demonstrated that mass and energy are fundamentally equivalent. For his explanation of the photoelectric effect, Einstein received the 1921 Nobel Prize in Physics for his services to theoretical physics. In 1915, he proposed the general theory of relativity, extending his earlier work to include gravitation. A paper published the following year explored the implications of this theory for the structure and evolution of the universe and introduced the cosmological constant, marking an early step in modern cosmology. In 1917, Einstein also introduced the concepts of spontaneous and stimulated emission, which later became central to the development of lasers and masers.

Kalpana Chawla was born on March 17, 1962 and was an Indian-American astronaut and aerospace engineer who was the first woman of Indian origin to fly to space. Chawla expressed an interest in aerospace engineering from an early age and took engineering classes at Dayal Singh College and Punjab Engineering College in India. She then traveled to the United States, where she earned her MSc and PhD, becoming a naturalized United States citizen in the early 1990s. She first flew on the Space Shuttle Columbia in 1997 as a mission specialist and robotic arm operator aboard STS-87. Her role in the flight caused some controversy due to the failed deployment of the Shuttle-Pointed Autonomous Research Tool for Astronomy ("Spartan") module. Chawla's second flight was in 2003 on STS-107, the final flight of Columbia. She was one of the seven crew members who died in the Space Shuttle Columbia disaster when the spacecraft disintegrated during its reentry into Earth's atmosphere on February 1, 2003. She was posthumously awarded the Congressional Space Medal of Honor, the NASA Space Flight Medal, and the NASA Distinguished Service Medal. Several buildings, spacecraft, and extraterrestrial landmarks have been named in her honor.

Amalie Emmy Noether was born on March 23, 1882 and was a German mathematician who made many important contributions to abstract algebra. She also proved Noether's first and second theorems, which are fundamental in mathematical physics.[4] Noether was described by Pavel Alexandrov, Albert Einstein, Jean Dieudonné, Hermann Weyl, and Norbert Wiener as the most important woman in the history of mathematics. As one of the leading mathematicians of her time, she developed theories of rings, fields, and algebras. In physics, Noether's theorem explains the connection between symmetry and conservation laws. Noether was born to a Jewish family in Erlangen, daughter of mathematician Max Noether. After earning her doctorate in 1907 under Paul Gordan, she worked without pay, reflecting barriers facing women. In 1915 David Hilbert and Felix Klein invited her to Göttingen, where she lectured under Hilbert's name until habilitation in 1919. Noether became a central figure in abstract algebra, mentoring the "Noether Boys." Her 1921 paper on ideals founded modern commutative algebra and introduced Noetherian objects. Noether's theorem linked symmetries and conservation laws in physics. Dismissed by the Nazis in 1933, she continued influential teaching and research in America. while Noether's theorem has widespread consequences for theoretical physics and dynamical systems. Noether showed an acute propensity for abstract thought, which allowed her to approach problems of mathematics in fresh and original ways.

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BroadMind Brainwonders

Advancing Scientific Career Guidance through Psychometric Testing and DMIT

A Timely Step Towards Evidence-Based Career Guidance Solution

As education systems evolve to meet the demands of a rapidly changing global workforce, the need for scientific, personalised, and future-oriented career guidance has never been greater. Traditional methods of judging students primarily through academic marks are increasingly proving inadequate in identifying true potential, learning styles, and long-term suitability for careers. In this context, BroadMind Education Consultant has taken a significant step by becoming an authorised centre of Brainwonders, bringing scientifically validated psychometric and DMIT-based assessment frameworks to students, parents, educational institutions, and professionals across the region. This collaboration aims to strengthen evidence-based career guidance, ensuring that decisions about education and careers are informed by objective insights rather than assumptions or social pressure.

The Need for Scientific Guidance in Modern Education

Today's learners face complex choices at multiple stages selecting subjects after Class 10, choosing streams after Class 12, deciding on higher education pathways, or even changing careers mid-life. Parents and educators, too, often struggle to guide students effectively due to rapidly emerging career options, evolving skill requirements, and a lack of structured decision-making frameworks.

As a result, many students experience:

- Career confusion and anxiety
- Mismatched course selections
- Academic disengagement
- Dropouts or repeated career shifts

Who is Brainwonders? A Pioneer Since 2011

Founded in 2011, Brainwonders has been a pioneer in applying scientifically validated, India-normed psychometric and DMIT (Dermatoglyphics Multiple Intelligence Test) frameworks within education and career guidance. The organisation introduced a structured approach to understanding learners through a combination of psychology, neuroscience, genetics, and behavioural science.

BroadMind

BroadMind's Role: Bringing Science to the Ground Level

Through this collaboration, BroadMind Education Consultant functions as an authorised centre of Brainwonders, responsible for promoting, administering, and interpreting psychometric, aptitude, and DMIT assessments. What makes this partnership impactful is the complementary strengths it brings together:

- Brainwonders' research-driven assessment expertise
- BroadMind's counselling experience and on-ground implementation capabilities

At BroadMind Brainwonders, assessment insights are not treated as mere reports. Instead, they are translated into practical academic, career, and developmental guidance, ensuring real-world relevance for students and families.

Understanding Psychometric Testing: Mapping the Acquired Self

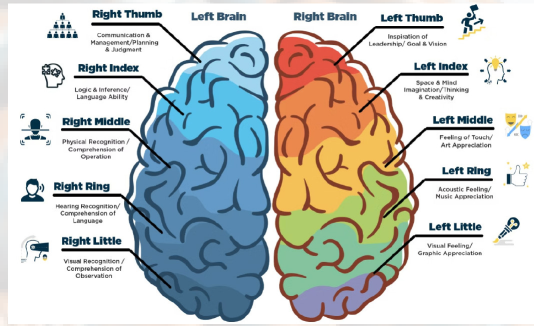
Psychometric tests are standardised scientific tools used to measure an individual's interests, aptitude, personality traits, and behavioural tendencies. Unlike academic exams that measure performance at a specific time, psychometric assessments explore how a person thinks, learns, and works.

At BroadMind Brainwonders, psychometric assessment typically includes: Together, these assessments help identify acquired strengths shaped by learning, exposure, and experience.

Introducing DMIT: Understanding the Inborn Self

While psychometric tests assess developed abilities, DMIT focuses on inborn potential.

Dermatoglyphics Multiple Intelligence Test (DMIT) is a non-invasive scientific assessment that analyses fingerprint patterns, which are genetically formed during early pregnancy and remain unchanged throughout life. Since fingerprints and the brain originate from the same embryonic layer, fingerprint patterns reflect neurological wiring and intelligence distribution.



Brain Mapping and the Five Brain Lobes

DMIT provides insights into the functioning of:

- Pre-Frontal Lobe 3 Leadership, communication, planning, vision
- Post-Frontal Lobe 3 Logic, language, creativity
- Parietal Lobe 3 Motor skills and coordination
- Temporal Lobe 3 Language comprehension and musical ability
- Occipital Lobe 3 Visual observation and imagery

The Power of Integration: Psychometric + DMIT

When psychometric assessments (acquired traits) are combined with DMIT (inborn traits), the result is a 360-degree understanding of the learner. This integrated approach answers three critical questions:

- What do I like? (Interest)
- What can I do well? (Aptitude)
- What am I naturally wired for? (Inborn intelligence)

  Such clarity significantly reduces trial-and-error in education and career planning.

Who Benefits from This Scientific Approach?

Students
Clear direction and confidence
Better alignment between ability and aspiration
Reduced stress and confusion

Parents
Scientific basis for guidance
Long-term clarity and assurance
Reduced conflict in decision-making

Educational Institutions
Objective student profiling
Personalised learning strategies
Improved academic engagement and outcomes

Employers
Better person role alignment
Improved productivity and retention
Job Seekers
Career clarity and suitability
Informed career transitions

BroadMind Brainwonders: A Comprehensive Guidance Ecosystem

At BroadMind Brainwonders, these methodologies are integrated into a structured guidance ecosystem supporting learners from early schooling through higher education and career decision-making. Assessments are followed by expert interpretation and counselling, ensuring that insights lead to actionable outcomes.

Since 2011, Brainwonders has emphasised ethical assessment, research-backed methodology, and professional interpretation for values that are carried forward through BroadMind's authorised centre. The shared mission is clear: to transform potential into purpose.

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