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What's Inside

COVER STORY

Image Courtesy: Wikimedia Commons

The first part of a series on Indian music explores musical instruments of the country, their evolution and importance in the growth of music traditions

Cover Image: Shutterstock

RESOLUTION PASSED AT THE 6TH RASHTRIYA ADHIVESHAN AND AGM OF VIBHA AT MIT-ADT UNIVERSITY IN PUNE, 21-23 JUNE 2024

Teacher as a mentor for Transformation in Education

The rich heritage of Bharat, in terms of knowledge, wealth and wellbeing of its people is widely acknowledged today. A scientific perspective, incorporating 'vidya' and 'avidya' in different walks of life, be it arts, architecture, lifestyle or philosophy, has been its unique identity. This tradition has been both sustained and enriched by the contributions of the great teachers of our society. The Vedas and the Upanishads are replete with anecdotes of the 'Guru' who guided the disciple towards ultimate reality, dispelling all illusion. Our philosophy as expressed in 'Vasudhaiva Kutumbakam' and 'Matha Bhoomi, Puthroham Prithivya' are manifestations of this perspective. This all-encompassing perspective had placed Bharat at a very high pedestal among the comity of nations. And yet again it is finding resonance across the world today.

The future of any society depends on the quality of contemporary knowledge exchange and learning process. We regarded education as the manifestation of the perfection already there in every human being. In a world passing through increasing tensions, fractured societies, calamities from climate change and increasing inequalities, the message of universal brotherhood, not just among mankind but across all beings is destined to lay out the roadmap for the coming decades and beyond. The need for transformation in our education, by connecting our ancient knowledge to the contemporary lifestyle for creating a bright future, is most relevant today.

And this transition may require modifications in lifestyle. Even otherwise, it has been our tradition to minimize requirements and regard development which transfers today's problems to a future date as simply unsustainable.

A teacher also needs to encourage logical thinking that emanates from observation, evidence and its analysis. Experiential learning needs to be incorporated. It leads to independent thinking and a zeal to look at actual picture of reality. Scientific vision thus evolved, helps us look at challenges of life in a very pragmatic way and lays down priorities of an individual and society. It also results in synergic development of the individual and society with the environment.

The National Education Policy 2020 (NEP 2020) paves the way for this transformation. And the teacher is at the centre of this. The role of a teacher in today's context is on a different stature as compared to that of a 'Guru'. Every society prepares teachers in order to protect and propagate its wealth of knowledge and heritage and hence to propel its progress. The System of Education, Teacher and the Society are interdependent in this cycle. In terms of behavior and practice, the teacher acts as a role model to both students and society at large, apart from his knowledge and the ability to impart the same. Teachers mould education and education moulds a society.

It is inevitable that knowledgeable and capable teachers with a scientific perspective, character and exemplary value systems need to be groomed and also empowered. It is also important that the society bestows teaching community the respect it deserves. Vijnana Bharati calls upon the authorities to give it requisite emphasis. We also call upon various agencies in the educational sector, educational authorities, civil society organisations and the public in general to contribute in every possible way to help realise the dream of Swavalambi Viksit Bharat by such transformation in education.

Send your letters to editor@scienceindia.in

Let's Connect

Dear Readers,
As monsoon rains bring us respite from the particularly excruciating heat wave of this summer, we send our esteemed readers greetings for the lovely Varsha Ritu.

This season, indeed, is distinct from all the other seasons of the year. One of the six seasons of the Indian subcontinent, as per the Hindu calendar, Varsha Ritu is the most magical as this is when the heavens connect with humans through thirst-quenching rain drops. Rains, in turn, bring music. The whole nature comes alive with the music of the rain drops, imbuing the atmosphere with a positivity and a song that no human creation can match. No wonder, some of the most evocative music has been composed in an ode to the months of Saavan and Bhadon (Shravan and Bhadrapada), the monsoon months spanning over July through September.

Music, incidentally, is also the subject of this edition's cover story. The first of a three-part series on music that we will carry in the subsequent editions of *Science India*, this story explores the science behind the rich indigenous musical instruments of India. The country's great music traditions, the Hindustani and Carnatic classical as well as the sweet and complex folk traditions, have been nurtured and enriched by a wide array of musical instruments, some of which originated in this land while some arrived from outside but were indigenised over centuries. An example is violin, an integral part of Western classical traditions but also a part of Carnatic classical tradition since the end of the 18th century.

While still on heritage, another intense read is an in-depth and exclusive interview with Chandrakant B Sompura, the Principal Architect of the epochal Ram Mandir of Ayodhya. He shares in detail the extraordinary journey of the making of this temple, which seemed a non-starter for decades for various reasons. Sompura is a 15th generation architect from a family of traditional temple-builders of the Nagara style, and is marking his signature, not just in India but important cities the world over.

No mention of science in India can ever be complete without discussing the country's continuous achievements in the space sector. This edition, we talk about Agnikul Cosmos, a space startup based in Chennai that has created a record by launching the world's first single piece 3D-printed rocket, appropriately titled Agnibaan. Young and raring to go, newbie space startups of India such as Agnikul Cosmos, Skyroot and others, are proof of how 'atmanirbharta' in research in this sector over the past several decades has resulted in spreading of the scientific temper far and wide, inspiring and igniting young minds.

The newbie space startups of India are proof of how 'atmanirbharta' in research in this sector over past several decades has resulted in spreading of the scientific temper far and wide, inspiring and igniting young minds

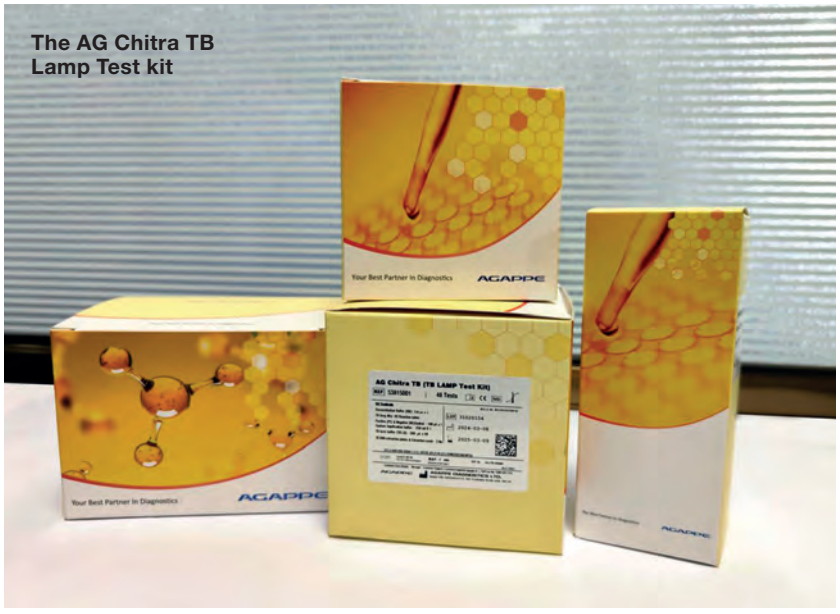
In another story, we present the novel and ever-expanding domain of bioceramics, which are proving crucial in biomedical engineering. By mimicking the natural human bone, bioceramics are able to provide interventions that are safer, sturdier and longer-lasting than implants from other sources.

When there is such all-encompassing progress taking place in science, why is it that some of our true scientific stalwarts remain unsung and unheralded, not just globally but within our own country? It's a tragic tale that gets repeated over and over again as one flips through the pages of India's science history. We profile two such individuals in this edition — Prof Jnanendra Nath Mukherjee and Dr Dhiman Barua. The readers are likely to ask at this instance, who were these individuals? That's precisely the reason why we urge you all to read their life stories, to feel awe over their achievements and also a bit of rancour for the way they were ignored while they lived. It's some solace that they continue to be honoured through their enduring contributions.

The Indian Meteorological Department has forecast above normal rain this season, with favourable La Nina conditions expected to set in by August-September. A La Nina year, like this one, brings good rainfall. We hope you will enjoy this season with a hot beverage and snacks, and this edition of *Science India*.

Innovative and Affordable Indigenous Tuberculosis Diagnostic Kit

Early and cost-effective detection of tuberculosis is vital to arrest the disease in a country like India, which accounts for nearly 25% of the world's TB cases



The AG Chitra TB Lamp Test kit

Images Courtesy: Dr Biju Dharmapalan

■ Dr Biju Dharmapalan

Tuberculosis (TB), an infectious disease caused by bacteria *Mycobacterium tuberculosis*, remains a significant global health issue, with millions of new cases and deaths reported each year. The World Health Organization (WHO) classifies TB as a priority infectious disease as it is so difficult to diagnose and treat. According to WHO Global Tuberculosis Report 2023, an estimated global total of 10.6 million people fell ill with TB in 2022, equivalent to 133 incident cases per 100,000 population. According to the same report, 1.3 million people succumbed to the disease in 2022.

TB BURDEN

With an estimated 2.64 million cases in 2021, India accounts for about 25% of the world's TB burden. In 2023, India saw an improvement in its TB notification numbers compared to 2022, with 2.5 m TB cases reported. Of these, 1.6 m cases were notified by the public sector, while the private sector reported 838,116 cases. The public sector achieved 93% of its TB notification target, whereas the private sector reached 89%. According to WHO, India has the highest burden of TB, with two deaths occurring every three minutes from TB. These numbers underscore the ongoing challenge of TB control and the need for sustained efforts to prevent, diagnose, and treat the disease effectively.

Tuberculosis predominantly impacts the pulmonary system, although it can also affect other anatomical organs, including the kidneys, spine, and brain. TB involves airborne transmission, wherein an individual afflicted with the disease expels minuscule droplets containing the bacterium through coughing or sneezing. When an individual breathes in these tiny liquid particles, the bacteria can establish themselves in the lungs and commence reproduction. The majority of individuals who contract TB do not immediately develop active disease. Instead, they acquire latent TB infection, wherein the bacteria reside in their bodies but remain dormant and do not produce any symptoms. However, in certain circumstances, particularly when the immune system is compromised, the bacteria might become active and result in the development of tuberculosis disease. TB is a significant public health issue. However, it can be prevented and treated with suitable measures such as immunisation (using the Bacille Calmette-Guérin or BCG vaccine), early detection, and successful treatment.

DETECTION AND PREVENTION

Conventional detection procedures, including smear microscopies, are frequently inconclusive due to their extremely low sensitivity. The nucleic acid amplification test (NAAT) is a fast TB

screening test that can identify TB bacteria from sputum samples in under three hours. PCR-based tests, such as CB-NAAT and Truenat, can be used to confirm instances of tuberculosis that have tested positive. While these technologies exhibit excellent accuracy, their capacity is limited to simultaneously processing only a few samples. Additionally, they are designed as closed systems, meaning they require a specific PCR machine to complete the process. Furthermore, these technologies are expensive.

Dr Anoop Kumar Thekkuveettil and his team at the Division of Molecular Medicine, BMT wing, Sree Chitra Tirunal Institute for Medical Sciences and Technology (SCTIMST) in Thiruvananthapuram have made a significant breakthrough in making early detection cost-effective. They have created a new nucleic acid amplification test to use the current PCR testing infrastructure. This has the potential to revolutionise the screening process for pulmonary TB on a big scale. The AG Chitra TB diagnosis kit employs a loop-mediated amplification methodology (LAMP) to amplify DNA isothermally. Contrary to polymerase chain reaction (PCR), which necessitates cycling through several temperature stages, LAMP amplifies DNA or RNA at a consistent temperature, usually about 60-65°C.

The LAMP reaction depends on a DNA polymerase that can displace strands and a group of four to six primers designed to identify six to eight places on the target sequence. These primers trigger the process of DNA synthesis and the subsequent synthesis of a displacement strand, resulting in the formation of stem-loop DNA structures known as amplicons. These amplicons act as templates for subsequent amplification, leading to exponential target sequence amplification.

An important benefit of LAMP is its exceptional specificity and sensitivity, enabling the identification of very minute quantities of target nucleic acid in a given sample. In addition, LAMP reactions can be visually examined for amplification using methods such as observing turbidity generated by the precipitation of magnesium pyrophosphate or utilising fluorescence-based detection techniques.

Scientists at the launch of AG Chitra TB testing kit

The researchers at SCTIMST altered the LAMP assay methodology to develop a real-time assay. Consequently, each sample will undergo analysis at one-minute intervals to examine the amplification profile, yielding exact outcomes. Throughout the experiment, 40 data points will be gathered from each sample to identify TB bacteria precisely. This test is a simplified nucleic acid amplification procedure compared to PCR. The test can be effortlessly conducted with minimum instruction and executed on any PCR machine with fluorescence detection.

The AG Chitra Tuberculosis diagnostic kit possesses the following characteristics:

1. This test is both fast and highly responsive, capable of being conducted in a laboratory setting in under 1 hour.
2. The test demonstrates a precision of 97.71%.
3. The device also incorporates an automated protocol for isolating DNA from TB germs in sputum samples.
4. It is more economical in comparison to PCR-based diagnostics.
5. The implementation of open-platform technologies for TB diagnostics will greatly contribute to the early detection of undiagnosed cases and help achieve the goal of eliminating TB by 2030.
6. The technology has been created indigenously and is safeguarded by intellectual property rights.

The kit includes all the essential reagents required to conduct the assay. Automated DNA isolation technology is available to extract DNA from the sputum sample. The cutting-edge technology has been officially authorised to M/S Agappe Diagnostics in Kochi. The AG Chitra TB testing kit has obtained manufacture and marketing approval from the Central Drugs Standard Control Organisation (CDSCO).

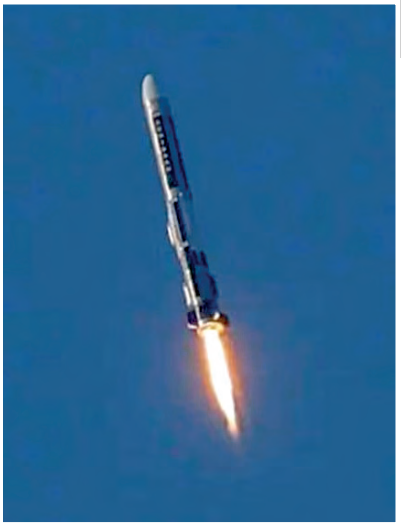
According to the lead researcher, Dr Anoop Kumar Thekkuveettil, the AG Chitra TB kit may be used with any PCR equipment, significantly decreasing the expenses associated with setting up TB screening centres. Furthermore, it will substantially affect the worldwide endeavours to attain a tuberculosis-free state by 2030. The countries can utilise their current infrastructure facilities for TB detection to identify undetected cases and establish an efficient treatment plan. It would be a commendable achievement if countries could successfully adopt TB screening and reduce the number of cases to less than 50 per 100,000 people during the next two-to-three years. In that case, we will achieve a world free from tuberculosis.

**The writer is a science communicator and an adjunct faculty at the National Institute of Advanced Studies, Bangalore. He can be reached at bijudharmapalan@gmail.com.*

The Agnikul team with ISRO Chairman S Somanath (centre, in sky blue shirt) at the Satish Dhawan Space Centre ahead of the first successful launch of Agnibaan

Redefining Aerospace with 3D-Printed Rockets

The world's first single piece 3D-printed rocket launched by Agnikul Cosmos marks a new chapter in innovation in Indian space industry



Agnikul Cosmos successfully carried out a sub-orbital test-flight of its home-built 3D-printed semi-cryogenic rocket Agnibaan

All Images Courtesy: Agnikul Cosmos

■ Sonam Singh Subhedar

The space industry has historically been characterised by significant financial investments, complex engineering, and prolonged development cycles. Traditionally dominated by government agencies like ISRO, NASA, ESA, and Roscosmos, the landscape has shifted dramatically in recent years with the entrance of private enterprises such as SpaceX, Blue Origin, and Rocket Lab. Among these innovative private entities, Agnikul Cosmos, an Indian aerospace startup, has emerged as a formidable player, recently achieving a landmark milestone: The successful launch of a 3D-printed rocket, which it carried out recently on 30 May. This accomplishment not only underscores India's burgeoning capabilities in space technology but also highlights the transformative potential of 3D printing in aerospace engineering. This article delves into the story of Agnikul Cosmos, the intricacies of their 3D-printed rocket, and the broader implications for the space industry.

Agnikul Cosmos was founded in 2017 by Srinath Ravichandran and Moin SPM, two visionary entrepreneurs with a shared dream of making space accessible to a broader audience. Based in Chennai, India, Agnikul's pri-

mary mission is to simplify space logistics through innovative technologies, thus democratising access to space. The company's focus on cost-effective and flexible launch solutions is aimed at catering to the burgeoning demand from small satellite operators and commercial entities seeking reliable and affordable access to space.

THE AGNIBAAN ROCKET

At the heart of Agnikul Cosmos' operations is the Agnibaan rocket, a small-lift launch vehicle designed to deploy payloads of up to 100 kg into low Earth orbit (LEO).

Agnibaan's design is a seamless blend of traditional aerospace engineering principles and cutting-edge manufacturing techniques, with its most distinguishing feature being its semi-cryogenic engine, Agnilet, which is entirely 3D-printed in a single piece.

THE AGNILET ENGINE

The Agnilet engine, which powers the Agnibaan rocket, epitomises the advantages of 3D printing in aerospace applications. Developed and manufactured in-house by Agnikul, Agnilet is a semi-cryogenic engine that utilises liquid oxygen (LOX) and refined kerosene (RP-1) as propellants. The engine's design is optimised for 3D printing, incorporating intricate internal cooling channels and complex geometries that would be challenging to produce using traditional manufacturing methods.

The production process of the Agnilet engine is remarkably efficient, with the entire engine being printed in less than four days. This rapid turnaround time is in stark contrast to the months typically required for conventional engine manufacturing. The ability to quickly produce and test engine components allows Agnikul to respond swiftly to market demands and continuously iterate on their designs, ensuring optimal performance and reliability.

THE LAUNCH: A HISTORIC MILESTONE

The successful launch of the Agnibaan rocket, powered by the 3D-printed Agnilet engine, represents a significant milestone for Agnikul Cosmos and the global aerospace industry. This achievement validates the reliability and performance of 3D-printed rocket components in real-world applications, demonstrating the viability of additive manufacturing for critical aerospace systems.

Dr Chaitanya Giri, Consultant for Space Policy & Space Diplomacy at the Research and Information System for Developing Countries, highlights the significance of Agnikul's achievement: "Agnikul's recent launch is a big game changer for the Indian space ecosystem. It is for the first time that any Indian space technology manufacturing entity has come up with an engine that can be manufactured at a short duration and manufactured on a conveyor belt."

Agnibaan during its second stage assembly

3D PRINTING IN AEROSPACE ENGINEERING

3D printing, also known as additive manufacturing, has revolutionised various industries by enabling the creation of complex geometries that are often impossible to achieve with traditional manufacturing methods.

"If you look at the current conventional engine manufacturers, they take around six to eight months to build an engine if the design is available. But with 3D printing technology, with an additive manufacturing technology, it is now possible to build engines within short durations on a scale of a few days or few weeks. At the same time, additive manufacturing is also allowing the use of new age materials, new age alloys, new age refractory materials that were never used earlier," Girl told Science India.

In aerospace engineering, 3D printing offers several significant advantages:

1.Rapid Prototyping: The ability to quickly design, produce, and test components accelerates the development cycle, allowing for more iterative and innovative engineering approaches.

2.Cost Efficiency: By reducing the number of parts and assembly steps, 3D printing lowers manufacturing costs and minimises the potential for assembly errors.

3.Weight Reduction: Optimising components for weight without compromising structural integrity enhances overall performance and efficiency.

4.Customisation: The flexibility of 3D printing allows for bespoke designs tailored to specific mission requirements, providing a high degree of adaptability.

CHALLENGES AND FUTURE PROSPECTS

Despite the remarkable success of their 3D-printed rocket, Agnikul Cosmos faces several challenges as they look to the future:

1.Regulatory Hurdles: Navigating the complex regulatory landscape for space launches, both domestically and internationally, presents a significant challenge for the company.

2.Market Competition: Competing with established players like SpaceX and Rocket Lab requires continuous innovation and effective cost management.

3.Technological Risks: Ensuring the reliability and safety of 3D-printed components in the harsh conditions of space remains an ongoing challenge.

Nevertheless, Agnikul's future prospects are promising, with several strategic initiatives planned to capitalise on their recent success:

1. Expansion of Manufacturing Capabilities: Agnikul intends to invest in advanced 3D printing facilities to scale up production and meet the growing demand for their launch services.

2. Orbital Missions: Building on the success of their suborbital launch, Agnikul aims to conduct orbital missions, deploying small satellites for a variety of applications, including Earth observation, communications, and scientific research.

3. International Collaboration: Partnering with international space agencies and private companies can help Agnikul expand its market reach and access new technologies.

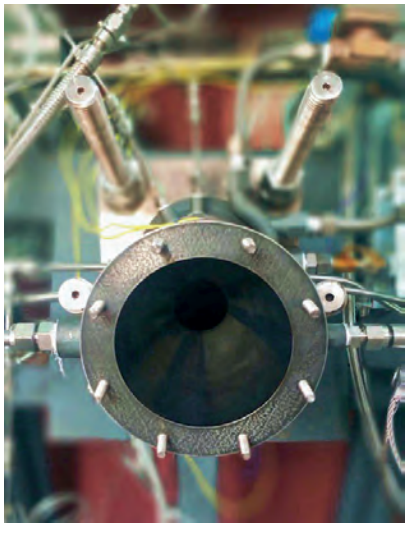
4. R&D Investment: Continuous investment in research and development will enable Agnikul to stay at the forefront of aerospace innovation, exploring new materials, propulsion systems, and manufacturing techniques.

Talking about the relevance of this launch in the defence sector, Dr Giri added, "There is a great demand for quick reaction launch vehicles in the defence domain where military end users or the armed forces are wanting to have rockets that could be launched through canisters at will under very short call of time. So, in case of circumstances where you need to have a large inventory of rocket available, additive manufacturing or 3D printing helps in a big way because you can manufacture rocket engines as well as other parts on a scale."

To fully appreciate Agnikul Cosmos' groundbreaking achievements, it is essential to delve deeper into the technological innovations that underpin their success. The following sections provide an in-depth analysis of the key technologies and engineering principles that set Agnikul apart from other players in the aerospace industry.

Single piece fully 3D-printed rocket engine, Agnilet, and 3D-printed cryogenic pump

Below: Agnilet on a thrust stand



ADVANCED 3D PRINTING TECHNIQUES

Agnikul Cosmos leverages state-of-the-art 3D printing techniques to manufacture the Agnilet engine and other critical rocket components. The use of advanced materials and precision printing technologies allows for the creation of components with complex geometries and integrated functionalities. Some of the key 3D printing techniques employed by Agnikul include:

1. Selective Laser Melting (SLM): This technique involves using a high-power laser to fuse metallic powders layer by layer, creating intricate and robust components. SLM is ideal for producing parts with high strength and durability, making it suitable for critical aerospace applications.

2. Electron Beam Melting (EBM): Similar to SLM, EBM uses an electron beam to melt and fuse metallic powders. EBM is particularly effective for printing high-performance alloys and achieving excellent material properties.

3. Direct Metal Laser Sintering (DMLS): DMLS is another additive manufacturing process that uses a laser to sinter powdered metal, creating solid structures. DMLS is known for its precision and ability to produce complex parts with fine details.

The success of Agnikul Cosmos in launching a 3D-printed rocket has

profound implications for the future of space exploration. The following sections explore the potential impact of this achievement on various aspects of the space industry.

"What Agnikul has done is also being attempted by American space companies. They are already doing it and all is done from the point of view of defence applications at present because defence is the only domain at present asking for quick reaction launches. The civilian sector is not as punitive, it is not as demanding as the military domain is. That's why you can definitely consider that companies like Boeing or Agnikul are going to cater to defence users more through their 3D printed engines than anybody else," added Dr Giri.

From left: SR Chakravarthy, Professor at IIT Madras, Moin SPM, co-founder of Agnikul, and Anand Prakasam, Country Manager, EOS India, at the signing of Agnikul's MoU with EOS to accelerate in-house 3D printing of rocket engines

COST REDUCTION AND ACCESSIBILITY

One of the most significant implications of Agnikul's success is the potential for substantial cost reduction in space missions. Traditional rocket manufacturing involves numerous complex and labour-intensive processes, leading to high production costs. By leveraging 3D printing, Agnikul can significantly reduce manufacturing costs, making space missions more affordable.

Lower costs can democratise access to space, enabling a broader range of entities, including small satellite operators, research institutions, and even educational organisations, to launch their payloads. This increased accessibility can drive innovation and spur the development of new technologies and applications.

RAPID PROTOTYPING AND DEVELOPMENT

The use of 3D printing allows for rapid prototyping and development of rocket components. Agnikul's ability to quickly design, print, and test components accelerates the development cycle, enabling more iterative and agile engineering approaches. This capability is particularly valuable in an industry where technological advancements and market demands are constantly evolving.

Rapid prototyping also facilitates experimentation with new designs and materials, allowing engineers to push the boundaries of what is possible in aerospace engineering. This iterative process can lead to the development of more efficient and reliable rocket systems.

CUSTOMISATION AND FLEXIBILITY

3D printing offers unparalleled flexibility in manufacturing, allowing for the customisation of rocket components to meet specific mission requirements. This capability is especially important in the context of small satellite launches, where each mission may have unique payloads and orbital parameters.

Agnikul's ability to tailor their rockets to the needs of individual customers provides a competitive edge in the market. Customisation can also optimise performance and efficiency, ensuring that each mission is conducted with the highest degree of precision and reliability.

SUSTAINABILITY AND ENVIRONMENTAL IMPACT

The aerospace industry is increasingly focused on sustainability and minimising environmental impact. 3D printing can contribute to these goals by reducing material waste and energy consumption during manufacturing. Traditional manufacturing processes often involve significant material wastage and require extensive machining and assembly, leading to higher energy usage.

By contrast, 3D printing uses only the necessary amount of material, minimising waste and reducing the environmental footprint of rocket production. Additionally, the ability to produce components locally can reduce the need for transportation and logistics, further decreasing the environmental impact.

Agnikul's success with 3D-printed rockets is likely to inspire further advancements in space technology. The validation of 3D-printed components in real-world missions demonstrates the viability of additive manufacturing for critical aerospace applications. This achievement can encourage other companies and research institutions to explore and adopt 3D printing technologies for their space missions. Their success story serves as an inspiration to the aerospace community and a testament to the transformative power of innovation.

**The writer is Associate Editor, Science India.*

HARMONIES UNVEILED: EXPLORING THE SCIENCE OF INDIAN MUSIC

The first part of this series takes a detailed look at various musical instruments of India, their evolution and their importance in the growth of different music traditions

■ Dr Punit Kumar

Editor's Note: *Given the immense richness of musical traditions of the subcontinent,* Science India *presents a three-part series that takes an in-depth look at what gives Indian music its unparalleled strength*

The appreciation of art, particularly music and visual arts, relies heavily on the human senses of hearing and sight. These senses afford us the highest aesthetic pleasures derived from experiencing the beauty of sound and imagery. Our comprehension of the world is greatly enriched through these sensory organs, upon which our very existence depends.

Sound and light are foundational elements in our daily lives. While light can traverse through vacuum, sound necessitates a medium for propagation. In a medium, mechanical vibrations from a source generate sound. These vibrations are transmitted to surrounding air molecules, propagating away from the source. The human body serves as a vibrating source, with vocal cords producing sound. Vibrations produced by the vocal cords travel through the mouth and into the atmosphere. The genesis of sound lies in the vibrations of material bodies. For instance, when a Veena is played, various components such as strings, the hemispherical bowl, stem, and gourd vibrate, producing sound. Similarly, instruments like the Jal Tarang exhibit vibrations in water, which are transmitted to porcelain cups. Wind instruments like the flute utilize air vibrations to generate sound.

SOUND, NOISE, MUSIC

Sound is broadly categorized into noise and music. Noise stems from irregular vibrations, resulting in unpleasant and non-repetitive sound, whereas music is characterized by regular, ordered vibrations that produce pleasant and repetitive sound. The differentiation between noise and music is not solely subjective but also based on the objective qualities of the sound waves they generate. While discussing musical sound, essential parameters include pitch, rhythm, loudness, and timbre.

Image Courtesy: Shutterstock

PITCH: It enables the organization of sounds on a scale related to frequency. In practical terms, pitch distinguishes between higher and lower sounds, especially in musical melodies. Pitch is quantified by sound frequency, typically expressed in Hertz (Hz). Higher frequency sound waves correspond to higher pitch. Expressing pitch as a musical note's position on a scale offers another perspective. Lower scale notes represent lower pitch sounds, while higher scale notes denote higher pitch sounds.

RHYTHM: Various drums, when struck, produce rhythmic sequences due to vibrations in their circular membrane drum heads. Despite initial membrane shape or velocity, distinct sets of frequencies are generated, creating rhythmic patterns that captivate listeners. These rhythmic patterns, repeated consistently over time, define rhythm in music and percussion. The concept of rhythm extends beyond music to daily life, such as the rhythmic patterns of heartbeats.

LOUDNESS: Loudness of musical sound is primarily determined by vibratory movement extent, directly related to waveform amplitude. For instance, a larger amplitude of string vibratory movement on a Veena produces louder sound. Loudness is intertwined with other sound parameters like timbre and pitch.

TIMBRE: Timbre, represented by a sound's unique frequency set, distinguishes between sounds sharing pitch, duration, and loudness. For example, playing the same note on the Tabla and Mridangam drums produces distinct sounds due to different overtone frequencies. Timbre is closely tied to waveform shape and characteristics.

These properties collectively contribute to our understanding and appreciation of musical sound, enriching our sensory experiences in the arts.

Image Courtesy: Pexels

Image Courtesy: Wikimedia Commons

THE EVOLUTION

India boasts a rich musical tradition deeply rooted in its civilization, evident through ancient sculptures, paintings, and scriptures. The *Sama Veda*, dedicated to the art of music, highlights the profound depth and melodious qualities of Indian classical music. Musical instruments are intrinsically linked with deities in Indian culture, with iconic representations such as Krishna with his flute, Devi Saraswati with a Veena, Shiva with a Damru, or Narada with his Tambura.

The evolution of Indian musical instruments dates back to the Vedas,

Above: A musical ensemble of wind and percussion instruments
Left: The Pung Cholom is a Manipuri dance where the dancers play the *pung* (a form of hand-beaten drum) while dancing at the same time

epics, and Samrithis. For instance, the Veena, mentioned in Sage Yagnavalka's *Samrithi*, holds significance in spiritual pursuits. Temples play a crucial role in deity worship accompanied by music. Ramanujacharya, mentioned in the *Nitya Grantha*, advocated using instruments like the Veena and flute during deity decoration in temples. This tradition continues in temples like Shri Nathji and Shri Dwarkadheesh Temple in Mathura, where devotional compositions are sung with instruments like Shankh, Ganta, Dhol, Manjeera, and Mridanga.

Ancient Indian musical instruments find mention in Sanskrit treatises, sacred texts, literature, sculptures, paintings, and folklore. Vedic texts like the *Atharva Veda*, *Bhagavata Purana*, and *Natyashastra* provide insights into the diversity of musical instruments. Over centuries, instruments like the Veena have evolved into various forms such as the Rudra Veena, Saraswati Veena, and Jantar. This evolution, seen in string and percussion instruments, reflects a continuous process of adaptation to changing needs in playing technique, design, and usage.

The *Natyashastra* categorizes musical instruments into four types: Tat or Tantu Vadya (stringed instruments), Sushir Vadya (wind instruments), Avanaddha Vadya (percussion or drums), and Ghana Vadya (bells, cymbals, and gongs). This classification underscores the diversity and complexity of India's musical tradition.

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TAT OR TANTU VADYA (STRINGED INSTRUMENTS)

'Tat Vadya' denotes string instruments (chordophones) where sound is generated by plucking the strings. These instruments can be classified into four types, each distinguished by its unique playing technique and method of sound production.

Plucked Instruments: Sound is produced by plucking the strings with fingers, thumb, or a plectrum, e.g., Tanpura, Sitar, Swarmandal, Mohan Veena, Rudra Veena, Saraswati Veena, and Jantar.

Stroking Instruments: Sound is produced by stroking the strings using nails or a plectrum, e.g., Sarod and Rebab.

Bowed Instruments: Sound is produced by drawing a bow across the strings, e.g., Sarangi, Israj, and violin.

Hammered Instruments: Sound is produced by striking the strings with wooden mallets (Mezrab), causing them to vibrate against the soundboard, e.g., Santoor.

In ancient times, strings for these instruments were crafted from materials such as hair, weeds, and animal skin. The origins of string instruments are often linked to the sound of a bow releasing an arrow during early human hunting activities. Mythologically, the creation of string instruments is attributed to Shiva's bow.

Modern string instruments exhibit variations in shapes, sizes, and the number of strings, yet they all share a common feature: A sound bridge to which the strings are attached. The frequency of the sound produced by these instruments depends on the string's length and its distance from the sound bridge.

The evolution of stringed instruments reveals that early versions lacked frets and sympathetic strings. Frets and sympathetic strings were introduced later, enhancing the development and versatility of these instruments.

Saraswati Veena: The Saraswati Veena, an esteemed and ancient Indian instrument, holds a revered position in South Indian classical music, particularly in Carnatic music. Often hailed as the 'queen of instruments', its origin can be traced back to around 1700 BC. Scholars classify four types of Veena instruments, including the Tanjavur (Saraswati) Veena, Rudra Veena, Vichitra Veena, and Gottuvadhyam (Chitra) Veena.

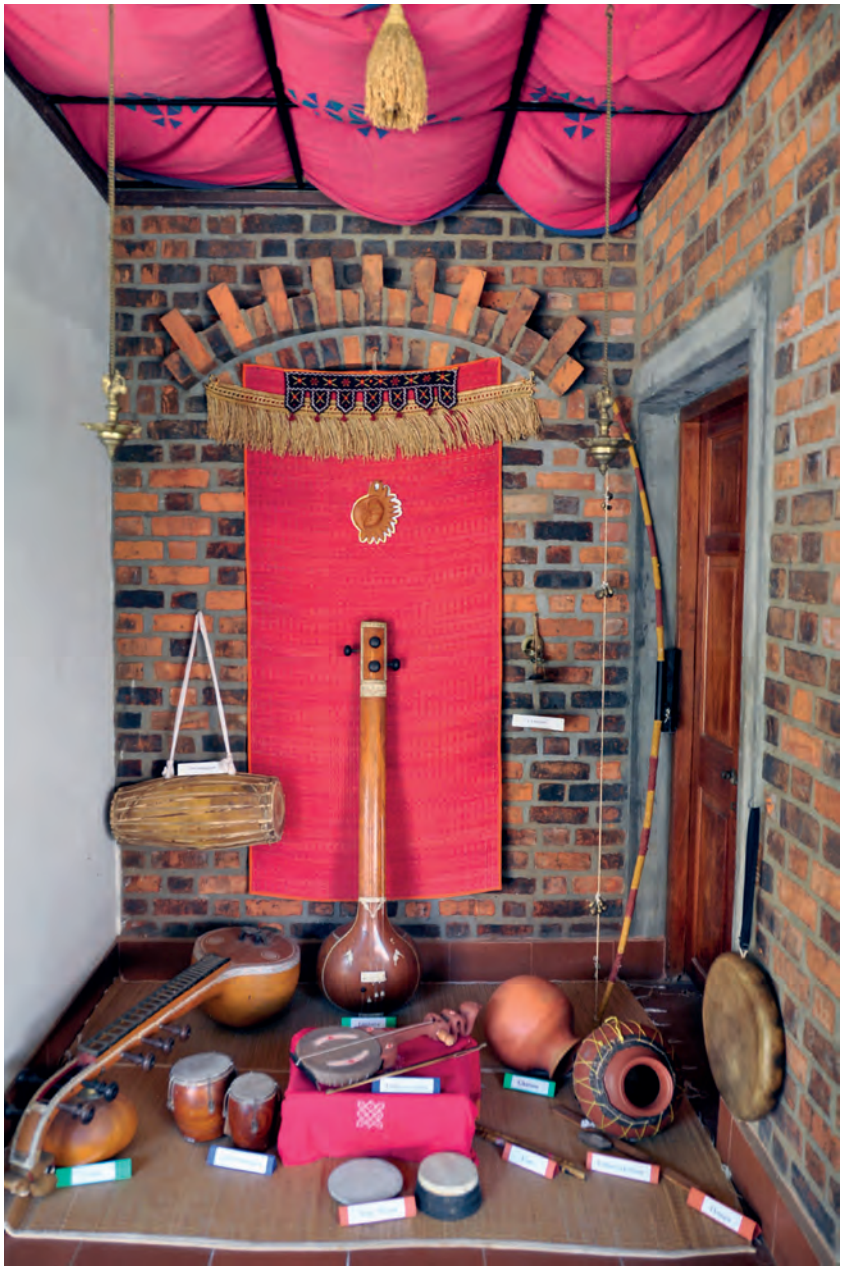
Sitar: The Sitar, a plucked stringed instrument, holds a significant place in Hindustani music, particularly in North Indian classical music. Believed to have been introduced to India in the 13th century by Amir Khusrau, a prominent musicologist, its name derives from the Persian word 'setar', meaning three-stringed. Celebrated for its enchanting and evocative sound, the Sitar stands as one of the most captivating instruments in Indian classical music. Its unique timbre and intricate playing techniques contribute to its allure, earning it a prideful place among Indian musical instruments. The Sitar's ability to evoke emotions and create a distinctive musical ambiance has cemented its status as an iconic instrument, both within India and on the global stage.

Sarod: The Sarod, an exceptional Indian musical instrument, embodies a fusion of the ancient Indian Veena and the medieval Rebab, tracing its origins to the Rebab of the Middle East. Its integration into Indian classical music can be credited to the legendary musician Tansen, renowned as one of the greatest figures in the history of Indian classical music.

Violin: The Violin, a four-stringed instrument played with a bow, has become an integral part of Carnatic music. Its introduction to Carnatic music occurred towards the end of the 18th century and the beginning of the 19th century. Besides serving as an accompaniment, the Violin gained popularity as a solo instrument within the Carnatic tradition. The ancestry of the Violin is believed to be linked to the Ravanahatha, a folk instrument originating from Rajasthan. The Ravanahatha is said to have originated during the time of Ravana, the powerful king of Lanka, who played it as a musical offering to Lord Shiva.

Tanpura: The Tanpura is a quintessential instrument in Indian classical music, providing a rich and resonant drone that serves as a foundation for melody and rhythm. Its origins can be traced back to ancient India, where it likely evolved from earlier stringed instruments. Initially, the Tanpura served as an accompaniment to vocal and instrumental performances, providing a continuous drone to support the melody. Over time, it became an integral part of Indian classical music ensembles, both in Hindustani (North Indian) and Carnatic (South Indian) traditions.

Guitar: The guitar, commonly associated with Western music, has a lesser-known historical connection to ancient India, particularly during the Vedic period when the musical form was known as Samgan. In that era, the Kachhapi Veena was utilized for solo performances and as an accompanying instrument. Over time, this instrument is believed to have migrated to various parts of the world, adopting different names,



An assortment of Indian musical instruments

Image Courtesy: Wikimedia Commons

Image Courtesy: Wikimedia Commons

A musician plays Dholak, one of the many ancient percussion instruments originating in the Indian subcontinent

while its presence in India waned. The classical gut-string guitar made its appearance in musical circles in Madras around the 1840s, marking a revival of the guitar tradition in India. The steel-string guitar has gained popularity in the North-East region of India and Goa, becoming a mainstream instrument in popular settings. Additionally, the guitar has occasionally been incorporated into Indian classical music, *ghazal*s, and other forms of light music in India.

THE SCIENCE OF TAT/ STRINGED INSTRUMENTS

Stringed instruments rely on soundboards to amplify their sound. It is evident that strings supported rigidly produce minimal sound. When strings are affixed to a soundboard, they transmit vibrations. The large surface area of the board allows it to convey these vibrations to the air. Our focus should extend beyond the string's vibrations to include the impact on the soundboard, which has a dual role of reinforcing and enhancing these vibrations. Designing soundboards for various stringed instruments is intricate, with the precise dimensions of components like the string bridge and soundboard settled empirically to achieve the desired tone quality.

The Tanpura and Veena are highly esteemed indigenous plucked instruments. In the Veena, sound output enhancement is delegated to the large pear-shaped bowl and associated elements. Typically crafted from jackwood or rosewood, the bowl is hollowed out in one piece. In southern instruments, a hollow gourd resonator substitutes the wooden bowl. The bridge, centrally positioned on the bowl, is meticulously curved on its upper metal surface. Additionally, a side bridge in the form of a brass arc and small holes near the bridge facilitate better transmission by establishing communication between the external and internal air.

These instruments typically feature seven strings, with four passing over frets for playing and three stretched at the side of the fingerboard for marking time. The method of exciting these strings involves plucking, drawing the tense string out of its equilibrium, and releasing it suddenly. Stringed instruments, largely derived from ancient Veena, exhibit unique acoustic richness due to boundary obstacle-induced vibrations. Researchers have modeled string vibrations, highlighting characteristics such as accurate harmonicity in numerous overtones, amplitude modulations, frequency modulations, and long-sustained sound. The finite bridge introduces nonlinearity, synchronizing string vibrations and creating the accurately harmonic sound observed in instruments like the Sitar and Veenas.

In the Veena, the bridge is notably higher above the body than in Tanpura. Even when strings are pressed on the frets during play, the curved upper surface ensures the strings leave the bridge at a tangent. Forces exerted by vibrating strings on the bridge in Tanpura differ significantly from those on an ordinary bridge. Most energy transfer to the bridge likely occurs at, or near the point of grazing contact, with forces resembling impulses during each string vibration cycle. This process explains the robust collection of overtones, including those initially absent. As the bridge reacts to the string, modifications to its vibration form occur, giving rise to initially absent partials. The explanation for Tanpura might not entirely apply to the Veena, as forces exerted by the string on the bridge are not purely impulsive. Still, a certain bridge portion experiences intermittent contact during vibration, suggesting a theory intermediate between that for Tanpura and those for stringed instruments with ordinary bridges.

**The writer is Associate Professor, Department of Physics, University of Lucknow.*

EXCLUSIVE INTERVIEW / CHANDRAKANT B SOMPURA

Ancient and Modern Principles Mingle in an Edifice Designed for 2500 Years

Principal architect of the Ram Mandir at Ayodhya, hailing from a family of traditional architects that has created some iconic temples, shares about the journey he undertook to make the most epochal monument of our times

Image Courtesy: C B Sompura

Ahmedabad-based octogenarian architect Chandrakant B Sompura might have gained global traction for designing the architectural marvel of Ram Temple at Ayodhya in Uttar Pradesh, but he is already an established name in the field of temple architecture in India. With many feathers in his cap, Sompura has a long list of aesthetically crafted temples to his credit in India and abroad. To name a few are Akshardham temple in Gandhinagar; Swaminarayan temple in Mumbai; Birla Mandir in Kolkata; Sun temple in Gwalior; BAPS Shri Swaminarayan Mandir in London; North American Hindu Union temple in Pittsburg, USA, and many more. He is currently working on Sita Maiyya temple at Sitamarhi, one in Ahmedabad, and a 700-ft Ram temple in Perth, Australia.

■ **Debobrat Ghose**

The Sompura family, which has centuries-long tradition of designing temples with exclusivity, has played a significant role in influencing temple architecture in India by building more than 200 temples. At present, he is assisted by his architect sons – Nikhil and Ashish Sompura – who oversee their father's design work.

In an exclusive interview with Science India, *Chandrakant Sompura (82), a 15th generation architect, discusses the long and arduous journey of the making of the Ram Mandir at Ayodhya. Excerpts:*

Q. When you were first approached for the construction of the Ram Janmabhoomi temple, did you anticipate how long it would take for the actual construction to begin? Given the political situation of the time, how realistic was the idea of this temple then?

The inception of the temple took place in 1988 when the president of Vishwa Hindu Parishad (VHP), Shri Ashok Singhal, intended to design a temple in

Chandrakant B Sompura

Ayodhya. As Ashok*ji* did not know any specialist in the field of temple architecture, he contacted industrialist Shri Ghanshyam Das Birla. As our family designed temples for Birla*ji*, who had many temples in his factories too, he contacted us for this project and introduced me to Ashok*ji*. That's how I got on board for this project and later, visited the site with Ashok*ji*.

From 1992 to 1996, the work was in full swing at three sites — one at the Ayodhya Karyashala and two in Pindwara (in Rajasthan). After 1996, the work was carried out only at the Ayodhya Karyashala.

The big question then was on the completion of the project. I too wondered if the project would be completed.

The big question was on the completion of the project. I too wondered if the project would be completed. After 2000, the chances of completion became minimal as the case went to the Supreme Court, but I still kept the hope. The rest is history

After 2000, the chances of completion became minimal as the case went to the Supreme Court, but I still kept the hope. And the rest is history.

Q. Could you talk in detail about the genesis of the temple's design to the actual works to give our readers an insight into the making of this iconic landmark?

As the temple had a religious feud, there were heavy security and army personnel present on the site. Due to security reasons, no instruments were allowed on the site. As measuring the area of the site was essential for the design, I started to measure with my footsteps. All the measurements needed were taken by footsteps and later converted to a plan. This

Ram Mandir at Ayodhya

Image Courtesy: PIB

was contrary to the regular practice of measurement in any architectural work.

This site plan was used for the design. I made three iterations of the design, of which one was selected in a meeting with the VHP. A wooden model was made and presented to the *sadhus* at the Kumbh Mela, and we received their blessings.

The design of the temple was always according to the *shastras*; any temple I design, the family follows it. As the temple was an important project for many people, the temple had two *mandaps* that could take care of the footfall. The principles of temple design which have been present for generations are always followed and I did the same for this project.

Q. Could you name some chief treatises of ancient Hindu temple architecture that you consulted while making the design of the temple?

As a temple architect, following the *Shilpa Shastra* is very important. *Shilpa Shastra* is an ancient collective body of texts that primarily deal with the practice of art, including architecture.

The knowledge of Shilpa Shastra was coupled with the experience gained by my grandfather, Padma Shri Prabhashankar Oghadbhai Sompura, one of the leading proponents of Nagar style, who designed the modern Somnath Temple

As temples are a part of religious faith, precise calculation in terms of ratios according to the *Shastra* becomes integral. The knowledge of the *Shastra* was coupled with the experience gained by my grandfather, Padma Shri Prabhashankar Oghadbhai Sompura, one of the leading proponents of the Nagar style — he designed the modern Somnath Temple — and who wrote 14 books on temple architecture. These books are also the ones that I referred to. The books talk about every element in detail, where the dimensions, the iconography and the placement of these elements are outlined.

I worked with my father for 15 years and got trained under him, which was an enriching experience for me.

I referred to *Agam Shastra*, where the temple architecture is outlined as a whole. The *Shastra* was one that holistically talked about temples. I used *Sam-*

ranganam Sutradhar which is a detailed account of temple architecture highlighting the elements in detail, putting them into different parts and expressing how they should be designed concerning all the elements keeping the architecture language the same. There are also Vedas that talk about temple architecture and referring to them was also important as they highlight the essence of the temples and their creation.

Q. How much creative freedom did the commissioning agency give you while designing the temple?

I had full freedom to design the temple and the trust always encouraged it as they knew that our work is always

Temples designed by Sompura: Renukeshwar Mahadev Temple at Renukoot in Uttar Pradesh (right) and Akshardham Temple in Gandhinagar, Gujarat (below)

All Images Courtesy: C B Sompura

Other temples designed by Sompura:

Above: Ganpati Temple, Alibaug, near Mumbai

Left: Sun Temple, Gwalior

Below: Swaminarayan Temple, London

All Images Courtesy: C B Sompura

according to the *Shilpa Shastra* and any changes made by me would also follow the *Shastra* principles. This was also the reason why I was able to design three iterations as their help and feedback helped in the creative process. One decision that I still remember is where I suggested an octagonal Garbhagriha (sanctum sanctorum) for the temple and the trust agreed to it.

Q. Is there any ancient Hindu temple that the Ram Janmabhoomi temple comes close to in terms of its design?

The design of this temple does not resemble any temple, nor has a design from previous works been repeated; it is uniquely thought of and designed.

Q. What makes this temple the most unique Hindu temple in the world?

We see some design elements that make this temple unique, the octagonal Garbhagriha which was done to represent Vishnu*ji*; it is something not commonly seen. We see there are five *mandaps* in the temple, with Sabha *mandap* and Kirtan *mandap* added for the visitors. It is the first temple intended to last at least 2,500 years. A 3D analysis of the structure was done, which also favours the temple to withstand calamities and stay erect for 2,500 years. One of the very unique features of the temple is the Surya Tilak. We have seen that the sunlight falls on the *murti* (idol) in ancient temples, but that is calculated through solar days. As the sun's position is marked nearly the same every year, the Surya Tilak can be seen in some ancient temples. But Ram Navami, when we see the Surya Tilak in this temple, follows the lunar days, which means that the Sun's position every year will change on the day of Ram Navami and so a unique technique was also devised for the Surya Tilak.

All Images Courtesy: C B Sompura

Above: Chandrakant B Sompura with sons Ashish and Nikhil

Above right: Sompura (in blue) with Ashok Singhal (extreme left), then president of VHP, who approached him to design the temple at Ayodhya

Right: Birla Temple, Kolkata

Q. Did the delay in the construction of the temple affect the design in any way?

There were changes made in the temple design as we progressed from 1998 to now. As the scale became larger and there was traction from the media and public, the temple had to go through some changes. In the design first selected, there were two *mandaps* (Gudh *mandap* and Rang *mandap*) and now, to cater to the increased footfall at the temple, we have five *mandaps* (Gudh *mandap*, Rang *mandap*, Nritya *mandap*, Sabha *mandap* and Kirtan *mandap*). These resulted in changes in all the dimensions and scales. This also created a challenge for the design. As the work for the temple started way back, 60000 cubic feet of work was done, and we had to use it, but it was also to be kept in mind that the image of the temple, the beautiful ornamentation and the presence that was there in the minds of the people from so long had to match.

Q. What makes the architecture of Ram Mandir different from that of all other temples?

The architecture of the temple is very different in comparison to other forms of architecture. This is due to the conceptualisation of the temple with qualitative aspects and fractions involved in its design. The temple is built with adorned elements so that the devotees feel its sanctity. The designing and construction of a temple is governed by a 'sacred' mathematics on which the positions, proportions and symmetry are vital and integral parts of the temple's design.

Temples are governed also by religion, like Buddhism, Jainism and Hinduism. The styles of temples also depend on the place they are built at, such as the north of India, south of India or the eastern part of India. Temple architecture is a combination of beliefs and techniques. The beliefs and faith that people have in the deity and the technique of precise calculations and ratios complement the aesthetics of the temple. It is a form of architecture present from ancient times and has evolved as the needs and lifestyles of people change. The architecture that we see around, where things like ventilation, space making, climate-oriented designs, are things that have always been a part of temple architecture with its unique use of carvings and details that are in precise measurement to one another.

**The interviewer is Editor, Science India*

PROFILE: DR JNANENDRA NATH MUKHERJEE

An Eminent Exponent of Colloid Chemistry

Very little is known about this illustrious scientist who fought odds at both the personal and professional fronts to nurture scientific temper and establishments in a newly independent India

■ Dr Jayanti Dutta

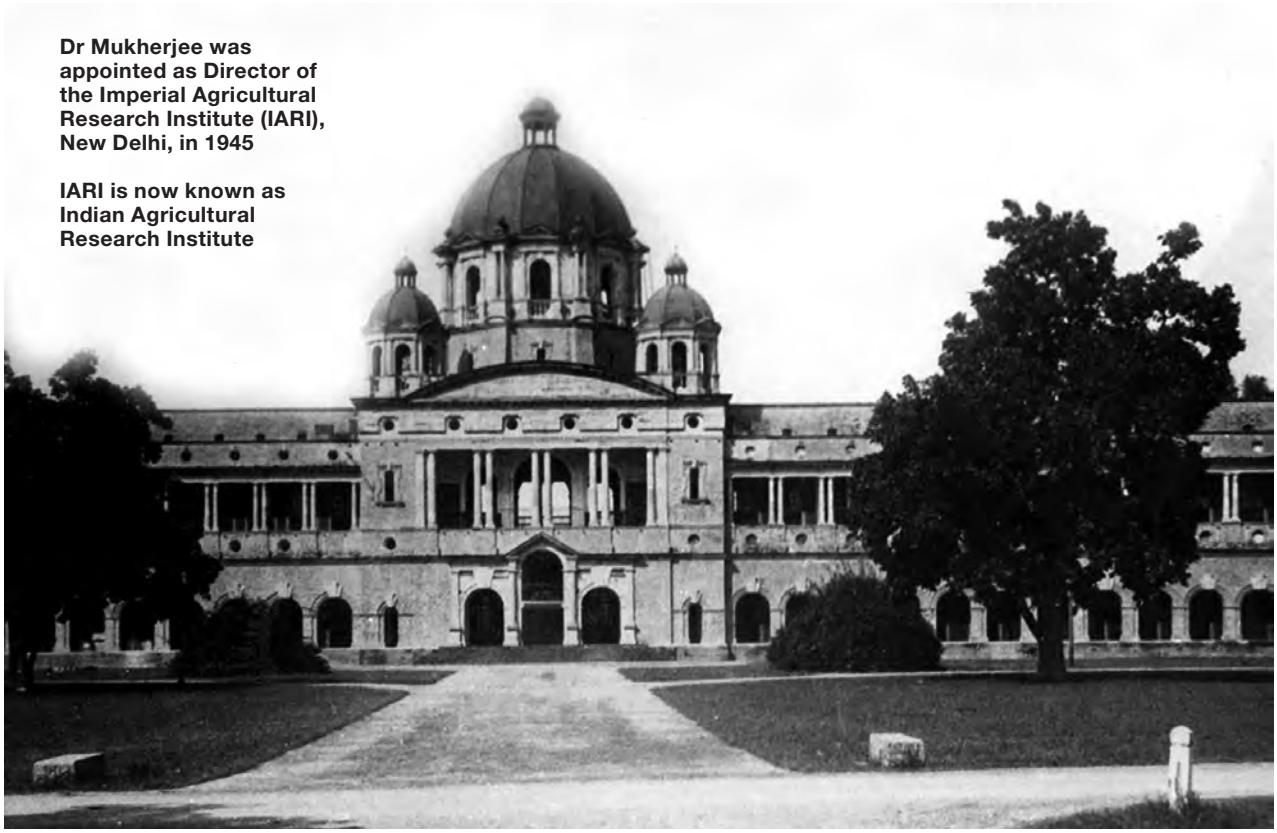
Image Courtesy: West Bengal Board of Secondary Education

While pondering on the amazing coincidence of several students of a single batch going on to become world-class scientists of great repute, one is struck by the magic created by the coming together of illustrious teachers, brilliant students and an ambient institution. That, it took place in the stifling environment of imperial governance makes the story much more profound and inspiring. It can be a case study to understand how students like Satyendra Nath Bose, Jnan Chandra Ghosh, Meghnad Saha, Prasanta Chandra Mahalanobis, Pran Krishna Parija and Jnanendra Nath Mukherjee, studying at the Presidency College in Calcutta taught by the greats like Jagadis Chandra Bose and Prafulla Chandra Ray founded, established and nurtured the scientific research traditions in pre-independence India.

The life of each of these scientists is worthy of deep attention and serious study so that we can catch hold of the pattern which carved out not only sharp scientific minds but also visionaries, nation-builders, pioneers and courageous personalities much needed by the colonized country whose confidence was brutally bruised.

NATIONALIST LEANINGS IN EARLY DAYS

Jnanendra Nath Mukherjee, born on 23 April 1893 in Rajshahi (presently in Bangladesh) was one among this shining galaxy who carved his path and left an indelible impression on the country's and world's science. Right from his childhood, we can see the factors contributing to the building of a disciplined personality of Jnanendra Nath. When his father died, Jnanendra Nath was twelve years old, and he and his younger brother were brought up by their mother, a woman of 'strong character, intelligence, courage, business ability and determination' as he portrays her in his biography, *About Myself*. His school-



Dr Mukherjee was appointed as Director of the Imperial Agricultural Research Institute (IARI), New Delhi, in 1945

IARI is now known as Indian Agricultural Research Institute

ing at Dinajpur High School and later at Municipal High School, Burdwan, nurtured nationalist feelings in him as he was a member of the Anushilan Samiti, an Indian fitness club, which was used as an underground society by anti-British revolutionaries. Insulting comments by Christian missionaries about Indian civilization pained Jnanendra Nath and filled him with an abhorrence towards British rule and he became a nationalist for life.

After obtaining his BSc and MSc degrees from Presidency College, Calcutta, Jnanendra Nath was appointed a lecturer in the University College of Science where Principal Ashutosh Mukherjee had created a vibrant atmosphere of knowledge and scholarship. Jnanendra Nath got his teaching assignment along with some rudimentary research facilities there. In 1919, he joined the University College, London, to work under the mentorship of Professor F G Donnan, who was a Fellow of the Royal Society.

BRILLIANCE & WESTERN APATHY

Jnanendra Nath's journey towards scientific eminence started from his MSc years with the publication of his research paper on colloids in the *Journal of the American Chemical Society* in 1915. Colloids, a mixture in which one substance consisting of microscopically dispersed insoluble particles is suspended throughout another substance, was to be his area of life-long research. In the Physical Chemistry laboratory of Prof Donnan, Jnanendra Nath worked on the origin and neutralization of the charge of colloids. Upon presentation, his work was appreciated for the lucid interpretation of the behavior of the complex colloid particles in suspension and their chemical reactions. His next groundbreaking achievement was the development of the boundary method for the determination of the cataphoretic speed of colloidal particles, i.e., the movement of charged particles in a fluid medium in response to an electric field. He published a research paper in 1928, describing the apparatus for using this method and its working. However, another scientist, Dr Arne Tiselius further developed a refined apparatus and was awarded the Nobel Prize for it. In the Indian history of science, this is another opportunity missed by a whisker in claiming international recognition.

Dr Jnanendra Nath Mukherjee was a member of the Anushilan Samiti, an Indian fitness club, which was used as an underground society by anti-British revolutionaries

The scientific community of the Western world did not give due recognition to the findings of Dr Mukherjee and N N Sen on coagulation and the effects of dilution, and these were not included in the textbooks on colloids. Similarly, despite being more complete in explana-

All Images Courtesy: Shutterstock

Left: Notable scientists from the University of Calcutta in a photograph from 1937. Seated (from left): Meghnad Saha, Acharya Jagadis Chandra Bose and J C Ghosh. Standing (from left): Snehamoy Dutt, Satyendra Nath Bose, D M Bose, N R Sen, Jnanendra Nath Mukherjee and N C Nag

tion and the first one to publish it, the Mukherjee-Sen rule was bypassed and the Burton-Bishop rule, which was of a later date and was less thorough, got mentioned in the scientific literature on colloids, reflecting the biased perception about scientific work of Indians. However, the brilliance of Dr Mukherjee's research work attracted the attention of colloid chemists from all over the world because his theory shone a light on the vaguely understood complexities of colloids and brought a clear understanding of their behaviour. The international science journal *Nature* feted Mukherjee as, '…the exponent of colloid chemistry in India, having established his reputation throughout the scientific world as an eminent worker in his field.'

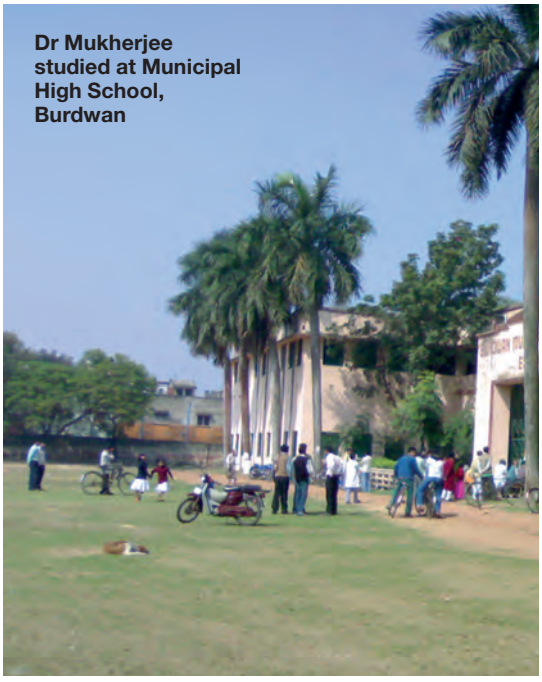
A NEW VISTA IN SOIL SCIENCE

With his sound investigations and creative scientific vision, Dr Mukherjee brought his research on colloids into the study of soil thus opening up a new vista in the domain of soil science, which was at that time considered to be an area of elite research. Dr Mukherjee's tools, techniques and methods along with the original ideas and insights gained through his patient research and his application of physical and colloid chemistry to problems of soil health and fertility helped in devising novel solutions in this virgin area.

Due to Dr Mukherjee's pioneering work, soil science ultimately became an area of significance in agricultural studies. How he methodically developed the domain is a study of strategic research. He first started detailed investigations with the colloidal sols of silica and alumina, the major constituents of soil. Then he studied clay fractions isolated from different soils of India, and subsequently the clay minerals which constitute the major portion of soil clays. His exhaustive research was published in a series of more than a hundred papers, written individually or in collaboration with his students. In doing these investigations, he created from his students a dedicated group of scientists trained in the field who constituted the 'Calcutta School of Soil Science', as named by Professor C E Marshall. These scientists later spread across the country occupying responsible positions in institutions dealing with soil health. Thus, Dr Mukherjee contributed to nation-building through teaching and research as if he were paying back the debt of gratitude that he owed to his illustrious teachers.

SHOWING THE LIGHT

Based on such rich experience, Dr Mukherjee was appointed as Director of the Imperial Agricultural Research Institute, New Delhi, in 1945 which was named as Indian Agricultural Research Institute (IARI) after independence. For Dr Mukherjee, this was the apt opportunity to initiate and press forward soil study research by creating advanced study departments such as Soil Physics, Agricultural Chemistry, Soil Fertility, Soil Microbiology Biochemistry, Organic Chemistry and Spectroscopy.



Dr Mukherjee studied at Municipal High School, Burdwan

Dr Mukerjee is especially remembered for drawing the soil map of India

along with two of his colleagues in the year 1944, which portrayed different soil types in different regions of the country. He later revised it in 1954. His classification of Indian soils into twenty different types based on climate, topography, vegetation, etc., still holds significance in Indian soil studies.

The directorship of the IARI was the first of several significant administrative positions that he held in his long career. In each of his administrative stints, we can see his indelible pattern of vibrant development, organizational expansion, consolidation and creative visionary strategies. It was fortunate for a new country that a person of the calibre of Dr Mukherjee was at the helm of affairs immediately after independence when Indian processes and procedures needed

to be established afresh and firmed up at the end of imperial governance.

He worked as a professor, director, scientific advisor, founder, trustee and member of several high-powered committees. He worked in the departments of education, agriculture, animal husbandry, community development, education, forestry, irrigation, and land utility. He was associated with eminent national institutions like the Central Building Research Institute, Roorkee, Union Public Service Commission, and Indian Statistical Institute.

Left: A picture of Dr Mukherjee from Satyendra Nath Bose National Centre for Basic Sciences Archive; Right: His potrait from Indian Society of Soil Science

In addition to governmental positions, Dr Mukherjee continued nurturing science associations and institutions. The first society that he founded along with Acharya P C Ray was the Indian Chemical Society in 1924 which functioned as an indigenous forum for the 'community of chemists and members of allied disciplines in the country'. Though it was the brainchild of Acharya Ray, Dr Mukherjee's driving force of nationalistic fervour too worked behind it; it was lovingly nurtured by all those Indian scientists who had studied in London. Dr Mukherjee was an office bearer in many other societies such as the Indian Society of Soil Science, Indian Association for the Cultivation of Science, Indian Science News Association, Indian Society of Soil and Water Conservation, Indian National Science Academy, Asiatic Society, etc., showing how popular an expert he was due to his collaborative, hardworking and trustworthy approach. Not only in the country but he was also sought after by several international bodies too.

In 1952, Dr Mukherjee was elected the president of the Indian Science Congress, thus carrying on the legacy of many of his class fellows who too led the country through scientific frontiers. His presidential address was titled, 'Science and our problems' in which, true to his ideology-based scientific training, he highlighted the moral responsibility of the Indian scientists to decide the direction of scientific research. The award of Padma Bhushan by the government of India was a recognition of his dedication to the nation.

On the family front, Dr Mukherjee remained a dedicated father to his only son whom he brought up single-handedly since he was two years old, after the early death of his wife. Though not much has been written about his personality or personal traits, his extremely successful professional life where he justified each position he held with deep commitment and farsightedness, indicates him to be a man of high principles. Two weeks after his colleagues and juniors celebrated his 90th birthday, Dr Mukherjee passed away peacefully on 10 May 1983, and left a career trail in science which has remained unmatched to date.

In his life, we can find an unbroken pattern of high moral value; scientific rigour of international standard; a pragmatic approach; creative, innovative, farsighted vision for the future of science in the country; grounded personality; nation-first attitude and single-minded dedication, just like his mentors Acharya P C Ray and Acharya J C Bose. Jnanendra Nath Mukherjee proved to be a worthy successor of his teachers.

**The writer teaches at Panjab University, Chandigarh.*

Aranmula Kannadi
The Unique Metal Mirror

Aranmula Kannadi was born in the eponymous temple town of Kerala using locally available technology

■ **Prof V P N Nampoori**

Aranmula Kannadi, a bimetallic mirror made in Aranmula in the district of Pathanamthitta, Kerala, holds a GI tag awarded by the Government of India

Image Courtesy: Shutterstock

Kerala has a wealth of scientific and technological practices being followed since ancient times. Brass artifacts and idols from a village called Mannar near Kottayam, bronze plate to take food made by artisans in Kadavallur village near Trichur, Pavithra Mothiram (Payyannur Mothiram, holy ring) made with gold made by artists from Payyannur in the same form as Pavithram of Darbha grass usually used by Acharyas during holy rituals, brass lamps and idols from Payyannur near Kasargod, etc., are some of the examples. Advancements in the studies of Mathematics and Astronomy by Kerala school of Mathematics during the 14th-19th centuries are now appreciated by modern science. Aranmula mirror or Aranmula Kannadi is one of the best examples of the crafting of bimetallic mirror, which is another traditional craft of Kerala exhibiting excellent use of local science and technology.

Aranmula Kannadi is a type of metal mirror that is made in the village of Aranmula, in the district of Pathanamthitta, Kerala, India. It is believed to be the oldest metal mirror in the world and is made using a traditional method that has been passed down through generations known only to a few artisans belonging to a family in the town of Aranmula, which has been declared as a heritage village by the government of Kerala. In Aranmula, there is a family of skilled metal-casting artisans crafting these unique metal mirrors using techniques passed down over more than 500 years.

The crafting process of these mirrors is an ancient craft that is closely guarded and passed down from generation to generation. The craft, which was not recognised by scientists and technologists, has started to get attention in recent years. Due to the showcasing of mirrors at craft fairs and due to online demand, it is slowly becoming more recognised globally as a unique and beautiful item for households.

A LEGENDARY STORY

A few centuries back, the high priest of Aranmula Parthasaradhy temple in Kerala found that the crown made for the deity was cracked. The local king then summoned the head of the bronze smith clan and ordered him to make a new crown within three days. The crown made out of the mixing of copper and tin turned out to be a marvel of art and craft. It was silver in colour, brittle like glass, shone with rare brilliance, and when cleaned acquired the quality of reflection. The *makudam* or crown as *kannadi bhimbom* (mirror idol) was preserved in the Aranmula temple till 1946. The casters soon worked out the ratios of different metals used.

The chieftain of Aranmula liberally patronized that craftsperson and even laid down an order that the mirror should form one of the eight auspicious articles used in all Hindu religious rites including marriages. Under the patronage of a few aristocratic ladies, the *vaalkannadi* (handheld mirror) flourished. The metal mirror has been mentioned in many ancient texts including the *Rig Veda*. Even in the carvings of Khajuraho, there has been a depiction of handheld mirrors.

There are many temples in which the *vaalkannadi* is used to symbolise a goddess without form. In the temple dedicated to Goddess Saraswati, the mirror is placed next to the musical in-

All Images Courtesy: Prof VPN Nampoori

Above: The metallic disc created by the alloy that eventually becomes the mirror. Right: Artisans at work with the alloy prepared by mixing copper, tin and zinc in specific proportion

strument of Veena, a vital signifier of this goddess of learning. The mirror, thus, has a lot of ritualistic importance.

SPECIALTY OF ARANMULA KANNADI

The specialty of the Aranmula Kannadi is not just its craft. Unlike the common glass mirrors in use, Aranmula Kannadi is unique because it is a mirror made of metal with a reflecting front. This makes it different from regular plane glass mirrors, where reflection takes place from the back surface of the glass. Back reflection makes the mirror image distorted, since light rays have to travel through the glass to the back and return through the mirror on reflection. This process makes the light rays undergo reflection as well as refraction.

With the Aranmula mirror, because of its unique combination of metals and hand polishing, the reflection takes place on the front surface unlike conventional glass mirrors. This eliminates any secondary reflection and distortion giving a pure and almost perfect reflection with no distortion in Aranmula mirror.

TECHNIQUE OF MAKING ARANMULA KANNADI

Casting of a high-tin bronze mirror of 33% tin with copper has good reflection compared to ordinary mercury-coated glass mirrors. The brittle silvery-white delta phase of bronze is optimized while avoiding lead which is toxic. Lead dulls the quality of the mirror. Scientific and anthropological studies of Aranmula mirror have revealed that mirrors were uniquely made of as a high tin 'delta' bronze, a binary copper-tin alloy with 32-34% tin matching with pure delta phase of bronze — an intermetallic compound $Cu_{31}Sn_{38}$ of fixed composition of 32.6% of tin. The Delta phase is a hard compound. The alloy will provide properties of a mirror as al-

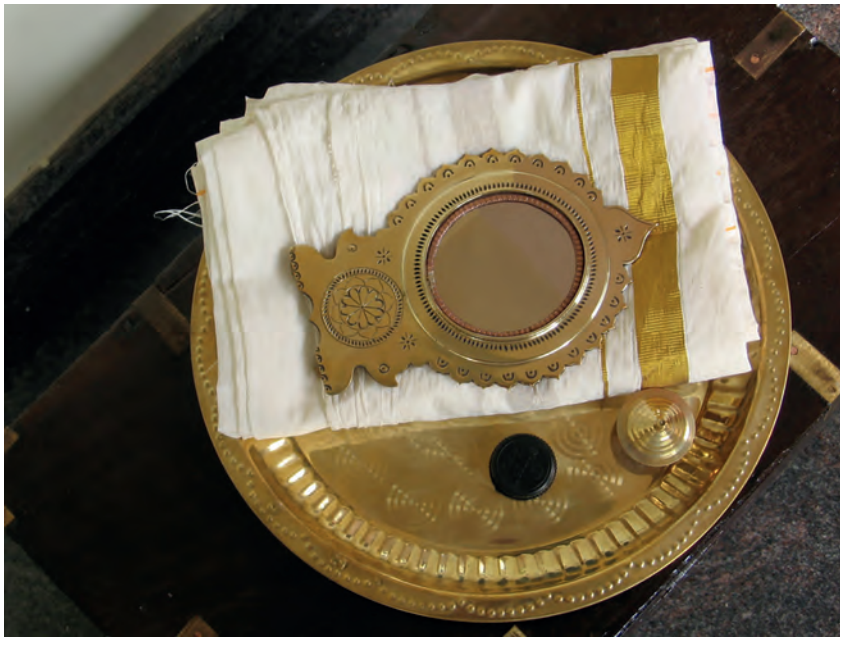
loy can be polished across the whole visible spectrum. Moreover, the delta phase is a stable compound which does not get tarnished or corroded easily, as stated by S Srinivasan and I Glover in their 2007 work, 'Skilled mirror craft of intermetallic delta high-tin bronze ($Cu_{31}Sn_8$, 32.6% tin) from Aranmula, Kerala', published in *Current Science*, Vol 93). Characterization of Aranmula Kannadi using modern techniques like photoacoustic effect and thermal lens effect was carried out by M S Swapna, V P N Nampoori and S Sankararaman, published in their study, 'Photoacoustics: A nondestructive evaluation technique for thermal and optical characterisation of metal mirrors' in *Journal of Optics*, Vol 47, 2018.

Creating the Aranmula Kannadi is a green and environment-friendly process. The material used is eco-friendly and obtained locally, and most of the material is reused, leaving almost minimal waste. The making of Aranmula Kannadi is a highly skilled and labour-intensive process. First, a metal alloy is created using a secret mix known only to the senior family member or his nominee. He will hand over the secret to the next person who will take over the leadership of the mirror making craft.

In 2005, the Government of India granted the GI (Geographical Indicator) tag to Aranmula Kannadi, which means that the exclusive right of making the mirror rests with specific artisans of Aranmula only

The alloy is then formed into a concave mirror shape and polished to a high shine. Due to the need for the perfect and smooth reflection on each mirror, each Aranmula mirror is hand polished and refined with two-three days spent purely just polishing the mirror using a secret herbal mix to achieve the perfect smooth finish and clear reflection. One craftsman can only make around 10-15 mirrors each month.

In 2005, the Government of India granted the GI (Geographical Indicator) tag to Aranmula Kannadi, which means that the exclusive rights for making this mirror rests only with Aranmula. Many people believe keeping an Aranmula Kannadi in the house brings great luck to the owner. And for this reason, it continues to be given as a gift during weddings, Diwali, and housewarming ceremonies.



The Aranmula Kannadi is one of the auspicious articles used in Hindu rituals

But people often ask, what is the best place to keep Aranmula Kannadi at home? The Aranmula Kannadi can be placed anywhere in the home, such as your living room, bedroom, or dining room. If possible, it is best to keep the Aranmula Kannadi in an east facing direction as the mirror reflects light as the sun rises and gives off positive energy to start each day. Even today, craftsmen use traditional, indigenous methods and materials to produce the reflecting wonder called Aranmula Kannadi. It takes great practice and a tremendous amount of focus and patience to produce a perfect mirror.

A Kowa or crucible made of wrought iron having an approximate capacity of holding 9 kg of molten metal is cleaned. The pieces of pure copper, tin and zinc are added in specific proportions known only to one family in Aranmula. The mouth of the *kowa* is sealed with clay. An opening lid made of clay is also provided. Two vertically opposite holes are provided to pour out the molten metal. One of these holes acts as an air vent. The *kowa* is then placed in an open pit furnace charged with burning charcoal. It is heated to about 400° Celsius (approximate melting point of brass). The molten metal is poured onto a flat surface (usually the ground itself). Once cooled, the alloy is then broken into pieces using a *chuttika* (hammer). The broken pieces are then inspected for the quality of the alloy. If found satisfactory, then it is re-melted.

The casting is checked for any deformities. Usually, the master craftsman prepares four-five mirrors and polishes them at a stretch. When one gets heated, he does the polishing for the next one while the other cools. To achieve high-quality reflective surfaces, the polishing can go on for one-to-two days. Once the required polished surface is achieved, it is then further polished using a piece of cotton cloth. Then final polishing is done using a velvet cloth. The velvet

The polishing that creates the mirror from metal is a labour-intensive process comprising different stages

tends to absorb the oil that was applied earlier on to the mirror. Hence, further polishing is continued on another dry piece of velvet.

The velvet cloth is placed on the ground and the mirror along with wooden plank is moved in the desired direction. Once the satisfactory finish is achieved, the disk is just heated to separate it from the wooden plank and the mirror is mounted on a brass frame. The finished mirror would be brighter and beautiful. The making process of Aranmula Kannadi involves a lot of effort, expertise, and patience. Aranmula Kannadi is not a replacement for a dressing table mirror, or it can't be made in such a huge size. Instead, this is a mirror with a lot of specialty, and it is used as a precious collectible. Yet, you can use it to view your face but the biggest Aranmula Kannadi that was made was around 12 inches in diameter, that itself would be at least 10 kilograms in weight with a huge frame size and can be very expensive. Normally, the Aranmula Kanandi comes in a size range of 2 inches to 6 inches — those are the most popular models, which people buy as gifts or to keep in their homes or business organizations.

As traditional as the mirror-making technology is the artisan's belief that the composition of the metal-mirror is divine and that some undisclosed metal alloy with copper and tin is responsible for the distortion-free images. "The imitators are using the combination of tin and copper, but they don't know the accurate combination of the alloy, a secret maintained by the family. They polish the mirror with grinding and buffering machines," share the artisans. The final polishing of Aranula Kannadi is done using an undisclosed herbal paste. At present, only 19 registered craftsmen called *acharis* have the legal right to make Aranmula Kannadi.

The process of making Aranmula Kannadi involves a lot of effort, expertise, and patience. It is not a replacement for a dressing table mirror as it cannot be made in a huge size. The most common Aranmula mirrors come in a size range of 2 inches to 6 inches

In conclusion, we can be sure that this mirror is marvelous indeed. Noted for outstanding beauty and shrouded in secrecy, the Aranmula Kannadi is considered a medieval marvel in the annals of metallurgy. It was in use much before the appearance of modern-day glass mirrors. The technical know-how behind the making of this unique metal mirror is confined to only some households of master craftsmen in Aranmula.

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Innovation to Remove Microplastics from Water

Scientists at the Indian Institute of Science (IISc) have created a sustainable hydrogel to filter out microplastics from water to tackle the threat of plastic pollution

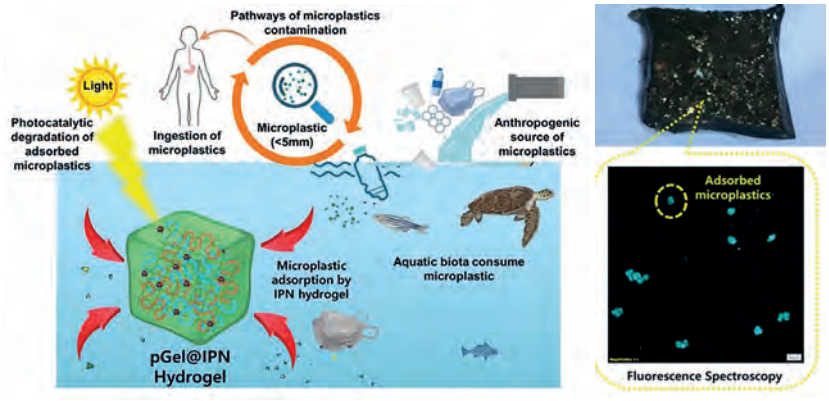
■ **Science India Bureau**

To combat the menace of plastic pollution, scientists at the Indian Institute of Science (IISc) have designed a sustainable hydrogel to remove microplastics from water. In a press release, Bengaluru-based IISc explained that the hydrogel has a unique intertwined polymer network that can bind the contaminants and degrade them using UV light irradiation.

Microplastics have been discovered practically everywhere on the Earth, from mountains to oceans. The United Nations Development Programme (UNDP) claims these microscopic plastic particles, which are less than five millimetres, have found their way into our land, oceans, and even the air we breathe. These microscopic particles are extremely dangerous to our health since they can get into our systems through the water we drink.

Prior attempts by scientists to eliminate microplastics have involved the use of filtering membranes. However, these membranes can become clogged with these tiny particles, making them unsustainable. Next, in search of a solution, the IISc team under the direction of Professor Suryasarathi Bose of the Department of Materials Engineering looked to 3D hydrogels.

The team's innovative hydrogel is made up of three distinct polymer layers that are entwined to form an Interpenetrating Polymer Network (IPN) architecture: Chitosan, polyvinyl alcohol, and polyaniline. The researchers added copper replacement polyoxometalate (Cu-POM) nanoclusters to this matrix. These nanoclusters function as catalysts, breaking down the microplastics with the help of UV light. According to the



All Images Courtesy: IISc

Above: The functioning of sustainable 3D hydrogel to remove microplastics from water
Left: Suryasarathi Bose (left) and Soumi Dutta of IISc, Bengaluru

press release, "The polymers and nanoclusters combined to create a robust hydrogel that can both adsorb and degrade significant amounts of microplastics."

The majority of microplastics result from the partial decomposition of common household fibres and plastics. In order to replicate this in the laboratory, the group crushed food container lids and other everyday plastic items to produce polyvinyl chloride and polypropylene, two of the most prevalent microplastics found in nature.

"Along with treatment or removal of microplastics, another major problem is detection. Because these are very small particles, you cannot see them with the naked eye," noted Soumi Dutta, SERB National post-doctoral scholar in the Department of Materials Engineering and the study's first author.

To be able to track how much of the hydrogel was being adsorbed and broken down under various circumstances, the researchers included a fluorescent dye into the microplastics as a solution to the issue. According to Dutta, "We examined the removal of microplastics at various water pH levels, temperatures, and microplastic concentrations."

To monitor the amount of microplastics that the hydrogel was absorbing and breaking down under various circumstances, they additionally added a fluorescent dye to the particles.

"It was discovered that the hydrogel was extremely effective; at approximately pH 6.5, it was able to eliminate roughly 95% and 93% of the two distinct kinds of microplastics from water," Bose stated.

After the hydrogel's useful life is over, it can be recycled to create carbon nanoparticles that can be used to remove heavy metals from contaminated water. The next step for the researchers is to create a large-scale tool that will assist in eliminating microplastics from different water sources.

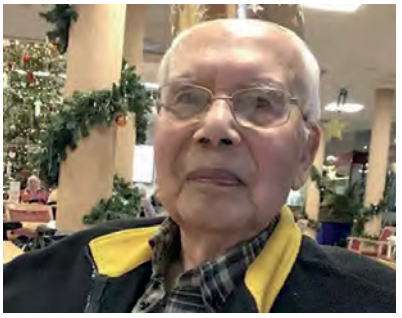
The Physician Who Converted ORS into a Household Medicine

It is a tragedy that Dr Dhiman Barua, who went beyond his brief to bring WHO's attention to 'potentially the most important medical advance of the 20th century' remains unknown, unsung and unheralded

■ **Kalyan Kumar Ganguli**

ORS or Oral Rehydration Solution, also known as ORT or Oral Rehydration Therapy is a solution of definite proportion of glucose and a few other salts and water. The famous medical journal, The Lancethailed it as 'potentially the most important medical advance of the 20th century'. The use of ORT has been estimated to decrease the risk of death from diarrheal diseases by up to 93%.

Dr Dilip Mahalanabis discovered ORS, but this life-saving discovery was doomed to be unutilised, unrecognised and forgotten forever, as its effectiveness as claimed by Dr Mahalanabis was looked upon with suspicion by the majority of global scientific communities. The indifference went to the extent that some publishers refused to publish his original papers, and recognition of the medicine by WHO was put in cold storage. It took seven more years, when Indian physician Dr Dhiman Barua, through his persistent efforts made the WHO authorities agree for a trial of ORS. Eventually, Dr Barua led the ORS trial in 105 countries against cholera and enteric diseases, leading to its global recognition as the primary medicine against cholera and enteric diseases by WHO. Dr Mahalanabis received international recognition but no honour from reputed Indian scientific committees and various governments of India in his lifetime. It is ironic that after his death on 16 October 2022, the government of India honoured him with the Padma Vibhushan posthumously in 2023.



Above: ORS or oral rehydration solution being administered to a patient in 1992 to help arrest his cholera-induced dehydration

Left: Dr Dhiman Barua

However, without the relentless efforts of Dr Dhiman Barua of WHO, the skeptical medical fraternity worldwide probably would not have been convinced even today that the therapy is an

Images Courtesy: Wikimedia Commons

effective substitute to IV saline in the primary stage and could be administered by people with little or no training, thereby saving millions of lives.

A NEW CHAPTER IN CHOLERA RESEARCH

In those days, since plastic bottles were not put in practice, IV saline was packed in glass bottles which became so heavy that transporting cost by air became much more than the medicine itself. In 1970, the cholera epidemic spread over almost all the countries in Africa. Intravenous saline was required in tonnes, which became impossible to supply. Patients died in huge numbers in front of the helpless doctors. That incident pressed the need for ORS afresh. In the meanwhile, a new chapter in cholera research was started in 1968 when SEATO Cholera Research Laboratory at Dacca and two labs at Calcutta, the Johns Hopkins University International Center for Medical Research and Training (JH-CMRT) and Cholera Research Center (renamed NICED later) intensified research for the development of ORS.

Very soon, scientists got the proof from laboratory and limited field trial experiments that glucose and a few other salts dissolved in definite proportion in water (even sugar and common salt from the kitchen) caused absorption of water in the intestine. Large scale trial could not be undertaken as Dr Robert Philips, Director, PSCRL was skeptical of the ORS treatment; in 1962, he had treated 30 patients with ORS of his own formulation, of whom 5 had died due to liquid overpressure. The opportunity of large-scale trial came soon in 1971 when cholera broke out in refugee camps in Bongaon, West Bengal, at the border of India-East Pakistan where lakhs of refugees took shelter due to the atrocities of the then Pakistan government. Dr Mahalanabis of JH-CMRT left his research and came to the refugee camps for the treatment of patients. There were only two cottages with a total of 16 beds in the cholera ward, while the number of patients was huge. IV saline and medical persons were in meagre numbers. Patients were dying in flocks. The atmosphere was reverberating with woe and wail all around. In desperation, Dr Mahalanabis resorted to ORS treatment (22 g Glucose, 3.5 g Sodium Chloride, 2.5 g Sodium Carbonate) without seeking permission of higher ups, and with the help of JH-CMRT. During the eight-week period in which he and his team administered the therapy, only 135 cases proved fatal out of a total of 3700 patients, translating to a case fatality rate (CFR) of 3.6% in comparison to the earlier CFR of 30%.

Image Courtesy: Internet

Dr Dilip Mahalanabis saved millions of lives when there was an outbreak of cholera in the refugee camps during the 1971 Liberation War of Bangladesh

DR DHIMAN BARUA OF WHO VISITS THE CAMP

During that period, Dr Dhiman Barua of WHO, who was Dr Mahalanabis's teacher in medical college, visited the camp and was amazed at the way Dr Mahalanabis was managing the whole episode, despite the shortage of staff and danger of liquid over pressure on the patients. ORS liquid in drums with a tap were put in designated places. Relatives, volunteers, friends, whoever was available, was asked to take glasses of liquid for patients to drink and to stop when the patient did not want to drink anymore. In this way, Dr Mahalanabis not only tackled the danger of liquid over pressure on patients (hypertonicity), but at the same time, he proved that diarrheal patients could be cured by family members without supervision of medical professionals.

The opportunity of large-scale trial of ORS came in 1971 when cholera broke out in refugee camps in West Bengal

WHO DG AGREES FOR ORS TRIAL

Dr Barua joined WHO Geneva office in 1966. Since then, he advocated for ORS as primary treatment against cholera. But his colleagues did not approve of the solution. Even the success of the ORS treatment in Bangladesh refugee camps by Dr Mahalanabis in 1971 could not change their opinion.

One day, Dr Barua met the Director General of WHO, Dr Halfdan Mahler, by chance, in the car garage. Though Dr Barua was a junior staffer, he boldly explained the utility of the application of ORS salts for recovery of cholera patients and gave Dr Mahler some packets of ORS ingredients. From that day onward, he had long discussions about the use of oral rehydration in place of intravenous fluid. Ultimately, Dr Mahler agreed with Dr Barua's proposal. He arranged for him to go to Africa to run five training courses in different countries in treating cholera patients with ORS. Fol-

Image Courtesy: Flickr via UNICEF/ Dhiraj Singh

Above: An ORS sachet with the osmolarity of its components Above right: A student demonstrates mixing of Oral Rehydration Salts (ORS) with water, outside a classroom in a school in Bihar's Madhubani district

Image Courtesy: Flickr via UNICEF/ Graham Crouch

An Anganwadi health worker delivers treatment of oral rehydration salts and zinc tablets in Pakauli village in Vaishali district outside Patna in Bihar

lowing its success,Dr Mahler decided to seek funding for the Diarrheal Disease Control (CDD) programme. The mainstay of the CDD programme for proper management of diarrheal disease was:

* Prevent or treat dehydration with ORS solution (IV only in serious case),

* Feeding and breastfeeding during the diarrhea episode to be continued,

* Use antibiotics only in cases of bloody diarrhea.

The programme was eventually led by Dr Barua.

ORS TREATMENT SPREADS WORLDWIDE

Prior to the discovery of ORS, IV saline was the only treatment for cholera. Hospital doctors regarded oral rehydration therapy as a second-grade treatment. Moreover, pediatricians in developed countries feared that sodium concentration in the formula was too high for children.

For ORS treatment to spread worldwide, caking of ORS ingredients due to absorption of moisture leading to short lifespan was an obstacle. Moreover, it took a long time to convince the critics that experience in practice showed no ill effects from ORS treatment, and they were invited to try it for themselves.

Fortunately, towards the end of 1970, a Swiss company succeeded in packaging the ingredients in aluminium foil bags to prevent absorption of moisture and caking of the powder. This increased its shelf-life, the cost of transportation was reduced, and handling became easy. Thereby, the ORS trial programme attained speed.

The opinion of the detractors was set aside when UNICEF reported in 1987: 'No other single breakthrough of the 20th century has had the potential to prevent so many deaths over such a short period of time and at such a little cost.'

Annual global mortality due to diarrhea in children aged under five years was 146 per 1000 in 1970 and 79 per 1000 in 2003, a big reduction. Oral rehydration therapy may not be solely responsible for this improvement, but it surely played a remarkable role in it.

HOW DOES ORT WORK?

Lumen refers to the cavity in the body which enables the function of the organ system. For example, the lumen of the intestines allows for free flow of digested food through the digestive system. Epithelial cells are a type of cell that cover the inside and outside surface of the body. They are found on skin, blood vessels, and organs, including urinary tract, intestine, etc. Intestinal epithelial cells (IECs) line the surface of intestinal epithelium, where they play an important role in the digestion and absorption of nutrients and protection of the body from microbial infections.

There are some transporter and ion channels in the intestine, such as Chloride-Bicarbonate exchanger which pumps chloride ions from the lumen of the intestine to epithelial cells of intestine, and pumps bicarbonate ions on the opposite side. The Sodium-Hydrogen exchanger pumps sodium ions in the intestine to epithelial cells of the intestine and sends protons in the opposite direction. The CFTR channel is an ion that helps to maintain the balance of salt and water in the body.

SGLT1: This is different from other pumps. It sends both the molecules in the same direction. It pumps Glucose and Sodium from the lumen of the intestine to the epithelial cells of intestine. Both the Sodium and Glucose cannot pass alone through SGLT1 without the company of the other.

Sodium-Potassium ATPase pump: It pumps from the epithelial cells of intestine 3 sodium ions to the flow of blood and 2 potassium ions in the opposite direction.

For a healthy person, 2000 to 3000 milligram sodium secretes in the lumen of the intestine which is absorbed almost totally in the blood to maintain balance. When cholera toxin enters the epithelial cells of the intestine, it deposits cyclic Adenosine Monophosphate (cAmp) in high amounts continuously. This disturbs normal functioning of Chloride-bicarbonate exchanger, Sodium-hydrogen exchanger and CFTR channel. As a result, the secreted Sodium and Chloride ions in the lumen of intestine exit out of the body as stool before being absorbed in blood. Only SGLT1 transporter is not affected by cAmp. Hence, if Sodium chloride and glucose (or sugar) water solution in the right proportion is provided to the patient, then SGLT1 will supply Glucose/ sugar and water from the lumen to the epithelial cells of the intestine, leading to its absorption there. Sodium-Potassium ATPase pump transports Sodium and water to the blood flow. With each cycle, hundreds of water molecules enter epithelial cells and rehydrate it. In this way, a simple solution of Salt, Glucose/ Sugar and water saves patients from dehydration.

Acute diarrhea normally lasts only a few days. Diarrhea is not stopped by ORT, it replaces the lost fluids and essential salts, thus dehydration is prevented, and it strengthens the patient with the supply of essential salts. ORT alone is an effective treatment for most of the patients suffering from acute watery diarrhoea. Except for serious cases, intravenous drip therapy is unnecessary.

LIFE DEDICATED TO HUMANITY

Dhiman Barua was born to a family of doctors and traditional medicine practitioners in Burma (now Myanmar), which was then a part of undivided British India. When he was four years old, his family moved to his ancestral village near Chittagong in in present-day Bangladesh. The area was infested with cholera. He saw a cholera epidemic causing deaths in almost every household of the village. In 1930, he took admission in Chittagong Medical School on a scholarship. Following that, he took a short commission posting in the Army Medical Corps during the World War II and served in Burma, India and Malaysia. After the war, he studied and earned a medical degree from the Lake Medical College in Calcutta, which was under the control of the Army then. He followed it up with a doctorate from Lucknow University, post-doctorate from Pasteur Institute, Paris, and the London School of Tropical Medicine.

Dr Barua began working for the WHO in 1965 with the cholera control team based in Manila, and in 1966, he moved to the WHO head office in Geneva as a medical officer for cholera and other diarrhoeal diseases. Throughout his career at WHO, he trained health workers globally in ORT and other aspects of diarrheal diseases. He passed away in Geneva on 19 August 2020, two months short of his 100th birthday.

Dr Mahalanabis bestowed full credit to his teacher Dr Dhiman Barua for the global recognition of ORS developed by him against cholera and enteric diseases. But Dr Barua himself received practically no recognition for his vision and efforts in spreading the life-saving treatment around the world.

Dr Barua deserves complete credit for converting the "most important medical advance" of the 20th century into a household medicine worldwide. It is a tragedy that Dr Dhiman Barua's contribution to humanity remains unhonoured by scientific communities and even the governments, including that of India. Will the Government of India honour him posthumously?

**The writer is ex-governing council member, Vijnana Bharati, and Retired Scientist, CSIR-CIMFR, Dhanbad. He can be reached at ganguli.kalyan@gmail.com.*

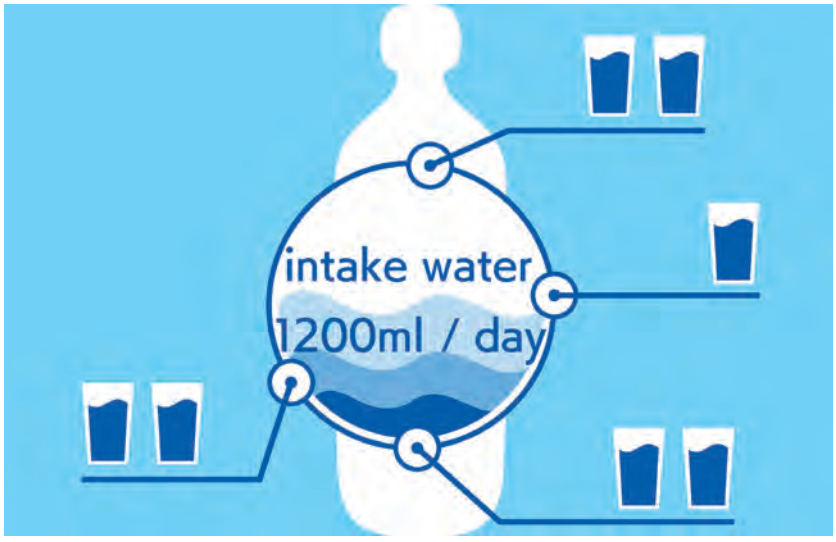
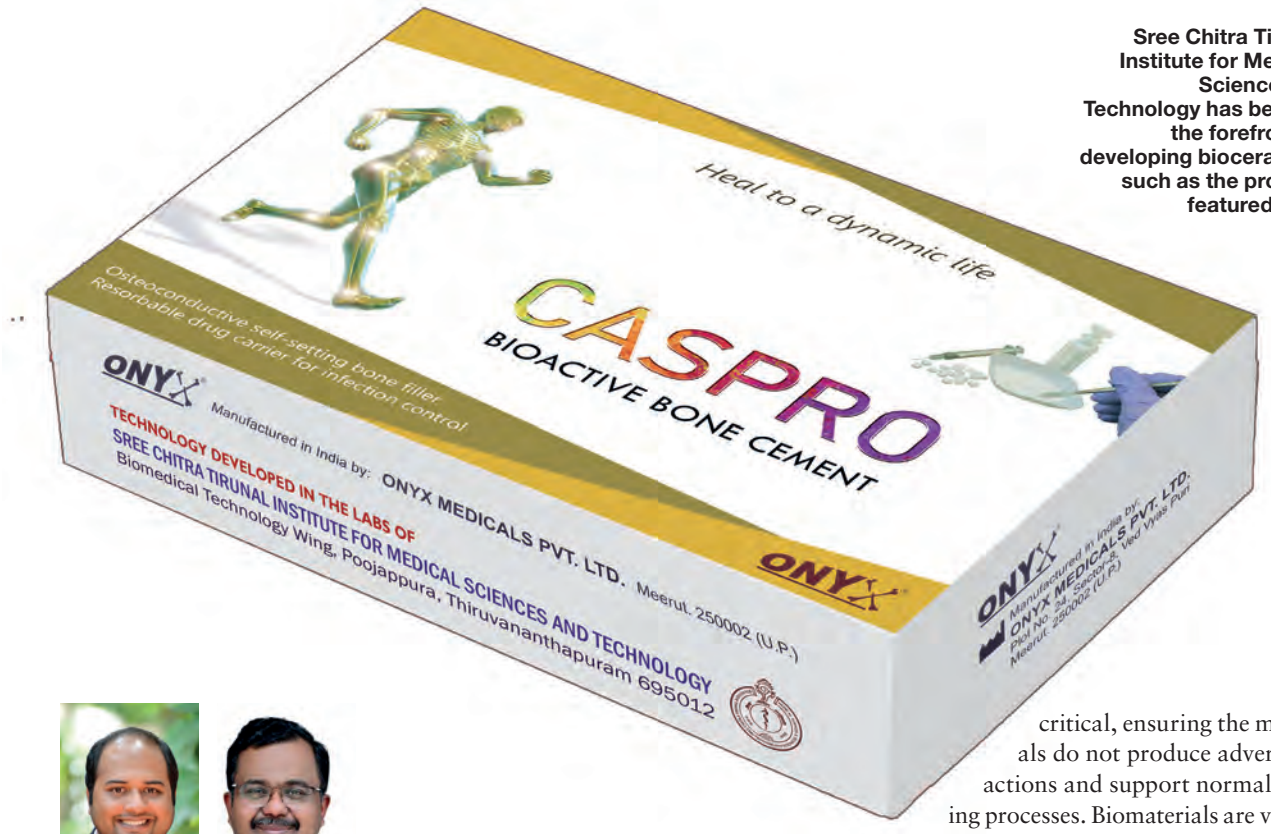


Image Courtesy: Shutterstock

A diagrammatic illustration of the standard daily fluid intake

Bioceramics Technology Translation: An Indian Perspective

Despite inherent challenges, bioceramics are increasingly proving to be effective in biomedical engineering



Sree Chitra Tirunal Institute for Medical Science and Technology has been at the forefront of developing bioceramics such as the product featured here

■ **Dr Francis B Fernandez and Dr Biju Dharmapalan**

Bioceramics, a distinct subgroup of biomaterials, have significantly transformed the medical industry through their utilisation in surgical implants, prosthetics, and regenerative medicine. These sophisticated materials, made from ceramic compounds, are specifically engineered to interact seamlessly with biological tissues.

Bioceramics are derived from ceramics, materials traditionally known for their hardness and resistance to wear. However, unlike their counterparts in pottery or construction, bioceramics are tailored for medical use. These materials include alumina, zirconia, and calcium phosphates like hydroxyapatite, which closely mimic the mineral composition of bone. Bioceramics have become a cornerstone of modern grafting techniques, offering unparalleled biocompatibility, bioactivity, and mechanical properties. From bone grafts to dental implants and joint replacements, these advanced materials are transforming the landscape of medical treatments. Biocompatibility is critical, ensuring the materials do not produce adverse reactions and support normal healing processes. Biomaterials are vital in enhancing the quality of human life and are widely used in joint replacements, artificial arteries, skin substitutes, and bone substitutes.

Bioceramics have significantly advanced over the past two decades, enhancing the repair and regeneration of calcified tissues. The increasing elderly population and related ailments drive the demand for novel biomaterials capable of replacing damaged tissues and promoting the body's regeneration potential. Bioceramics, such as calcium phosphates, bioactive glasses, and glass ceramics, are designed to mimic the structure of native calcified tissue, play-

All Images Courtesy: Dr Francis B Fernandez and Dr Biju Dharmapalan

Bioceramics have significantly advanced over the past two decades, enhancing repair and regeneration of calcified tissue

ing a crucial role in tissue engineering and drug delivery.

The Bioceramics Lab at Sree Chitra Tirunal Institute for Medical Science and Technology (SCTIMST) has been at the forefront of developing Bioceramics based on calcium phosphate and calcium sulphate routes. The development of materials via indigenous routes and with adherence to quality standards that are at par or exceed international standards provides Indian citizens access to high-tech health care. The lab has been established under the leadership of Dr Harikrishna Varma PR and is currently led by Dr Manoj Komath. The research carried out in this lab has been supported by product viability in the market, which is attested to by the current market trends and ongoing demand in the Indian sub-continent and abroad for synthetic bone grafts for routine applications. The lab has more than 30 patents filed, and granted, ensuring that technology development is completed within the time frame.

BIOCERAMICS AS SYNTHETIC BONE GRAFTS

Bioceramics are a notable breakthrough in bone grafting since they possess a blend of biocompatibility, bioactivity, and mechanical properties that facilitate successful bone regeneration and integration. Bone is a metabolically active tissue that contains a variety of cells interspersed in a complex system. Components of the system include extracellular matrix, which consists of collagen and a mineral phase of calcium phosphate crystals, which is primarily composed of hydroxyapatite. Due to its inherently dynamic nature, bone has the capacity to regenerate in small quantities. However, critical sized defects require bone substitutes in order to heal adequately and retain their original strength. These are inordinately acquired via high energy trauma, infections, and as an aftermath of tumour excision.

Autografts have remained the 'gold standard' of bony reconstruction. This is met with a lack of supply and associated morbidity in practical application. In the Indian scenario, lack of access to quality banked bone also renders reconstruction painful and reliant on Ilizarov's apparatus or other modes of distraction osteogenesis. Ideally, large-sized defects created secondary to trauma, infection or pathology ultimately require bone replacement strategies, and this may be in the form of an osteoinductive, osteoconductive or osteogenic material. Bioceramics are favoured in this application due to the following properties,

1. Biocompatibility

Bioceramics are highly biocompatible, meaning they do not induce an immune response when implanted in the body. This compatibility reduces the risk of inflammation and rejection, which is crucial for the success of bone grafts.

2. Bioactivity and Osteoconductivity

Many bioceramics, such as hydroxyapatite (HA) and tricalcium phosphate (TCP), are bioactive and osteoconductive. They support the growth of new bone by providing a scaffold that encourages the attachment and proliferation of osteoblasts, the cells responsible for bone formation. This property enhances the integration of the graft with the natural bone.

3. Osteoinductivity

Some bioceramics possess osteoinductive properties, meaning they can stimulate precursor cells to differentiate into osteoblasts. This capability is particularly significant for enhancing bone regeneration in areas with limited natural bone growth.

4. Structural similarity to bone

Bioceramics like hydroxyapatite closely mimic the mineral composition and structure of natural bone. This similarity promotes better integration and stability of the graft within the bone tissue.

5. Mechanical properties

While bioceramics can be brittle, advances in material science have developed composites and engineered structures that improve their mechanical strength and toughness. This makes them suitable for load-bearing applications where mechanical stability is essential.

6. Porosity and Resorbability

Bioceramics can be engineered to have a porous structure, which facilitates vascularisation and the infiltration of bone cells. Additionally, certain bioceramics are resorbable, meaning they gradually

dissolve and are replaced by natural bone over time. This resorbability helps in complete integration of the graft into the body.

7. Reduced risk of disease transmission

Unlike allografts (bone grafts from a donor) or xenografts (bone grafts from another species), synthetic bioceramics eliminate the risk of disease transmission. This factor makes bioceramics a safer option for patients.

8. Customizability

Bioceramics can be easily shaped and tailored to fit specific defects or surgical requirements. Advanced manufacturing techniques, such as 3D printing, enable the creation of custom implants that perfectly match the patient's anatomy.

STEPS INVOLVED IN THE DEVELOPMENT OF BIOCERAMICS

The development of bioceramics begins with extensive research into their chemical composition, structure, and mechanical properties. The primary goal is to create materials that mimic the natural bone environment, promoting osteoconduction (bone growth on the surface) and osteoinduction (inducing the formation of new bone). The consistent interaction with clinicians catalyses this to understand day-to-day problems that can be solved by innovation in material science.

Preclinical Testing

Before clinical use, bioceramics undergo rigorous preclinical testing to evaluate their safety, efficacy, and performance. Sree Chitra Tirunal Institute for Medical Sciences and Technology (SCTIMST), Thiruvananthapuram, offers an accredited process for engaging in material development and validation.

1. In Vitro Studies:

- In vitro tests assess cell viability, proliferation, and differentiation when in contact with bioceramics. These studies help understand the material's cytocompatibility and its potential to support bone cell growth.

S.No.	Generic name	Class of medical devices
1	Cardio-vascular Devices (Biological Evaluation as per ISO 10993)	Class D
2	Neuroprosthesis (Biological Evaluation as per ISO 10993)	Class D
3	Orthopedic Implants (Biological Evaluation as per ISO 10993)	Class C
4	All medical devices and materials (Biological Evaluation as per ISO 10993)	Class D
5	Dental Implants (Biological Evaluation as per ISO 10993)	Class B

2. In Vivo Studies:

- Animal models are used to study the bioceramic's integration with bone tissue, its degradation rate, and the overall biological response. These studies provide crucial data on the material's osteoconductive and osteoinductive properties.

3. Sterilisation and Stability:

- Bioceramics must withstand sterilisation processes without losing their beneficial properties. Studies also evaluate the long-term stability of the material in the body.

INNOVATION AT SCTIMST BIOCERAMICS LABORATORY

The lab has translated technologies related to pure hydroxyapatite, silica-substituted apatite, calcium sulphate cements and drug delivery systems. In collaboration with Dr Vrisha of CMC Vellore, the lab demonstrated the first in-human application of tissue-engineered ceramic for bone reconstruction.

Regulatory Approval

The transition from preclinical studies to clinical use involves obtaining regulatory approval from agencies like the US Food and Drug Administration (FDA), European Medicines Agency (EMA) and Indian Council of Medical Research (ICMR), and Central Drugs Standard Control Organisation (CDSCO). Bioceramics must meet stringent regulatory guidelines for safety, biocompatibility, and performance. This involves extensive documentation and submission of preclinical data.

At SCTIMST, about 20 biological tests, including biocompatibility testing, are accredited by Le Comité Français d'Accréditation (COFRAC) of France. The test reports of all accredited tests are issued with the COFRAC logo. SCTIMST has also received a Certificate of Registration to carry out Test of Evaluation of Medical Devices on behalf of the manufacturer under the Medical Device Rules 2017. The table above lists medical devices that can be tested or evaluated as required.

Clinical Implementation

Upon successful regulatory approval, bioceramics are introduced into clinical practice. Human clinical trials are conducted in phases to assess the safety and efficacy of the bioceramic material in a controlled environment. These trials help identify potential adverse effects and verify the material's performance in humans.

This stage involves collaboration between material scientists, biomedical engineers, clinicians, and surgeons.

1. Orthopaedic Applications:

- Bioceramics are used in bone grafts, spinal fusion devices, and joint replacements. Their ability to integrate with bone tissue makes them ideal for these applications.
- For example, HAp coatings on titanium implants enhance osseointegration, improving the stability and longevity of the implants.

2. Dental Applications:

- In dentistry, bioceramics are used for tooth root replacements, bone grafts in periodontal defects, and as coatings for

dental implants. These materials promote faster and more reliable integration with the jawbone.

3. Customised Implants:

- Advances in 3D printing technology allow for the customisation of bioceramic implants to match the patient's anatomy. This personalised approach enhances the fit and function of the implants.

CHALLENGES AND FUTURE DIRECTIONS

Despite the significant progress, several challenges remain in the clinical translation of bioceramics.

1. Mechanical Limitations:

- The brittleness of bioceramics can limit their use in load-bearing applications. Research is ongoing to improve their mechanical properties while maintaining bioactivity.

2. Resorption Rates:

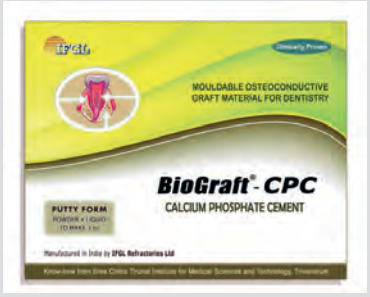
- Balancing bioceramics' resorption rate with the new bone formation rate is crucial. Materials that resorb too quickly may not support new bone growth.

3. Complex Biological Interactions:

- Understanding the complex interactions between bioceramics and the biological environment is essential for optimising their performance. This includes studying the immune response and the influence of various biological factors on material degradation and bone formation.

CONCLUSION

The clinical translation of bioceramics represents a significant achievement in biomedical engineering and materials science. Through rigorous research, testing, and collaboration, bioceramics have become vital tools in orthopaedic and dental applications, offering improved patient outcomes. As research continues to address existing challenges and explore new frontiers, the future of bioceramics in clinical practice looks promising, with the potential for even more advanced and effective treatments



Bioceramics are used in bone grafts, spinal fusion devices, joint replacements, and tooth root replacements, among several other cases. As they are biocompatible, they do not induce an immune response when implanted in human body

for bone-related conditions. Bioceramics face challenges such as brittleness and lower tensile strength, limiting their use in load-bearing applications. Advanced processing techniques are necessary to achieve desired properties, which can be complex and costly. Continuous advancements in material science and technology are essential to overcome existing challenges and expand the applications of bioceramics in biomedical engineering.

The Bioceramics Laboratory at the Biomedical Technology Wing, SCTIMST has translated technologies related to pure hydroxyapatite, silica-substituted apatite, calcium sulphate cements and drug delivery systems. The lab has been at the forefront of maintaining the cutting edge in ceramic technologies for life-saving applications in India. The technologies translated from the SCTIMST will benefit the patients not only in the country but globally, making Indian healthcare products acceptable globally.

Sree Chitra Tirunal Institute for Medical Sciences and Technology (SCTIMST) is an Institution of National Importance in India established in 1976 in Thiruvananthapuram, Kerala. The institute is a statutory body under the Ministry of Science and Technology and is under the administrative control of the Department of Science and Technology, Government of India. It has three wings: A tertiary referral super speciality hospital, a biomedical technology wing and the Achutha Menon Centre for Health Science Studies. The institute focuses on high-quality, advanced treatment of cardiac and neurological disorders, indigenous development of biomedical devices and materials technologies, and public health training and research. The institute has excellent facilities and teams of professionals dedicated to developing innovative biomedical devices and products, evaluating medical devices to global specifications, training in novel medical specialities, and conducting research in medical and public health areas of social relevance. The institute is a Technical Research Centre for Biomedical Devices and has a medical devices incubator (TIMed). The institute has the status of a university and offers postdoctoral, doctoral and postgraduate courses in medical specialties, public health, nursing, physiotherapy, basic sciences and healthcare technology. More about the institute is available on the website, https://www.sctimst.ac.in/

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HERB HERITAGE: HARITAKI

A Medicine for all Seasons

Known to Indians since ancient times, the wide-ranging benefits of Haritaki have been mentioned in great detail in the 16th century text, *Bhavaprakash Nighantu*

■ Vaidya Preeti Bhosle

Once upon a time, when lord Indra was consuming Amrit, a few drops fell on the earth. Those drops were converted into a medicinal herb known as Haritaki. Also known by the name of Terminalia chebula, Haritaki is one of the most widely used medicinal plants. The Indian system of medicine, Ayurveda, gives a detailed description of *harad* or Haritaki but Acharya Bhavamishra in the 16th century AD elaborated for the first time the complete profile of Haritaki in his work, the *Bhavaprakash Nighantu*, which is an important text of Ayurvedic pharmacology. This text focuses on the source, types, flavours, undertones, aliases, traits, appearance, attributes, and healing benefits of Haritaki.

Detailed therapeutic benefits of Haritaki, including the use of processed Haritaki, combining it with various adjuvants, considering food intake, and utilizing it as a rejuvenation therapy, are elaborated in *Bhavaprakash Nighantu*. Acharya Charaka labeled Haritaki as 'Haritaki Pathyanam,' indicating its beneficial effects on the body. He also recognized Haritaki as *amritakalpa*, attributing it as possessing the qualities of nectar such as being life-promoting, a tonic, and sustaining youthfulness. As per Acharya Vagbhatta, Haritaki not only alleviates diseases but also enhances intelligence, preserves youthfulness, promotes longevity, and enhances the strength of the mind and sense organs.

The word Haritaki refers to 'a dark greenish yellow fruit that helps prevent diseases'. It is called Abhaya (highly secure), Avyatha (heals pain), Pathya (harmless for bodily pathways), Kayastha (enhances body strength), Putana (removes toxins), Hemavati (found in the Himalayas), Chetaki (clears mind by purifying channels), Shreyasi (cares for the user), and Shiva (brings all positive things). Other synonyms include Amruta, Bhishagvara, Devi, Divya, Jaya, Jivanika, Jivanti, Jivapriya, Jivya, Pathya, Pranada, Rohini, Vayastha, and many more.

Some of these above mentioned synonyms have specific interpretations as well:

Haritaki: It provides a good complexion or colour.
Abhaya: It relieves fear against all diseases.
Avyatha: Its usage provides relief from many diseases.
Pathya: It cleanses the channels, hence beneficial to the body.
Kayastha: Once used internally, it always remains successful (fruitful) in eliminating diseases.
Putana: Cleanses the body by purgation.
Amrita: It has a *rasayana* property, rejuvenates the body and removes diseases.
Hemvati: Grows (everywhere and) in the Himalayas.
Chetaki: It cleanses the channels in the head and improves mental function.
Shreyasi: It is highly beneficial due to its good properties.
Shiva: It brings good fortune.
Vijaya: It specifically conquers diseases.
Jivanti: It provides *rasayana* (rejuvenative) effect for a long time and thus increases longevity.
Rohini: It is useful for healing of wounds.

Abhaya is also known by the following vernacular names:

Sanskrit: Abhaya, Kayastha, Shiva, Pathya
Assamese: Shilikha

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Bengali: Haritaki
English: Myrobalan
Gujrati: Hirdo, Himaja, Pulo-harda
Hindi: Harre, Harad, Harar
Kannada: Alalekai
Kashmiri: Halela
Malayalam: Katukka
Marathi: Hirda, Haritaki, Harda, Hireda
Oriya: Harida
Punjabi: Halela, Harar
Tamil: Kadukkai
Telugu: Karakkaya

Interestingly, Harad gives different therapeutic benefits corresponding with different ways of processing/ administration (as identified by Acharya Bhavamishra):

1. Charvita (when chewed): Increases appetite
2. Peshita (when pounded): Laxative
3. Swinna (when boiled): Anti-diarrhoea
4. Bhrishta (when fried): Pacifies/ balances three *doshas*
5. After meal with *ghee:* Acts as *rasayana*
6. Kalka (paste) with *ghee:* Balances *vata* in central part of the body
7. Haritaki with Erand *taila:* Considered wholesome
8. After consuming with some oil: Pain management
9. Haritaki with *dhanyak tusha siddha jala:* Vayu in abdomen
10. Fruit of Haritaki: Spleen, gastritis, stiffness in thigh region, anaemia, worms
11. Kalka (paste) with *shunthi* and *saindhav lavan:* Indigestion
12. With Shunthi: Poor digestive fire
13. With Saidhava Lavana: Fever(s)
14. With Dadhi and Takra: Diarrhoea
15. With Madhu: TB
16. With Gomutra: Inflammations
17. With equal quantity of Sarkara: Anaemia
18. With Matulunga Svarasa: Emaciation, burning sensation

There are seven major varieties of Haritaki which are mentioned in the table below along with their attributes.

Certain varieties have specific functions, such as:

1. Vijaya: Sarvaroga (Cures all diseases)
2. Rohini: Vrana (Wound healing)
3. Putana: Pralepa (Used for application)
4. Amrita: Shodhana (For purification)
5. Abhaya: Netraroga (Eye diseases)
6. Jivanti: Sarvaroga (Cures all diseases)
7. Chetaki: Rechaka (Purgation)

Therapeutically, Haritaki is used in following diseases in different dosage forms:

Shwas (Asthma), Kasa (Cough), Prameha (Diabetes), Arsha (Piles), Kushtha (Skin disorders), Udar (Ascitis), Krimi (Worms infestation), Visarpa (Herpes), Jwara (Fever), Chhardi (Vomiting), Hridrog (Cardiac diseases), Kamala (Jaundice), Yakritvikar (Liver disorders), Ashmari (Calculi), etc.

One of the highly captivating applications of Haritaki is '*Ritu haritaki*', which means that it can be used in different ways as per the ongoing season (*ritu*) to avail *rasayana* (rejuvenative and restorative) benefit. Still, in order to achieve the *rasayana* effect, it requires different supportive *dravyas* in various *ritu*.

During the Grishma *ritu* (summer season), excessive dryness and pungent taste of *dravyas* can weaken a person's strength. The accumulation of *vata* and reduction of *kapha* occurs during this season. Combining Haritaki with *guda* (jaggery) can help prevent *vata* accumulation by balancing the heaviness and unctuousness of *guda* with the warmth and sweet taste of Haritaki.

In Vasanta *ritu* (spring season), moderately dry and astringent properties of food and medicines can also weaken a person's strength. To mitigate aggravated *kapha* during this season, Haritaki is taken with honey to balance its lightness and dryness with the astringent taste of honey.

During Shishira *ritu* (autumn season), dryness and coldness can also weaken a person, and Haritaki with *pippali* can help mitigate accumulated *kapha* by balancing its properties with *pippali*'s pungent taste and lightness.

In Sharada ritu (autumn season), Haritaki with *sharkara* purifies provoked *pitta* with its *snigdha guna*, *madhura rasa*, and *vipaka*, restoring strength and digestive capacity.

In Varsha *ritu* (rainy season), Haritaki with *saindava lavana* brings *sanchita pitta* to equilibrium with its *laghu guna* and *madhura vipaka*. This helps enhance metabolism impaired by *vata prakopa* and *pitta sanchaya*, acting as an appetizer, digestant, and strength restorer.

In Hemanta *ritu* (winter season), the *snigdha guna* and *madhura rasa* are predominant. Haritaki with *shunti* mitigates *kapha* and prevents aggravation with its *ushna virya*, *katu*, *tikta*, *kashaya rasa*, *laghu*, and *ruksha guna*. It helps bring back *pitta* to equilibrium with its *madhura vipaka*.

S.No.	Variety name	Habitat	Characteristics	Therapeutic uses
1	Vijaya	Vindhya mountains	Fruit resembles round gourd, oval in shape	Useful in all kinds of diseases
2	Chetaki	Himalayas	Fruit has three ridges on it	Preferable to use in the form of powder, and as indicated
3	Putana	Sindh region	Fruit is less bulky having small seed inside	Useful in external application
4	Rohini	Paithana region (Maharashtra)	Fruit is round in shape	Useful in wounds
5	Amrita	Champaranya region (Bihar)	Fruit is bulky with thick, hard pulp	Useful in purificatory measures as a purgative
6	Abhaya	Champaranya region (Bihar)	Fruit has five ridges on it	Useful in eye diseases
7	Jivanti	Saurashtra region (Gujarat)	No reference available	No reference available

**The writer is an Ayurveda physician, DST Woman Scientist A, AIIMS New Delhi, and founder of Pratha Ayurveda.*

IN FOCUS: IISER BHOPAL

Nurturing Science & Future Scientific Leaders

A relatively young institute, IISER Bhopal has already made a name for itself in promoting quality education and research in science and allied areas

■ **Team IISER Bhopal**

The Indian Institute of Science Education and Research Bhopal (IISER Bhopal) was established on 20 February 2008 by the Ministry of Education, Govt. of India (then the Ministry of Human Resource Development). IISER Bhopal aspires to achieve excellence in teaching and scientific research. The institute is steadfast in its commitment to creating an atmosphere that nurtures innovation, creativity, and excellence among its students. It is amongst the seven IISERs that are Institutes of National Importance, created through a proclamation of the Ministry of Education (then Ministry of Human Resource Development), Government of India, to promote quality education and research in science and allied areas.

The institute is governed by the NITSER (Amendment) Act, 2017 and the Statutes of IISERs. The first academic session of IISER Bhopal began on 16 August 2008. IISER Bhopal's sprawling 200-acre campus is located in Bhauri at Bhopal Bypass Road. The campus offers excellent world-class infrastructure for all-round development of the students enrolled in its various academic programs that include the 5-year Bachelor of Science-Master of Science (BSMS), 4-year Bachelor of Science (in Engineering or Economics departments), 2-year Master of Science (in Biological Sciences, Chemistry and Mathematics), Integrated PhD program (in Physics and Mathematics), and PhD program (in all the ten departments). The disciplines covered at IISER Bhopal include biological sciences, chemistry, physics, mathematics, earth and environmental sciences, data science and

Right: The lecture hall at IISER Bhopal; Facing page and below: Different buildings at the 200-acre campus at Bhauri on Bhopal Bypass Road

All Images Courtesy: IISER Bhopal

engineering, electrical engineering and computer science, chemical engineering, humanities and social sciences, and economic sciences. A two-year MA program in Liberal Arts will start from the next academic year, 2025-2026.

IISER Bhopal is committed to nurturing curiosity and enabling students with the necessary skills to become leaders in their chosen fields. Students at IISER Bhopal work on cutting-edge interdisciplinary problems that bring together the best minds in science, engineering, and humanities. The institute's academic programs align well with the National Education Policy (NEP 2020) in spirit and philosophy. Our world-class faculty together with our bright students, who are amongst the best minds in the nation, have carved a niche for themselves in this short span of time. Together, we are building an Institute of Excellence that is becoming a pride of the nation by churning out new knowledge, innovative technologies and high-quality researchers.

Looking ahead, in alignment with the institute's motto, Vidya Amrutam Asnute (Knowledge bestows immortality), IISER Bhopal will continue to illuminate the world with its academic brilliance, shaping the future by producing the next generation of research leaders and innovators, dedicated to serving not only the nation but the entire world.

The disciplines covered at IISER Bhopal include biological sciences, chemistry, physics, mathematics, earth and environmental sciences, data science and engineering, electrical engineering and computer science, chemical engineering, humanities and social sciences, and economic sciences

OUR GLOBAL PRESENCE

IISER Bhopal has been ranked 4th in the academic category as per the rankings released recently by the Nature Index annual table 2023. Also, IISER Bhopal has acquired top position among all IISERs in the country in overall category and is ranked 6th in the overall category based on the Nature Index data. IISER Bhopal has secured 60th place in the NIRF Ranking 2023 and is at Overall Rank 351-400, South Asia Rank 90, and India Rank 55 in 2024 of the QS Asia Ranking 2024. IISER Bhopal secured 64th overall out of 77 Indian Institutions/ Universities in the top 1500 global rank 1201-1500 in the Times Higher Education 2024 world ranking.

OUR STRENGTHS AND INCLUSIVENESS

At this moment we have a total of ~160 faculty members in the ten (10) academic departments. So far, ~ 1600 students have graduated from IISER Bhopal and most of them have been well placed in different corners of the world, bringing glory to the institute. A number of the alumni are currently employed as faculty members at prestigious institutes such as the IITs, NITs, Central Universities, and others premier research institutes.

Currently, around 2500 students are enrolled in the BS, BSMS, PhD and Integrated PhD programs, of which more than 37% are female. The institute has a stellar record of publishing 3086 research papers, securing 226 R&D Project Grants and hosting 42 Fellowships, NPDFs, INSPIRE Faculties so far. IISER Bhopal is continuously contributing towards capacity building in science and engineering education.

FOSTERING RESEARCH EXCELLENCE

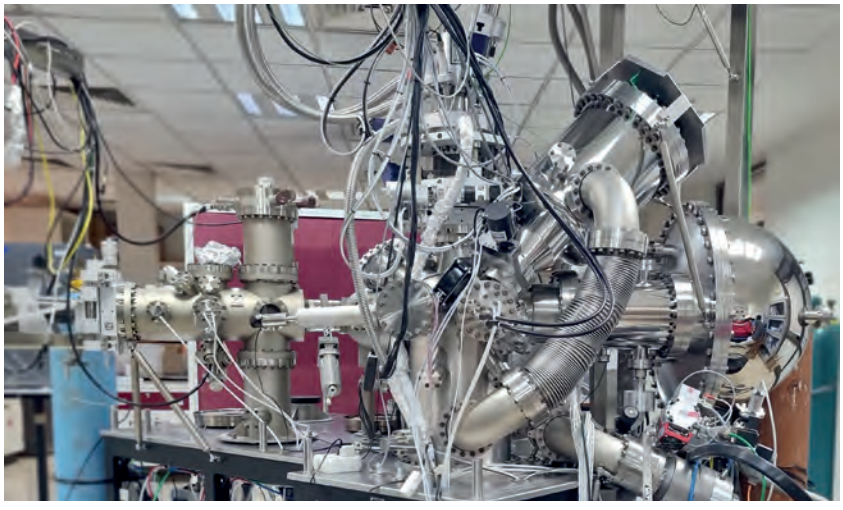
The institute is home to state-of-the-art laboratories and research facilities that support cutting-edge scientific inquiry. The institute had a rich and diverse research portfolio of more than Rs 130

crores in the form of sponsored research as well as industrial consultancy projects in FY 2023-24. Our major funders include SERB (now ANRF), DST, DBT, MoE, CSIR, MoEFCC, India Alliance, and ICMR. The institute envisions executing projects in collaboration with industries on the strategic fields of affordable healthcare, agriculture, rural development, and socially relevant areas. Currently, IISER Bhopal is a node in central India for research and testing facilities. The institute houses world class analytical instrumentation and other advanced research facilities.

The Central Instrumentation Facility (CIF) at IISER Bhopal houses 400, 500, and 700 MHz NMR, MALDI, UPLC, LRMS, FE-SEM, HR-TEM, BET, DSC, TGA, AFM, XRD, Rheometer, VSM, ITC, Confocal Microscope, EPR. DLS and other equipment for research and testing. The facility is open to all researchers. Industries in the country can get their samples analyzed at IISER Bhopal upon payment of reasonable charges. In addition to the institute website, IISER Bhopal R&D infrastructure is also listed on the I-STEM website, an initiative by the Government of India. The institute library is a unique knowledge center offering access to essential and specialized information resources and other services to meet growing information needs, both for cutting-edge research. The library has a total of 15,000 print books in its collection. The library provides access to 6500+ e-journals/ e-databases on various subjects. In the research output, we have registered a steady growth in the research publications, and in the last year, we have published a total number of ~420 research papers.

The institute envisions executing projects in collaboration with industries on the strategic fields of affordable healthcare, agriculture, rural development, and socially relevant areas

In addition to the publications, many important innovations with high societal value have been made at IISER Bhopal. For example, a group of researchers in the electrical engineering and computer sciences department developed a smart air quality monitoring system 'Pawamaan'. The researchers bagged second position for their invention at the Environmental Sensing Project Competition (2022) organized by the University of Helsinki, Finland.



IISER Bhopal houses world class analytical instrumentation and other advanced research facilities

Another research group from the same department designed a sign language translator which has been selected at the IEEE CASS Student Design Contest for R10 Regional level. This innovation may act as a strong bridge for communication with disabled people as the device follows Indian sign language gestures and translates them into a readable LED based text in real-time. In another innovation in the healthcare sector, we have developed a prototype of an automated wheelchair for patients without speech abilities. IISER Bhopal researchers have also developed an autonomous cleaning boat to clean the water bodies. The group successfully demonstrated the device application in Bhopal city's lower lake.

PROMOTING ENTREPRENEURSHIP

Alongside publishing highly impactful scientific articles that have advanced human knowledge in diverse fields, we are witnessing an exponential growth in translating new knowledge to human welfare through filing of patent applications. Of the 47 patents filed, 25 have been granted. It is noteworthy that 30 of those applications were submitted in the last four years alone.

The Innovation and Incubation Center for Entrepreneurship (IICE) has been established as a Technology Business Incubator (TBI) at IISER Bhopal and has been supported by the Department of Science and Technology (DST), under NIDHI TBI Scheme. With an aim to create "Impactful, Innovative and Successful Enterprises" towards making India a developed nation, IICE has been instrumental in creating an innovation ecosystem in IISER Bhopal as well as in central India. IICE is presently supporting 14 start-ups and is having a pipeline of incubates working in frontier areas of science and technology like Med-Tech, Health-Tech, Skin Care, AI/ML, Semiconductors, Biotechnology, Diagnostics, Animal Biotech, Simulation technologies, etc. IICE has prepared for strong expansion and a roadmap to power science-driven economic growth of India to contribute towards the vision of Viksit Bharat.

The research facilities at IISER Bhopal are open to all researchers

OUTREACH: BRINGING YOUNG MINDS ON BOARD

IISER Bhopal is committed to inspiring young minds and fostering a culture of scientific inquiry and scientific temper among the broader community. The Centre for Science and Society (CS2) at IISER Bhopal organizes various outreach programs such as an open house, science fairs, workshops, and lectures in vernacular languages aimed at school students, teachers, and the general public. The Teaching Learning Centre (TLC) at IISER Bhopal was established with funding support from the Malaviya Mission-Teacher Training Programmes scheme of the Ministry of Education (MoE). The TLC encourages a variety of pedagogies in both instruction and learning. In order to facilitate active, cooperative learning, we have also constructed contemporary classrooms with technology at the centre. We also organize institute talks, which are open to the public. Some of India's top scientists, such as Dr N Kalaiselvi, Director General of CSIR, Prof Abhay Karandikar, Secretary of DST, Prof Anand Ranganathan, School of Molecular Medicine, JNU, Prof V K Saraswat, Niti Ayog, have given lectures at the institute during the past few months.

Left: Cleaning boat developed at IISER Bhopal to clean water bodies

THE WAY FORWARD

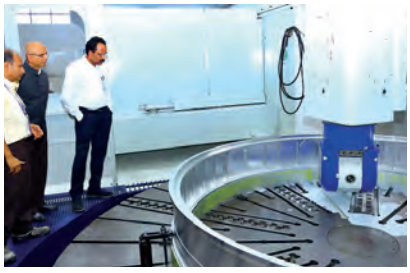
IISER Bhopal aspires to expand and enrich its infrastructure further in the near future to cater to the growing needs of our young and aspirational country. We target to reach out further to the community through augmenting the infrastructure on the campus. For example, we are in the process of establishing a world-class research center for solar power and renewable energy. The proposed center will foster multidisciplinary research in electrical and allied engineering sciences and to achieve the national objective of reducing carbon footprint and increasing the green energy capacity. The center will also aim to enhance solar cell capacity, grid line efficacy, loss minimization, and promote other renewable energy avenues. With all of its present efforts, IISER Bhopal hopes to soon become India's first net-zero carbon emission campus. Further, IISER Bhopal plans to establish an Animal Biosafety Level III Lab (ABSL III lab) and a Cyro-EM facility to undertake research in developing novel vaccines and therapeutics.

In terms of academic and residential infrastructure for our ever-growing student community, there are plans to build another lecture hall complex, a new academic building with world class amenities, expanding residential infrastructure by developing a new 1,050-seater hostel for accommodating the students as the institute plans to achieve a total student strength of more than 3,600 by the academic year 2028-2029. We are also building a new health center with all modern medical equipment and facilities. Notably, IISER Bhopal has followed the Ministry of Education's guidelines to increase the undergraduate student intake gradually. Starting from this academic year (2024-2025), we have increased our student intake by around 25%.

The institute intends to create a wellness centre and a health centre with all the amenities for our community. This will allow students and staff to enjoy the best of campus life while working in a stress-free atmosphere to develop their ability and potential.

ISRO chief inaugurates new HAL facility

In a significant boost to India's space programme, S Somanath, Chairman of the Indian Space Research Organisation (ISRO), opened cutting-edge Propellant Tank Production and CNC Machining facilities at Hindustan Aeronautics Limited's (HAL) Aerospace Division in Bengaluru recently.



ISRO chairman S Somanath at HAL's Aerospace Division, Bengaluru

The newly constructed facilities will greatly improve ISRO's ability to meet its rising production requirements, particularly for the Launch Vehicle Mark-3 (LVM3), India's heaviest and most powerful rocket.

ISRO's joint mission with France on climate data

ISRO is cooperating with the French Space Agency CNES on an ambitious new satellite mission named Trishna, which will significantly contribute to global efforts to monitor and mitigate climate change. Trishna, or Thermal infraRed Imaging Satellite for High-resolution Natural Resource Assessment, is designed to provide high spatial and temporal resolution measurements of the Earth's surface temperature, vegetation health, and water cycle dynamics. Trishna, set to launch in 2025, will use space-based thermal infrared photography to research the effects of climate change and promote sustainable management of natural resources, including water.

IIT-NASA team discovers 'superbug' on Space Station

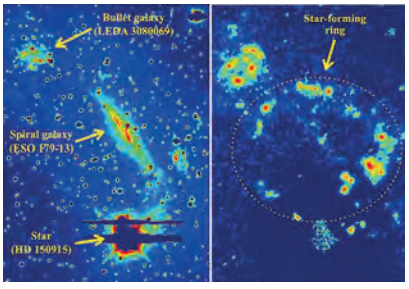
Researchers from the Indian Institute of Technology Madras and the NASA

A drug resistant bacterium has been found on International Space Station

Jet Propulsion Laboratory have discovered disturbing evidence of the emergence of a strain of bacteria on the International Space Station that differs from the ones present on the Earth. The study, led by Principal Investigator Dr Kasthuri Venkateswaran, examined strains of Enterobacter bugandensis, a prominent multi-drug resistant bacterium. Detailed genomic study revealed that these space-dwelling populations had suffered major genetic alterations, separating them functionally and genetically from their Earth-bound counterparts.

Indian astronomers locate explosive star factory in Milky Way

A team of Indian astronomers has discovered a gamma-ray producing collisional ring galaxy in the cosmos. The 'Kathryn's Wheel' is only 30 million light-years from the Milky Way galaxy. This mysterious formation arises when a smaller 'bullet' galaxy pierces a larger galaxy near its centre, causing a shock wave to sweep off interstellar gas, leaving behind a ring of star-forming regions and a gas-poor

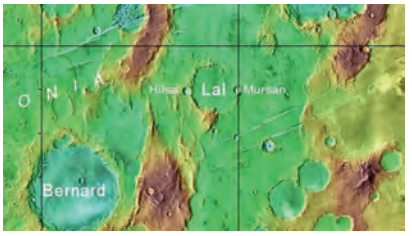


An explosive 'star factory' has been located in the Milky Way

galaxy. Prof Vaidehi S Paliya and Prof Dhruba J Saikia of the Inter-University Centre for Astronomy and Astrophysics (IUCAA) published a study in the *Astrophysical Journal Letters* that found intense star-forming activity around the central spiral galaxy, possibly caused by a galaxy collision.

Two new craters on Mars named after UP, Bihar villages

Scientists from the Physical Research Laboratory (PRL) in Ahmedabad made a significant addition to planetary research by discovering three previously undiscovered craters on Mars. The International Astronomical Union (IAU) has authorised naming



Lal, Mursan and Hilsa are names of three new craters on Mars. These are named after an Indian scientist and two Indian villages

the craters after the former PRL director Prof Devendra Lal, and two small Indian villages. Lal, Mursan, and Hilsa craters are located on Mars' Tharsis volcanic area at 21.0°S, 209°W. They have official names.

PM Modi commends Agnikul's momentous rocket launch

In a significant milestone for India's private space sector, Agnikul Cosmos successfully launched its 3D-printed semi-cryogenic Agnibaan rocket, earning accolades from Prime Minister Narendra Modi. The launch of the Agnibaan rocket, propelled by the world's first single-piece 3D printed semi-cryogenic engine, was a key milestone for the Chennai-based firm and the country's space ambitions. The Prime Minister commended the Agnikul team on 'a remarkable feat which will make the entire nation proud!'

All Images Courtesy: Internet

Russian cosmonaut becomes first to spend 1,000 days in space

A 59-year-old Russian cosmonaut has become the first person to spend 1,000 days in space, according to Russia's space agency Roscosmos. Oleg Kononenko reached the milestone on

Oleg Kononenko is the first astronaut to spend a thousand days in space

June 11, having completed five trips to the International Space Station dating back to 2008. His current tour to the ISS began on September 15, 2023, when he launched with NASA astronaut Loral O'Hara and colleague Nikolai Chub. In February 2024, Kononenko broke Gennady Padalka's 2015 record of 878 days, 11 hours, 29 minutes, and 48 seconds for the most time spent in space. If Kononenko's mission finishes as planned on September 23, 2024, he would have spent 1,110 days in orbit.

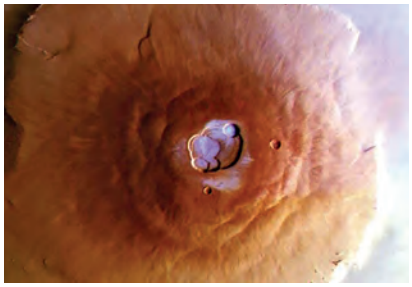
$41 billion lost in six months since COP28 due to climate change

A recent analysis finds that extreme weather events connected to climate change have cost at least $41 billion in damage in the six months after COP28. The research underscores the huge economic and human toll of catastrophic events, emphasising the urgent need for enhanced climate action and help for affected countries. The research focuses on four of the most destructive extreme weather events linked to climate change since COP28: Floods in southern Brazil, Southwest Asia, and East Africa, as well as extreme heat waves across most of Asia. These incidents have affected millions of individuals, resulting in at least 2,539 deaths, which are likely underestimated.

The economic and human toll of climatic events is humongous

Water frost discovered on Mars' tallest volcanoes

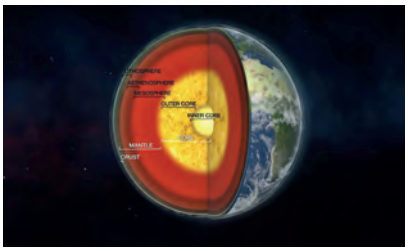
In a stunning discovery that calls into question earlier assumptions about Mars' temperature, the European Space Agency, ESA's spacecraft discovered water frost atop the towering Tharsis volcano near the planet's equator, an area thought to be too warm for such frozen formations. ESA's ExoMars Trace Gas Orbiter (TGO) detected frost on the tallest volcano in the solar system, Olympus Mons, which is approximately three times higher than the Mount Everest. Later observations by TGO's NOMAD instrument and the Mars Express orbiter confirmed the unexpected presence of frost on many volcanoes in the Tharsis region.



Frost has been discovered on the tallest volcano in the solar system

Rotation of the Earth's inner core is slowing down

Scientists at the University of Southern California (USC) have made a revolutionary discovery: The Earth's inner core has been slowing down in proportion to the planet's surface since about 2010. This conclusion, published in *Nature*, settles a long-standing scientific controversy about the movement of our planet's deepest layer. This layer has a complex interior structure that determines the pattern of outer core convection, and thus the Earth's magnetic field.



The Earth's inner core determines the planet's outer core convection

Grey Whale's body diminished by 13% in last 20 years

A new study from Oregon State University (OSU) found that grey whales who spend their summers feeding in the shallow waters along the Pacific Northwest coast had experienced a considerable drop in body length since approximately the year 2000. This fall in size could have serious ramifications for the health and reproductive performance of the whales, as well as serve as an ominous indicator of possible problems within their marine food network. The study, published in the journal *Global Change Biology*, examined the Pacific Coast Feeding Group (PCFG), a subset of 200 grey whales in the Eastern North Pacific population.

The decrease in the length of whales could point to ecological problems

All Images Courtesy: Internet

Quiz: Zoonotic Diseases

1.What is a zoonotic disease?
A. A disease caused by bacteria
B. A disease that can be transmitted from animals to humans
C. A disease caused by a virus
D. None of the above

2. Which of the following is observed as the World Zoonoses Day, to honour the very first vaccination that was administered for a zoonotic disease?
A. 4 July
B. 6 July
C. 7 July
D. None of the above

3. Who is most at risk of getting a zoonotic disease?
A. Pregnant women
B. Elderly
C. Infants
D. All of the above

4. Which of the following is not a zoonotic disease?
A. Rabies
B. Diabetes
C. Anthrax
D. None of the above

5. How can zoonotic diseases be transmitted from animals to humans?
A. Through direct contact with the infected animal
B. Through insects
C. Through contaminated food or water
D. All of the above

6. Which of the following is not a preventive measure for zoonotic diseases?
A. Wearing gloves
B. Vaccination of pets
C. Hygiene
D. All of the above

7. Which of the following is a common symptom of zoonotic diseases?
A. Fatigue
B. Fever
C. Vomiting
D. All of the above

8. Which of the following animals is a common carrier of the hantavirus?
A. Lizards
B. Tiger
C. Rats
D. None of the above

9. Which zoonotic disease can be transmitted through consuming undercooked pig meat?
A. SARS
B. Swine Flu
C. Anthrax
D. None of the above

10. What is an example of a zoonotic disease that spreads through insect vectors?
A. Leptospirosis
B. SARS
C. Anthrax
D. None of the above

Enrich Yourself With Facts On UFOs

■ Every year on July 2, the World UFO Day is observed to increase awareness of unidentified flying objects and the possibility that there is life beyond Earth.

■ Space aficionados have always been captivated by the hypotheses surrounding unusual objects, beginning with the Roswell incident that occurred in New Mexico, possibly in July 1947. Later, the US military claimed it was a balloon, but ever since, conspiracies have surfaced all around the world.

■ Over the past year, UFOs have made news often; the most recent was in June, when a US family reported seeing 'non-human' beings crash in their property.

■ The World UFO Day was first observed on June 24, which was the date set by UFO researcher Haktan Akdogan in 2001, to commemorate an American pilot called Kenneth Arnold's sighting of a cluster of unexplained flying objects.

■ The date was then rescheduled to July 2 to correspond with the sightings in Washington, DC, though, because it conflicted with other UFO-related events.

■ World UFO Day is significant for those interested in UFOs and wishes to learn more about them. It provides a platform for open and courteous discourse, eliminating myths and prejudices, and promoting scientific research into UFO sightings.

■ The most recent case of UFO sighting comes from Venezuela where, on June 17, a pair of friends spotted a mysterious circular spot hovering in the clouds above the city of Valencia in the northern Venezuelan state of Carabobo. Though the sighting was disputed at the time of going to the press, it did re-ignite passion for the whole UFO phenomenon.

Answers: 1 (B), 2 (B), 3 (D), 4 (B), 5 (D), 6 (D), 7 (D), 8 (C), 9 (B), 10 (A)

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Shreeram Shankar Abhyankar

(22 July 1930 – 2 November 2012)

Image Courtesy: Wikimedia Commons

Indian American mathematician Shreeram Shankar Abhyankar was known for his contributions to algebraic geometry. He is most well-known for Abhyankar's conjecture of finite group theory

Celebrating Science This Month

JULY 1
National Doctors' Day is observed.

IRNSS-1A, first satellite in the Indian Regional Navigation Satellite System, was launched in 2013 by PSLV-C22 from SDSC-SHAR Centre, Sriharikota.

JULY 4
Swami Vivekananda, the great scientific visionary, passed away in 1902. The establishment of the prestigious Indian Institute of Science in Bengaluru was a result of an interaction between Swamiji and the industrialist Jamsetji Tata. His discussions with American engineer and inventor Nikola Tesla are a wonder to read.

JULY 6
Daulat Singh Kothari was born in 1906. He was elected as the General President of the Indian Science Congress in 1963 and as the President of the Indian National Science Academy in 1973. His notable research on Statistical Thermodynamics and Theory of White Dwarf Stars gave him international recognition.

JULY 10
INSAT-4C was launched from Satish Dhawan Space Centre SHAR (SDSC-SHAR), Sriharikota, in 2006.

JULY 11
World Population Day.

Cotton scientist, Chandrakant T Patel, was born in 1917. He developed the first commercial cotton hybrid, known as Hybrid-4 (Sankar-4) in 1970.

JULY 12
CARTOSAT-2B was launched in 2010 by PSLV-C15 from SHAR Centre Sriharikota.

JULY 14
Padma Shri TS Chandrasekar, an internationally renowned Interventional Gastroenterologist and the Founder & Chairman of MedIndia Hospitals, Chennai, was born in 1956.

JULY 15
GSAT-12 was launched in 2011 by PSLV-C17 from SHAR, Sriharikota, India.

JULY 16
Indian Council of Agricultural Research (ICAR), formerly known as the Imperial Council of Agricultural Research, was established in 1929 as a registered society under the Societies Registration Act, 1860 in pursuance of the report of the Royal Commission on Agriculture.

JULY 18
One of India's oldest educational institutes, University of Bombay, was founded in 1857.

Kadambini Ganguly, first Indian female doctor who practiced with a degree in western medicine was born in 1861. Her lectures made Calcutta Medical College finally open its doors to women. Ganguly was also the first female speaker at the Indian National Congress.

JULY 22
Indian American mathematician, Shreeram Shankar Abhyankar, was born in 1930 in Ujjain. He is known for his contributions to algebraic geometry.

Chandrayaan-2 was launched in 2019 by GSLV-Mk III - M1. It reached lunar orbit in August 2019.

Pi Approximation Day is observed as the fraction 22/7 (22nd of July) is the common approximation of mathematical constant pi.

JULY 25
Central Electro Chemical Research Institute (CECRI) was established in 1948 in Karaikudi, Tamil Nadu, and started functioning from January 1953.

Indian space scientist Nilamber Pant was born in 1930 in Almora, Uttarakhand. He was a former member of the Space Commission of India and a pioneer of satellite-based communication and broadcasting in India.

JULY 27
Aerospace engineer and former President of India, Dr APJ Abdul Kalam, passed away in 2015. Working at DRDO and ISRO, he was involved in India's civilian space and military missile development programme. He played a pivotal role in India's Pokhran-II nuclear tests in 1998. While delivering a lecture at IIM Shillong, the Missile Man of India died of cardiac arrest.

JULY 28
World Nature Conservation Day is observed.

JULY 29
Indian Association for the Cultivation of Science was founded in 1876 by Mahendra Lal Sircar. It focuses on research in basic sciences.

JULY 31
Indian polymath, Damodar Dharmananda Kosambi, was born in 1907. He contributed to genetics by introducing the Kosambi map function. In statistics, he was the first to develop orthogonal infinite series expressions for stochastic processes via the Kosambi–Karhunen–Loève theorem.

The Indian Academy of Science, Bangalore, founded by CV Raman, was inaugurated in 1934.

Compiled by Surbhi Agarwal and Dr Rajeev Singh, University of Delhi.

सीएसआईआर–हिमालय जैवसंपदा प्रौद्योगिकी संस्थान
CSIR-Institute of Himalayan Bioresource Technology
पालमपुर–176 061 (हि.प्र.) Palampur-176 061 (H.P.)

R&D HIGHLIGHTS

VISION

To be a global leader on technologies for boosting bioeconomy through sustainable utilization of Himalayan bioresources

MISSION

To discover, innovate, develop and disseminate the processes, products technologies and knowledge from Himalayan bioresources for society, industry, environment and academia

Bioresource

- Plants, Algae, Microbes (bacteria, fungi & viruses)
- Vegetation Assessment
- Mapping, Remote Sensing
- Status
- Prospection
- Plant databases
- Conservation, Propagation

Technology

- Agrotechnology
- Biotechnology
- Chemical Technology
- Dietetics & Nutrition Technology
- Environmental Technology
- Extension of Technologies & Capacity Building

Bioeconomy

- Aromatics
- Floriculture, Horticulture, Spice Crops
- Food & Nutraceuticals
- Industrial Enzymes
- Pharmaceuticals
- Biomolecules
- Biowaste Management
- Biofertilizers

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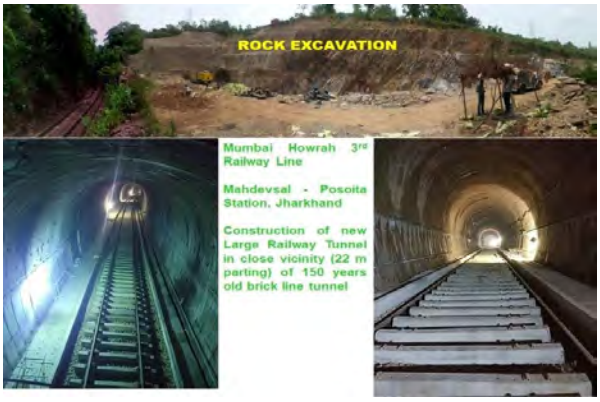
सीएसआईआर- केन्द्रीय खनन एवं ईंधन अनुसंधान संस्थान, धनबाद

विज्ञान एवं प्रोद्योगिकी मंत्रालय, भारत सरकार, नई दिल्ली के अंतर्गत सीएसआईआर की एक अंगीभूत प्रयोगशाला

CSIR-CENTRAL INSTITUTE OF MINING AND FUEL RESEARCH (CIMFR), DHANBAD, a constituent laboratory under the aegis of Council of Scientific and Industrial Research (CSIR), New Delhi aims to provide R&D inputs for the entire coal-energy chain encompassing exploration, mining and utilization with the Vision **"To be an internationally acclaimed mining and fuel research organisation"**



Major Contributions of CSIR-CIMFR are:

- Development of Safe Methods and Assessment of Stability of Mine Workings
- Design of Backfilling Systems for Stabilization of Mine Workings
- Design of Safe Blasting Patterns of Mines
- Assessment of Subsidence and Ground Movement due to Mining
- Design of Environmental Management Plan for Eco-Friendly Mining and Coal Based Industries
- Investigations on Methane Emission due to Mining and GHG Inventories
- Resource Evaluation and Reservoir Modeling of Coal bed Methane
- Evolution of Methods to Control Mine Fire
- Design of Support Systems for Mines
- Design & Development of Equipment, Instruments and Components for Safe Mining
- Coal Quality Assessment
- Basic Studies on Coal Science
- Coal Preparation
- Coal Carbonization
- Coal Liquefaction – Direct and Indirect routes
- Coal Gasification
- Coal Combustion
- Non Fuel Uses of Coal/ Value Added Chemicals
- Fly Ash Utilization

CSIR-CIMFR also extends testing, evaluation, calibration and consultancy services for explosives and accessories, mine ventilation and safety equipment, roof supports, personnel protection equipment, flameproof and intrinsically safe equipment, electrical cables, mining and allied industrial components, wire ropes, cage and suspension gear components, aerial ropeways, etc., for their safe use. All facilities for conventional & instrumental analysis of coal & coke, coal washing pilot plant, pilot coke oven by electrical heating & non-recovery type, XRF, XRD, FTIR, FETR, DTF, TGA, Surface Area Analyser, Porosimeter, coal water emulsion, GTL, PTGA-MS, HPLC, CPT, IPT, etc; EIA & monitoring of air, water, noise & soil pollution, GC, particle size analyzer, washability investigations on coals for cleaning potentialities, various laboratory tests on coal preparation, coal washing pilot plant for coarse and fine coal beneficiation.

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