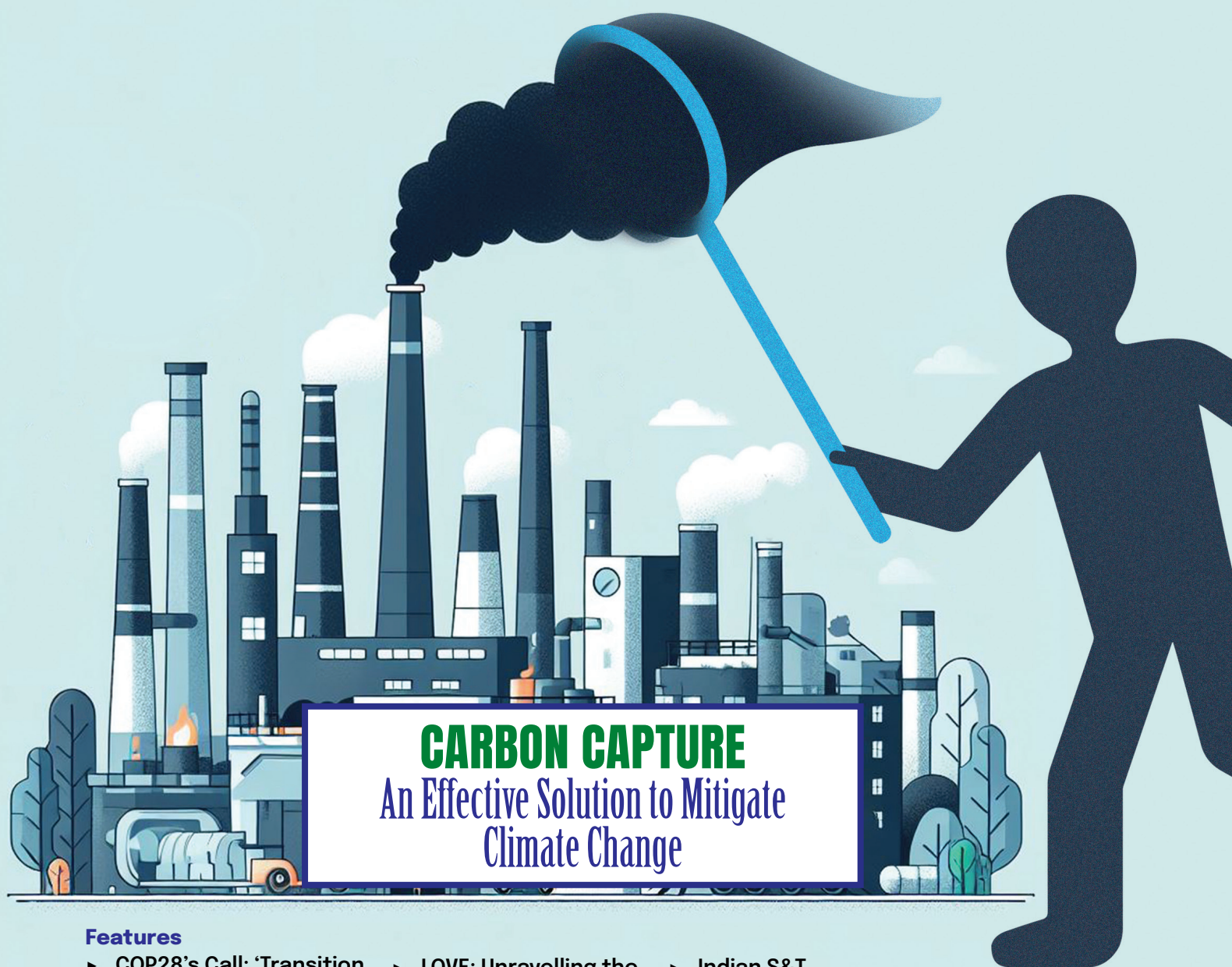


Science Reporter

A CSIR Publication

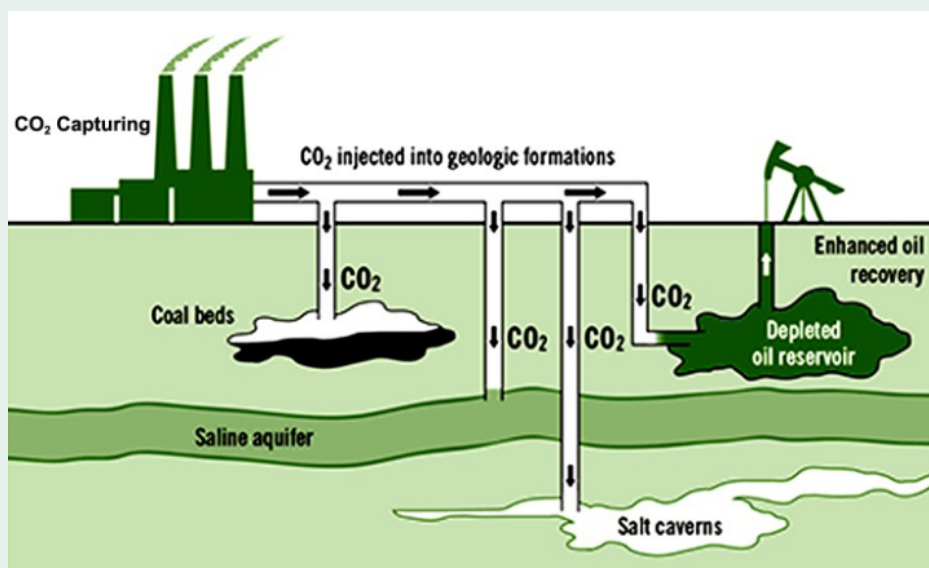


Features

- ▶ COP28's Call: 'Transition away' from Fossil Fuels
- ▶ Climate and Crops
- ▶ Snowflakes: A Symphony of Nature's Design
- ▶ LOVE: Unravelling the Biochemistry behind it
- ▶ Intelligence — Myths and Measures
- ▶ Indian S&T Breakthroughs
- ▶ Q&A, Science Cartoons, Fiction, Puzzles & much more

CONTENTS

14



20

24



EDITORIAL

ISRO's Aditya-L1

Reaches its Destination

Ranjana Aggarwal

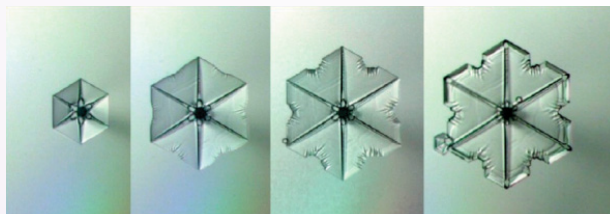
9

FEATURES

Snowflakes: A Symphony of Nature's Design

Ajai Chawla

26



Bodh to Bodhodaya

A Transformation towards Sustainable Nation

Sushovan Ghosh

30

Science Diplomacy: A New Paradigm in the Post-truth world

Felix Bast

32

LOVE: Unravelling the Biochemistry behind it

Soumik Goswami

36

Intelligence — Myths and Measures

Govind Bhattacharjee

40

Prime Editing: Towards more Precise, Targeted Genome Editing

Sheel Yadav, Laxmi Sharma & Shashi Meena

46

INDIAN S&T BREAKTHROUGHS

National Quantum Mission

SMCC, CSIR-NIScPR

34

REPORT

10th Anniversary of Heidelberg Laureate Forum

HS Fatesingh & RC Parida

48

SCIENCE FICTION

Bounty

Aryan Menon

52

Spectrum

10

Nature's Marvels

54

What's New

56

Test Your Knowledge

58

Puzzle Corner

60

Science Cartoons

62

DIRECTOR
Dr Ranjana Aggarwal

ASSOCIATE EDITOR
Sonali Nagar

LAYOUT & DESIGN
Manender Singh

PRODUCTION
Ashwani Kumar Brahmi
Arun Uniyal
Anil Kumar

BUSINESS DEVELOPMENT
Neelu Srivastav
Dr Arvind Meena

COVER DESIGN
Manender Singh

ISRO's Aditya-L1 Reaches its Destination

WITH the start of the year 2024, India has marked another success story in space science. The country has once again achieved a big feat by placing the solar spacecraft Aditya-L1 in a Halo orbit around Sun-Earth Lagrangian point 1 (L1) on 6 January 2024. The solar spacecraft has been named after the Sun god 'Aditya' in Hindu mythology. With this accomplishment, India, in its maiden mission to the Sun, has joined the league of countries advancing solar understanding. Aditya-L1 started its remarkable journey to explore the Sun just after the successful landing of the Chandrayaan-3 on the Moon on 23 August 2023. With the successful touching of the Chandrayaan-3 on the south pole of the Moon, India became the first country in the world to do so.

Indian Space Research Organisation (ISRO), with the Aditya-L1 mission, aims to observe and understand the chromospheric and coronal dynamics of the Sun. Aditya-L1 spacecraft was launched by Polar Satellite Launch Vehicle (PSLV-C57) on 2 September 2023 from Satish Dhawan Space Centre (SDSC), Sriharikota. The satellite successfully reached its intended destination, the Halo orbit at L1, around 1.5 million km from Earth on the continuously moving Sun. The placing of the satellite has the significant advantage of viewing the Sun continuously without interruption, allowing for real-time observation of solar activities and their effect on space weather conditions near the Earth.

Researchers worldwide have often turned their telescopes towards the Sun to understand our solar system's hot glowing ball of gases, which provides enormous amounts of energy to keep our oceans warm, drive photosynthesis, vary weather patterns, affect climate & atmosphere, etc. Therefore, this mission is crucial to gain a deeper understanding of how the Sun's ever-changing conditions make an impact on Earth, other planets, and space weather, which can affect communication systems, power grids and satellite operations.

This mission is equipped with various state-of-the-art instruments to study the Sun comprehensively. The spacecraft carries seven indigenously developed scientific payloads to observe the photosphere, chromosphere and the corona of the Sun. The Aditya-L1 will study the heating process, plasma physics, and the development and origin of Coronal Mass Ejections (CMEs). Besides, one of the key aspects of this mission is to observe the *in-situ* particle and plasma environment to study particle dynamics from the Sun.

Over the years, India has taken tremendous strides in S&T that showcase its technological prowess and commitment to advancing scientific and technological knowledge for the benefit of society. The successful reach of Aditya-L1 to its parking spot is a testament to the dedication put into the mission by our scientists and their teams for executing such a complex mission with precision. Acknowledging their tireless efforts behind the scenes to make this mission a reality is crucial.

The mission's achievements will further contribute to the broader area of astrophysics and our understanding of the universe. Moreover, the Aditya-L1 has far-reaching effects in astronomy and fields like climate, technology and innovation. Such missions also inspire the young generations to push the boundaries and achieve!

Prof. Ranjana Aggarwal



Science Reporter is published monthly by the National Institute of Science Communication and Policy Research (NIScPR), CSIR Dr KS Krishnan Marg, New Delhi-110 012. NIScPR assumes no responsibility for statements and opinions advanced by the authors or for any claims made in the advertisements published in *Science Reporter*.

For Editorial Queries: Ph.: 91-011-25848702; **Email:** sr@niscpr.res.in; **Fax:** 91-011-25847062

For Sales & Subscription Related Queries: Ph.: 91-011-25841647, EPABX: 011-25846301 Extn. 289; **Email:** psmsupport@niscpr.res.in

For Advertisement Related Queries: Ph.: 91-011-25843359, EPABX: 011-25846301 Extn. 291; **Email:** psmsupport@niscpr.res.in

Website: <http://www.niscpr.res.in>

Subscription: (w.e.f 1 January 2023) Inland: 1 yr: Rs 750/-; 2 yrs: Rs 1425/-; 3 yrs: Rs 2025/- Foreign: 1 yr (Air Mail): US \$ 108 (Annual)

© National Institute of Science Communication and Policy Research (NIScPR)

NDMC Schools' Annual Science Fair

Celebrating Innovation, Technology, and Creativity

THE New Delhi Municipal Council (NDMC) Schools' Annual Science Fair, Themed "Technology and Toys," commenced on 5 December 2023 at the NDMC Convention Centre after being paused for three years due to the pandemic. However, the fair captivated students, educators, and science enthusiasts alike.

Dr Jitendra Singh, the Hon'ble Minister of State for Science & Technology, Govt of India, adding a prestigious touch to the celebration of scientific endeavours, inaugurated the fair on 5 December. Dr Jitendra Singh appreciated the efforts of the students to showcase their scientific aptitude. He suggested the students be aware of the schemes launched by the Hon'ble Prime Minister to promote innovation and invention at a young age. He also urged the authorities to plan a trip for the students to ISRO.

The esteemed dignitaries, including NDMC Chairman Mr Amit Yadav and Vice Chairman Mr Satish Upadhyay;



Member Ms Vishakha Sailani; and Director Education Mr RP Sati, honoured the inauguration, igniting an event full of scientific fervour and enthusiasm.

The event lasted two days, from 5-6 December 2023, during which students from various schools, including St Columbus and St Thomas, participated in various activities.

The students showcased over seventy exhibits reflecting their scientific aptitude and innovative minds, aligning with the goals of Atmanirbhar Bharat. The fair



featured a diverse array of projects, including "Mission LiFE" by primary students, consisting of fifteen exhibits exploring seven LiFE themes. Additionally, middle, secondary, and senior secondary students presented twenty-five science projects, while twenty projects delved into the realm of mathematics.

Furthermore, ten projects centred around ATL (Atal Tinkering Lab)/PTL (Palika Tinkering Lab) projects added a technological touch to the competition.

In tandem with the exhibits, the event hosted Health Mela, Science Games, and Interactive Workshops covering topics such as "Innovative Hands-on Practical of Physics" and "Science behind Miracles." Including fun with science workshops engaged students in a dynamic learning environment.

The fair also extended its reach beyond the conventional boundaries of science, incorporating Nukkad Nataks, addressing crucial themes like environmental conservation, millet kranti, and gender sensitisation. A dedicated focus on cleanliness, or "Swacchta," was evident in various exhibits and activities.

Adding an element of fun, "Aao Khele Khel" featured engaging games related to science and mathematics while the live orchestra band performed science-themed songs, creating an immersive experience for attendees.

The DIY Zone provided an opportunity for hands-on exploration, allowing participants to delve into the practical application of scientific principles. Visitors were also treated to displays by the Museum of Illusion and Science Magazines, including contributions from *Science Reporter* and *Aavishkaar*.

For the first time, a Health Mela was integrated into the fair, featuring tools to check BMI, CPR demonstration, millet and adulterated food substances, and yoga promoting health awareness among attendees.

In conclusion, the NDMC Schools' Annual Science Fair went beyond the traditional boundaries of a science exhibition, fostering a spirit of innovation, curiosity, and interdisciplinary exploration. The event celebrated the achievements of budding scientists and ignited a passion for science, mathematics, and technology among students and attendees.

IISER Bhopal researchers develop material to break down chemical warfare agents like Mustard Gas

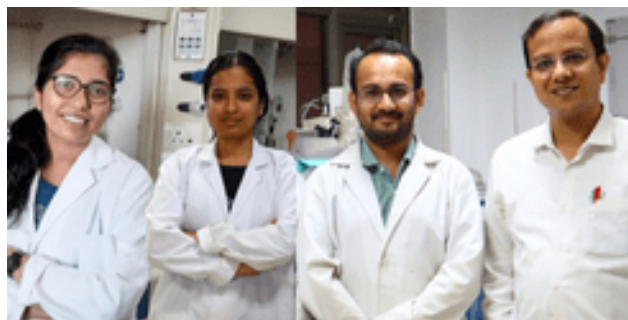
INDIAN Institute of Science Education and Research, Bhopal (IISER Bhopal) researchers have developed an effective photocatalyst, a substance that absorbs a wide range of solar energy and light to quicken chemical processes in laboratories and industries.

This new, sustainable development contributes to harnessing a renewable energy source for detoxifying harmful substances such as chemical warfare agents. Chemical warfare agents include mustard gas simulants like '2-Chloroethyl Ethyl Sulfide' (CEES) and nerve agents, which are highly poisonous chemicals that affect a person's nervous system.

This research represents a significant advancement in the field of 'Photocatalysis', a process where a substance (a photocatalyst) is used to change the rate of a chemical reaction when exposed to light. While many different types of photocatalysts are used in various industries for effective light harvesting, they all suffer from a drawback in that they only absorb UV or high-energy parts of light.

But this novel photocatalyst developed by IISER Bhopal researchers solves that problem. This newly-developed material called 'UC-POP-Au' displays remarkable strength and catalytic efficiency as it absorbs the entire spectrum of light, making it a more potent catalyst during chemical processes.

The findings of this research have been published in the peer-reviewed journal *Angewandte Chemie*. Explaining the



scenarios in which the photocatalyst can be deployed in the real world, Prof. Abhijit Patra, Department of Chemistry, IISER Bhopal, said, "The current investigation unveils a novel direction in the development of advanced light-harvesting porous organic polymer nanocomposite materials, showing potential applications in designing smart protective coatings against chemical warfare agents under natural sunlight conditions."

This composite material has integrated near-infrared absorbing upconversion nanoparticles and visible light absorbing gold nanoparticles with UV rays absorbing conjugated Porous Organic Polymer (POP). The use of upconversion and gold nanoparticles enhances the chemical reaction so drastically.

Speaking on the technical aspects of this research, Prof. Abhijit Patra said, "We have developed an innovative design approach that involves the integration of plasmonic and upconversion nanoparticles with a conjugated porous organic polymer, which opens up new vistas towards artificial light harvesting."

To test the applicability of this photocatalyst, the research team coated a small piece of cotton cloth with the UC-POP-Au under direct sunlight to detoxify mustard gas simulant, a popular chemical warfare agent. Displaying excellent performance compared to a regular polymer-based photocatalyst, the UC-POP-Au significantly expedited photocatalysis.

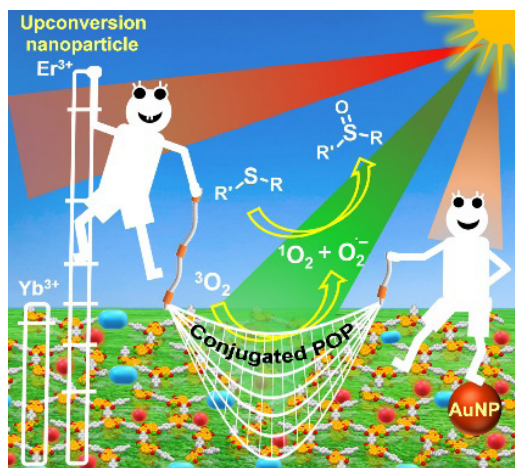
What stands out is that this photocatalyst is also reusable and can be used five times over. No significant change in the catalytic activity was observed during multiple uses, unlike some other catalysts, which can not be collected and reused.

The detoxification of chemical warfare agents is currently being explored all over the world. And with photocatalysts such as UC-POP-Au, that process can now become faster. The research team suggests that the developed photocatalyst UC-POP-Au can be used for creating personal protective equipment and also has high application potential as promising materials for various other industries beyond the detoxification of chemical warfare agents.

The research team from IISER Bhopal is now further expanding the scope of their work in developing advanced materials for harnessing light energy to break down other toxic chemicals.

Reference: D.O.I: <https://doi.org/10.1002/anie.202312910>

Source: IISER Bhopal Press Release



The way the brain learns is different from and better than the way that AI systems learn

RESearchers from the MRC Brain Network Dynamics Unit and Oxford University's Department of Computer Science have set out a new principle to explain how the brain adjusts connections between neurons during learning. This new insight may guide further research on learning in brain networks and may inspire faster and more robust learning algorithms in Artificial Intelligence (AI).

The essence of learning is to pinpoint which components in the information-processing pipeline are responsible for an error in output. In artificial intelligence, this is achieved by backpropagation: adjusting a model's parameters to reduce the

error in the output. Many researchers believe that the brain employs a similar learning principle.

However, the biological brain is superior to current machine learning systems. For example, we can learn new information by just seeing it once, while artificial systems need to be trained hundreds of times with the same pieces of information to learn them. Furthermore, we can learn new information while maintaining the knowledge we already have, while learning new information in artificial neural networks often interferes with existing knowledge and degrades it rapidly.

These observations motivated the researchers to identify the fundamental principle employed by the brain during learning. They looked at some existing sets of mathematical equations describing changes in the behaviour of neurons and the synaptic connections between them. They analysed and simulated these information-processing models and found that they employ a fundamentally different learning principle from that used by artificial neural networks.

In artificial neural networks, an external algorithm tries to modify synaptic connections in order to reduce error, whereas the researchers propose that the human brain first settles the activity of neurons into an optimal balanced configuration before adjusting synaptic connections. The researchers posit that this is in fact an

Invasive Species and its Associated Health Risk Issues in India

INVASIVE Alien Species (IAS) have been identified as one of the main drivers of global biodiversity loss, gravely affecting food security by devastating agriculture and aquaculture production and posing a severe threat to humans and wildlife. Globally, the research community and policymakers are concerned only about biodiversity and economic loss and conspicuously overlook the disease-causing ability and the associated health risks IAS poses on wildlife and humans.

IAS generally causes diseases/outbreaks through the co-introduced pathogen and vectors. Sometimes, alien species can also convert/modify/create some micro-ecosystem, which emerges as an epicentre for the outbreak of an existing or new disease. For example, frequent outbreaks of avian malaria caused by *Plasmodium relictum* were reported in Hawaii islands. Researchers found that the *P. relictum* infected mosquitos, i.e., acted as a vector and transmitted malaria in several parts of the islands. Further investigation revealed the deleterious role of invasive feral pigs *Sus scrofa* on avian malaria outbreaks. The feral pigs create small cavities in trees and wallow on soil, and these modified structures become effective breeding sites for the vector.



Damaged cobs for sale in local markets

Several research studies established that most alien species introduced along with exotic pathogens (co-introductions) significantly increase the pathogen diversity in the invaded area and pave the way for the outbreak of epidemic diseases to humans and wildlife. For example, the population of red squirrel *Sciurus vulgaris* in the United Kingdom has drastically declined due to the spread of the squirrel pox virus, which came along with the American eastern grey squirrel *Sciurus carolinensis*.

The outbreak of bubonic plague resulted in the deaths of 75–200 million people in Asia, Europe and Africa from 1346 to 1353, caused by the bacterium *Yersinia pestis*, and the rat species *Rattus rattus* acted as a vector. In addition, the United Nations has also emphasised that recent outbreaks such as Ebola, bird flu, Rift Valley fever, West Nile virus and Zika virus have also originated from animals and affected humans. Besides, the illegal international pet and ornamental trade, wet markets, habitat destruction and ongoing climate change events facilitate more pathogen and vector introduction into new habitats.

efficient feature of the way that human brains learn. This is because it reduces interference by preserving existing knowledge, which in turn speeds up learning.

Writing in *Nature Neuroscience*, the researchers describe this new learning principle, which they have termed 'prospective configuration'. They demonstrated in computer simulations that models employing this prospective configuration can learn faster and more effectively than artificial neural networks in tasks that are typically faced by animals and humans in nature.

The authors use the real-life example of a bear fishing for salmon. The bear can see the river, and it has learned that if it can also hear the river and smell the salmon, it is likely to catch one. But one day, the bear arrives at the river with a damaged ear, so it can't hear it. In an artificial neural network information processing model, this lack of hearing would also result in a lack of smell (because while learning there is no sound, backpropagation would change multiple connections, including those between neurons encoding the river and the salmon) and the bear would conclude that there is no salmon, and go hungry. But in the animal brain, the lack of sound does not interfere with the knowledge that there is still the smell of the salmon; therefore, the salmon is still likely to be there for catching.

The researchers developed a mathematical theory showing that letting neurons settle into a prospective configuration reduces

interference between information during learning. They demonstrated that prospective configuration explains neural activity and behaviour in multiple learning experiments better than artificial neural networks.

Lead researcher Professor Rafal Bogacz of MRC Brain Network Dynamics Unit and Oxford's Nuffield Department of Clinical Neurosciences says: "There is currently a big gap between abstract models performing prospective configuration and our detailed knowledge of the anatomy of brain networks. Future research by our group aims to bridge the gap between abstract models and real brains and understand how the algorithm of prospective configuration is implemented in anatomically identified cortical networks."

The study's first author, Dr Yuhang Song, adds: "In the case of machine learning, the simulation of prospective configuration on existing computers is slow because they operate in fundamentally different ways from the biological brain. A new type of computer or dedicated brain-inspired hardware needs to be developed that will be able to implement prospective configuration rapidly and with little energy use."

Source: University of Oxford News Release

The invasion of water hyacinth *Eichhornia crassipes* (Mart.) in India caused a huge loss to aquatic biodiversity and the regional economy. Besides, the dense vegetation provides a home to several disease-causing vectors, such as mosquitoes, flies and snails, which can transmit diseases like cholera, malaria, filariasis and schistosomiasis. Moreover, the proliferation of water hyacinths in urban water bodies, especially rivers, drastically increases the vector population and upsurges the occurrence of mosquito-borne disease. However, no empirical study is available to correlate the water hyacinth proliferation and outbreaks of mosquito-borne diseases in India.

Likewise, the weed parthenium is reported to cause severe health disorders in men and animals in India. Asthma, bronchitis and other respiratory issues, diarrhoea, black spots, blisters around eyes and regular coughing are reported among Indians. In parallel, cattle species experienced alopecia, anorexia, dermatitis, diarrhoea, poor WBC count, malfunction of liver and kidneys, and mouth ulcers with excessive salivation.

In 2018, India witnessed a large-scale invasion of *Spodoptera frugiperda*, widely known as Fall Armyworm (FAW), in corn and maize fields. Currently, the invasion of the species has been reported from more than 20 Indian states and has caused a massive loss in maize (37,000–75,000 tonnes), one of the important cereal crops, which accounts for 9% of the total food grain production of India.

The FAO (Food and Agriculture Organisation) mentioned that the damaged/infested corn and maize cobs are highly prone to fungal infection, producing aflatoxins. The European Food Safety Authority has classified aflatoxins as one of the worst mycotoxins by considering their hazardous toxigenic, mutagenic and carcinogenic nature. Aflatoxins are known to cause vomiting and abdominal pain and are also reported to accelerate cancer growth in humans and animals. The FAO also mentioned that aflatoxins are more toxic to animals. Here in India, we do not have any direct studies

about aflatoxins from infested maize and corn. However, the damaged and infected cobs are extensively available in local markets for human and animal consumption.

A study in 2020 from Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, disclosed high levels of aflatoxin in raw, pasteurised and UHT (Ultra-High-Temperature) milk. The study also pointed out that most dairy farms provide cereals, including maize, as a major feed to their cattle. Parallel reports also confirmed the high concentration of aflatoxins in cattle feeds. In addition, India's unique climatic conditions and irregular rainfall patterns facilitate more fungal growth in cereals and favour more aflatoxin synthesis. The invasion of FAW and its harmful impacts on maize and corn will aggravate the aflatoxin synthesis. Beyond doubt, the degree of exposure to aflatoxin might have increased in India after the invasion of FAW. Since we have a feeble FAW eradication process, the chance of exposure to aflatoxins will possibly be higher in the coming days. What we see is only the tip of the iceberg!

Educating the consumers and farmers about the toxic impacts of infected cobs is the need of the hour. Stringent policies and laws related to marketing and discarding infected cobs need to be developed.

Besides, more studies are needed to explore the health risks of invasive alien species in India. So far, 150 invasive species have been reported from India. To protect humans and wildlife, a complete screening is needed to confirm the pathogen and vector species associated with this invasion.

Contributed by Mr S Sandilyan, Former Fellow on Invasive Alien Species (IAS), Centre for Biodiversity Policy and Law (CEBPOL), National Biodiversity Authority (NBA), Taramani, Chennai-600113. Email: ssandilyan@gmail.com

COVER STORY

CARBON CAPTURE

AN EFFECTIVE SOLUTION TO MITIGATE CLIMATE CHANGE

Deo Prakash Chaturvedi
and Sumita Kumari



CARBON and Carbon dioxide (CO_2) play essential roles in various ecological processes and the overall functioning of the Earth's system. Carbon is the key element in the structure of all living organisms, from simple bacteria to complex plants and animals. Carbon-based molecules, such as proteins, carbohydrates, lipids, and nucleic acids, are the building blocks of cells and tissues. They provide energy, store genetic information, and facilitate the biochemical reactions necessary for growth, reproduction, and metabolism. Carbon is also involved in the structure of ecosystems, as it forms the basis of food chains and supports biodiversity by providing habitats and resources for a wide range of species.

Carbon dioxide, on the other hand, plays a crucial role in regulating Earth's climate. It is a greenhouse gas that traps heat in the atmosphere, creating the natural greenhouse effect that helps maintain suitable temperatures for life on the planet. Without CO_2 and other greenhouse gases, Earth would be much colder, making it uninhabitable for most life forms. Carbon dioxide is a vital component of photosynthesis, the process by which green plants and algae convert sunlight, water, and CO_2 into oxygen and glucose. This process produces oxygen, essential for all aerobic organisms, and acts as a carbon sink, removing CO_2 from the atmosphere and storing it in biomass and soils. In this way, carbon dioxide is crucial in maintaining the balance of gases in the atmosphere and supporting the overall health and functioning of ecosystems.

However, human activities, such as burning fossil fuels, intensive agriculture and deforestation, have resulted in elevated CO_2 levels, disrupting the balance of the greenhouse effect. Excess CO_2 intensifies the greenhouse effect, causing accelerated global warming and climate change. The consequences include rising sea levels, melting ice caps and glaciers, more frequent extreme weather events, altered precipitation patterns, ecosystem shifts, food and water security risks, and human health and well-being.

Addressing climate change requires reducing carbon emissions and mitigating CO_2 release. However, reducing emissions alone may not be sufficient to tackle the climate crisis and should be supplemented with active Carbon Capture, Utilisation and Storage (CCUS).

Capturing the Carbon

Carbon capture technologies can play a vital role in removing CO_2 from the atmosphere, and they are broadly classified into two categories:

(a) **Carbon Capture at Source:** removal of CO_2 from point sources such as power plants and industrial facilities before they are released into the atmosphere, thereby preventing their contribution to the greenhouse effect and subsequent impacts on climate change.

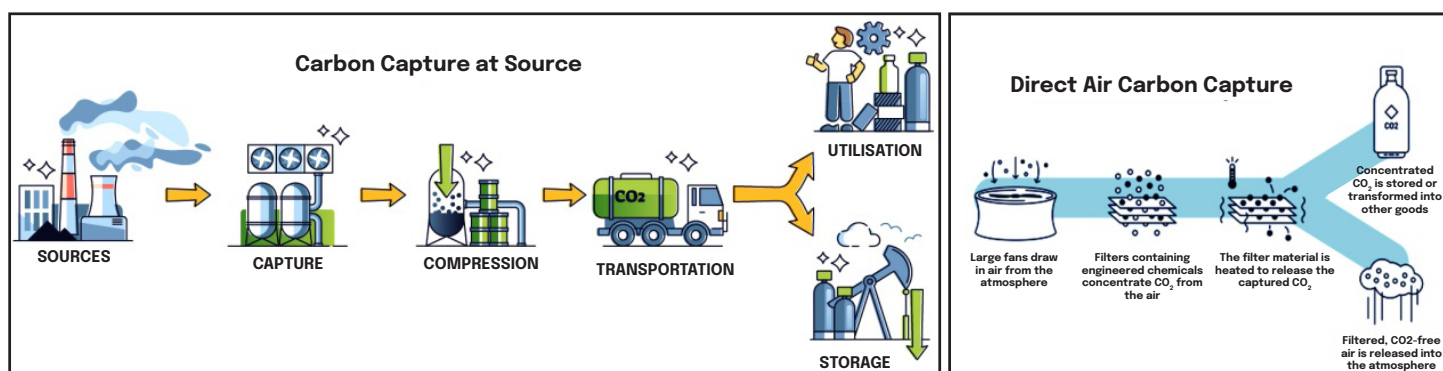
This helps slow down global warming and provides a pathway for achieving climate goals and targets set by international agreements such as the Paris Agreement. Carbon capture also serves a bridge between current fossil fuel-dependent energy systems and a future dominated by renewable sources, enabling a transition while minimising environmental impact. Furthermore, it plays a significant role in sectors like manufacturing, facilitating the decarbonisation of industries that face challenges in reducing emissions through conventional means.

As per the International Energy Agency estimates, 35 CCUS facilities worldwide are currently being applied for industrial processes, fuel transformation, and power generation and can capture more than 40 Mt CO_2 each year. CCUS has gained momentum, and around 300 projects are in different phases of development.

There are different methods of carbon capture at source points depending upon the treatment of the fuel, including:

1. **Post-combustion capture:** removes CO_2 from the fuel gases produced by power plants or industrial processes. It typically uses solvents or other absorption techniques to separate CO_2 from the exhaust gases.
2. **Pre-combustion capture:** captures CO_2 before the fuel is burned. It is commonly used in Integrated Gasification Combined Cycle (IGCC) power plants, where the fuel is converted into a synthetic gas (syngas) before combustion, allowing for easier CO_2 capture.
3. **Oxy-fuel combustion:** burns fuel in pure oxygen instead of air, producing a flue gas primarily composed of CO_2 and water vapour. The CO_2 can then easily be captured from the concentrated fuel gas.

(b) **Direct Air Capture (DAC):** pulls CO_2 directly from the atmosphere; it is relatively more energy intensive and expensive as CO_2 in the atmosphere is comparatively more dilute than in source industries that burn fossil fuels. DAC requires special liquid or solid adsorbent



Carbon Capture Projects and Case Studies in India and Around the World

Several notable carbon capture projects and case studies in India and around the world showcase the application and potential of carbon capture technologies. Here are a few examples:

Around the world

1. **Petra Nova, United States:** is a carbon capture project located at the WA Parish power plant in Texas, USA. It is one of the largest post-combustion carbon capture projects in the world. The project captures CO₂ emissions from a 240 Mega Watt (MW) flue gas stream generated by a coal-fired power plant. The captured CO₂ is transported via pipeline to an Oil Field for Enhanced Oil Recovery and underground storage. Petra Nova has demonstrated the successful integration of carbon capture with EOR, resulting in reduced emissions and increased oil production.
2. **Gorgon, Australia:** this project in Australia incorporates CCS to reduce emissions from natural gas production. This captures and compresses CO₂ from the gas reservoir and transports it via a pipeline for injection and storage in an offshore deep geological formation. The project demonstrates the use of carbon capture and storage in a large-scale industrial operation, contributing to emissions reduction and environmental sustainability.
3. **Sleipner, Norway:** the Sleipner field in the North Sea is an early and successful example of carbon capture and storage. The project operated by Equinor (formerly Statoil) has been capturing and storing CO₂ since 1996. Captures CO₂ from natural gas production and injects it into a deep saline aquifer for permanent storage. The project showcases the long-term viability and effectiveness of carbon capture and storage in reducing emissions from hydrocarbon production.
4. **Boundary Dam, Canada:** is a post-combustion carbon capture facility integrated with a coal-fired power plant. It is the world's first large-scale coal-fired power plant with a fully integrated carbon capture system. The project captures approximately 90% of the CO₂ emissions from the flue gas and stores it underground. The project demonstrates the technical feasibility of retrofitting existing power plants with carbon capture technologies, reducing emissions from coal-fired generation.
5. **Northern Lights, Norway:** is focused on establishing a full-scale CCS value chain, including the capture, transport, and storage of CO₂. It aims to provide storage capacity for CO₂ from industrial sources across Europe. The project involves the development of an onshore terminal for receiving, processing, and shipping captured CO₂ to be stored in offshore geological formations. The project represents an essential initiative in creating infrastructure for large-scale carbon capture and storage across multiple industries and countries.

In India

1. **ONGC's CO₂ Capture and Utilisation:** The Oil and Natural Gas Corporation (ONGC), India's largest oil and gas exploration and production company, has undertaken CO₂ capture and utilisation initiatives. ONGC has set up a carbon capture and utilisation plant at its flagship oil field in Gujarat. The captured CO₂ is used for enhanced oil recovery, which helps increase oil production while simultaneously reducing CO₂ emissions.
2. **Carbon Capture at Coal-Fired Power Plants:** India has initiated pilot projects to explore carbon capture technologies in the coal-fired power sector. The Ministry of Power has supported the development of CCS demonstration projects at several coal-based power plants. These projects aim to capture and store CO₂ emissions, contributing to emissions reduction in the power sector.

While the number of carbon capture projects in India is currently limited, the government's focus on clean energy and climate action provides opportunities for further development. India's diverse industrial sectors, including steel, cement, and chemicals, offer potential for carbon capture deployment. The expansion of renewable energy, coupled with carbon capture technologies can contribute to a more sustainable and low-carbon future for India.

material to capture CO₂ from the air. It helps balance emissions that are difficult to avoid and offers a solution for historical emissions. There are 18 Direct Air Capture facilities operating in Canada, Europe, and USA.

Where does the captured CO₂ go?

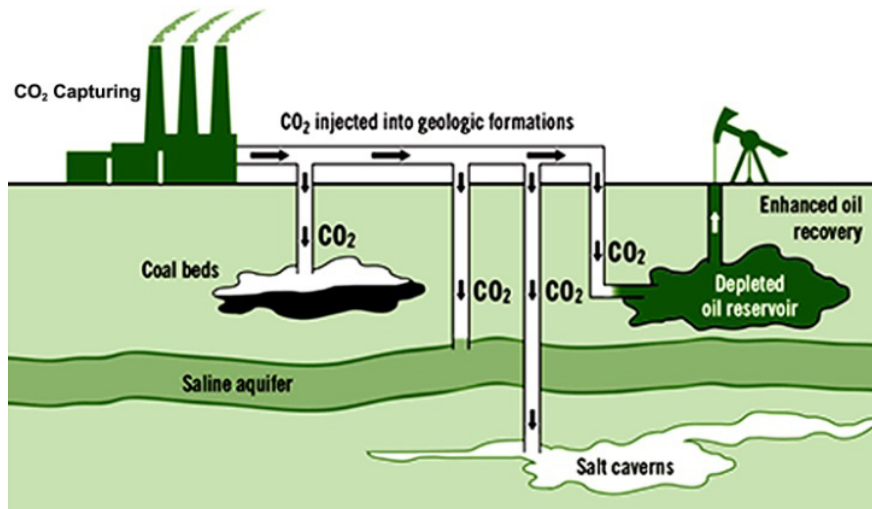
Once captured, the CO₂ can be stored underground or utilised in various applications, such as producing synthetic fuels or materials. There are several methods for storing captured carbon, commonly referred to as carbon storage or carbon sequestration. These methods aim to prevent the released CO₂ from entering the atmosphere and contributing to climate change. Here are some key approaches:

1. **Geological Storage:** also known as Carbon Capture and Storage (CCS), captures CO₂ emissions from industrial processes or power plants, transports, and injects the captured carbon deep underground into geological formations. Suitable storage sites include depleted oil and gas fields, deep saline aquifers (porous rock formations filled with salty water), and unmineable coal seams. The CO₂ is stored in these reservoirs, often in a supercritical state, and held securely over long periods.
2. **Carbon Di-Oxide Enhanced Oil Recovery (CO₂-EOR):** involves injecting captured CO₂ into oil reservoirs to enhance oil extraction. While the primary goal is to increase oil production, it also results in the long-term

storage of CO₂ underground. EOR can be considered a form of carbon capture and storage, as it involves permanently storing a portion of the captured CO₂.

3. Carbon Di-Oxide Enhanced Gas Recovery (CO₂-EGR): involves injecting captured CO₂ into natural gas reservoirs to increase gas production. This process can enable the storage of CO₂ while recovering additional natural gas resources.

4. Mineralisation: converts CO₂ into a stable mineral form through a process called mineral carbonation. The CO₂ is reacted with certain minerals, such as magnesium and calcium silicates, to produce solid carbonates and heat. Since the reaction releases heat, the formation of carbonates is thermodynamically favoured at low temperatures. Mineralisation occurs naturally over geological timescales, but research is ongoing to accelerate the process and make it commercially viable.



Ecosystem-derived Carbon Capture Strategies

Carbon Capture and Utilisation (CCU) technologies come at a huge investment cost and, when done at source points, need to be retrofitted with the existing industrial infrastructure and need new installation; DAC needs specialised materials and energy-intensive, expensive setup.

Furthermore, these technologies are not up to scale yet, and the capacity of CCUS must grow several folds to address climate change adequately. Natural large-scale ecosystems

linked to global carbon cycles offer immense potential to develop novel pathways for CO₂ sequestration for long-term storage. Plant-microbe, deep subsurface, and marine ecosystems are the three major biomes that act as natural CO₂ sinks and store CO₂ volumes several folds more than the atmosphere. Diverse biological systems in these biomes can be harnessed through varied technologies to sequester CO₂ for different durations. Most of these systems have an inherent capacity to absorb CO₂ and convert it into various organic and inorganic bio-products. They can thus be used to capture and store CO₂ for different periods.

a) Plant-Soil Biome: within plant root-soil biomes, plants harness the power of photosynthesis to capture atmospheric CO₂ and transport it underground, where it is stored in the rhizosphere. This process involves intricate connections between plants and soil bacteria and fungi, facilitating the exchange of organic carbon within the soil. Ultimately, this carbon is either returned to the atmosphere or stored in the ground in more resistant forms. The dynamics of this carbon flux are influenced by close ecological interactions and localised geochemical factors. Diverse life forms in the plant-soil biome can be potentially used for carbon capture in several ways, including:

- i. **Microbial Carbon Capture:** microorganisms, such as bacteria and algae, can capture and convert CO₂ into biomass through photosynthesis or other metabolic processes. These microorganisms can be cultivated and utilised in various ways to capture and store carbon.
- ii. **Enhanced Soil Microbes:** soil microbes play a crucial role in carbon cycling and sequestration. Improving microbial activity in agricultural soils makes it possible to promote carbon sequestration through processes like increased organic matter decomposition and the formation of stable carbon compounds in the soil.
- iii. **Agricultural Practices for Carbon Sequestration:** agricultural practices can be implemented to

Carbon Offsetting

Carbon capture and carbon offsetting are two different approaches to addressing CO₂ emissions and mitigating climate change. While both aim to reduce greenhouse gas emissions, their methods and objectives differ.

Carbon offsetting involves compensating for CO₂ emissions by investing in projects or activities that reduce or remove an equivalent amount of CO₂ from the atmosphere. These projects can include renewable energy projects, reforestation initiatives, or energy efficiency programmes. Carbon offsetting aims to achieve a net-zero carbon footprint by balancing the emissions generated in one place with emission reductions elsewhere. It allows individuals or organisations to take responsibility for their emissions by supporting projects that offset or compensate for their carbon footprint.

Carbon offsetting can be seen as a broader approach that involves a range of activities beyond direct CO₂ capture and storage. Both approaches are complementary and can be used together as part of a comprehensive strategy to achieve significant reductions in greenhouse gas emissions and combat climate change.

enhance carbon sequestration in soils, effectively capturing and storing CO₂.

- **Conservation Agriculture:** techniques such as reduced tillage, cover cropping, and crop rotation help improve soil health, increase organic matter content, and enhance carbon sequestration in agricultural soils.
- **Agroforestry:** planting or integrating trees on agricultural lands with crops and livestock systems can contribute to carbon sequestration. Trees capture CO₂ through photosynthesis and store it in their biomass and the soil.
- **Biochar Application:** biochar is a form of charcoal produced through the pyrolysis of organic waste materials. When applied to soil, biochar can act as a stable carbon sink, helping to sequester carbon for long periods and improve soil fertility.

Implementing microbial carbon capture and agricultural practices offers numerous benefits beyond carbon sequestration, including improved soil health, enhanced biodiversity, increased water retention, and sustainable agriculture. However, further research, development, and large-scale implementation are necessary to fully understand their effectiveness, optimise their application, and address challenges related to costs, logistics, and compatibility with existing agricultural systems.

b) Ocean Biome: the deep ocean biome has a high functional capacity for CO₂ sequestration. Once carbon enters the deep ocean, it remains there for thousands of years. The Atlantic Ocean has been estimated to have sequestered carbon dioxide equivalent to the total atmospheric CO₂ released during the last glaciation event about seventy thousand years ago. The CO₂ sequestration capacity of the oceans is largely conferred by the photosynthetic marine microbes, viz. algae, cyanobacteria, phytoplanktons, benthic microalgae and other marine organisms and can be used in the following ways:

- Algae Cultivation:** algae are efficient carbon dioxide absorbers and can be grown in controlled environments such as photobioreactors or open ponds. As they grow, they absorb carbon dioxide and convert it into biomass. This biomass can be harvested and used for various purposes, including biofuels, animal feed, or soil amendments.
- Cyanobacteria:** can be used as drivers of biomineralisation of CO₂ through calcium carbonate precipitation. They are known to capture CO₂ through photosynthesis and convert it into inorganic calcium carbonate. They are being explored to fortify building materials to retain carbon for an extended period. However, a better understanding of mineralisation and associated pathways is warranted before it can be used commercially at a large scale.

c) The deep subsurface: is largely unexplored and refers to the biomes below the soil and ocean floor sediments. It is inhabited by microflora with a huge capacity for CO₂ sequestration and represents a significant sink for CO₂. The deep biosphere is already being used to temporarily store and transport CO₂ into deep geological formations such as oil reservoirs, aquifers, and deep un-minable coal seams. More knowledge is, however, needed to understand how resident microbiomes can be harnessed to develop pathways for CCU biotechnology.

Bioengineering solutions for long-term CO₂ storage

Biotechnology significantly advances carbon capture technologies by offering innovative solutions for harnessing microorganisms and genetic engineering techniques to enhance carbon sequestration. Here are some key aspects of biotechnology in carbon capture:

- **Engineered Microbes:** by engineering microorganisms, researchers can enhance their ability to capture and convert carbon dioxide into valuable products or store it more efficiently. This could involve modifying metabolic pathways, improving photosynthetic efficiency, or increasing biomass production.
- **Carbon-neutral Biomaterials:** can replace fossil fuel-derived products. For example, researchers are exploring the use of genetically modified microorganisms to produce bio-based plastics, chemicals, and construction materials. These biomaterials sequester carbon during production and can contribute to long-term carbon storage in various applications.
- **Synthetic Biology:** researchers can create synthetic pathways that efficiently capture and convert carbon dioxide by combining genetic components from different organisms. These synthetic systems can be applied in various contexts, such as engineered plants, algae, or microbes, to enhance carbon sequestration capabilities.
- **Genetic Engineering of Crops:** by modifying genes involved in photosynthesis, carbon fixation, or root development, scientists aim to create crops that capture and store more carbon in their biomass and soil. This approach holds the potential for increasing carbon sequestration in agricultural systems.

Benefits and Potential of Carbon Capture

Here are some of the critical benefits and potentials associated with carbon capture:

- 1. Climate Change Mitigation:** by capturing and storing CO₂ emissions from power plants and industrial processes, carbon capture technologies can significantly reduce greenhouse gas emissions, thereby slowing down the pace of global warming and its associated impacts.
- 2. Low-risk Transition of Fossil Fuels:** carbon capture allows for the continued use of fossil fuels while reducing their carbon footprint. Since fossil fuels play a significant role in global energy production, carbon capture provides a transitional solution by enabling the capture and storage of CO₂ emissions until cleaner energy sources become more prevalent and affordable.

3. **Industrial Emissions Reduction:** carbon capture can be applied to various industrial processes that generate substantial CO₂ emissions, such as cement production, steel manufacturing, and chemical production. Capturing and storing CO₂ from these processes can significantly reduce emissions from industrial sectors, which are major contributors to global greenhouse gas emissions.
4. **Negative Emissions Technologies:** carbon capture, when combined with bioenergy, can facilitate the development of negative emissions technologies. Bioenergy with Carbon Capture and Storage (BECCS) involves generating energy from biomass while capturing and storing the resulting CO₂ emissions. The stored CO₂ can be considered negative emissions since it represents a removal of CO₂ from the atmosphere, contributing to net-negative emissions.
5. **Enhanced Oil Recovery (EOR):** injecting captured CO₂ into depleted oil fields can increase the oil recovery rates while simultaneously storing the CO₂ underground. This dual benefit makes carbon capture economically viable in certain regions where EOR projects are feasible.
6. **Research and Technological Advancements:** the development and deployment of carbon capture technologies drive innovation and advancements in research and engineering. This helps improve the efficiency, cost-effectiveness, and scalability of carbon capture processes, making them more viable and widely accessible in the long run.
7. **Job Creation:** implementing carbon capture projects requires a skilled workforce for various tasks, including engineering design, construction, operation, and maintenance of carbon capture facilities. This creates job opportunities across different sectors, ranging from engineers and technicians to project managers and operators. Additionally, the growth of industries related to carbon capture can generate employment in supporting sectors, such as manufacturing, supply chain, and transportation.

Challenges and Limitations of Carbon Capture

While carbon capture technologies hold promise for mitigating climate change, they also face several challenges and limitations that need to be addressed. Here are some main challenges associated with carbon capture:

1. **Cost:** one of the primary challenges of carbon capture is its high cost. The capture, transportation, and storage of CO₂ require substantial investments in infrastructure and energy. The current cost of carbon capture technologies is often considered prohibitive for widespread implementation. Further research and development are needed to reduce costs and improve cost-effectiveness.
2. **Energy Requirements:** carbon capture processes can be energy-intensive, requiring significant energy to capture and separate CO₂ from flue gases or other sources. This can result in a decrease in the overall efficiency of the power plant or industrial process where carbon capture is implemented. Developing more energy-efficient carbon capture technologies is essential to minimise energy penalties and make the process more viable.
3. **Scale and Deployment:** implementing carbon capture technologies at a large scale is a challenge. It requires

adequate infrastructure, such as pipelines for CO₂ transportation and storage sites. The availability and suitability of storage sites can also be a limitation in certain regions. Expanding the deployment of carbon capture will require significant planning, investment, and coordination among various stakeholders.

4. **Environmental and Safety Concerns:** the storage of captured CO₂ underground raises concerns about potential leakage and environmental risks. Ensuring the integrity of storage sites and developing robust monitoring systems are essential to minimise any adverse environmental impacts. Additionally, the transportation of CO₂ via pipelines requires safety considerations to prevent accidents or leaks.
5. **Limited Applicability:** carbon capture technologies may not apply to all sectors or industries. While it is effective for large point source emitters like power plants and industrial facilities, it may not be feasible or economically viable for smaller or dispersed emission sources. Therefore, carbon capture is most effective in specific industries and processes, limiting its impact on greenhouse gas reduction.

Capture and Carbon Pricing Mechanisms

Carbon pricing mechanisms, such as carbon taxes and cap-and-trade systems, can create economic incentives for carbon capture and storage. By putting a price on carbon emissions, these mechanisms provide a financial motivation for industries to reduce emissions through technologies like carbon capture. Carbon pricing can benefit carbon capture projects in several ways:

- **Revenue Generation:** carbon capture projects that successfully capture and store CO₂ can generate carbon credits or offsets that can be sold in carbon markets, generating revenue for project operators.
- **Cost Recovery:** carbon pricing mechanisms can support the higher costs associated with carbon capture projects. The revenue generated from carbon pricing can offset the capital and operational expenses of implementing carbon capture technologies.
- **Investment Incentives:** carbon pricing can attract investment in carbon capture projects by making them more economically viable. The potential for revenue generation through carbon credits incentivises businesses and investors to finance and develop carbon capture initiatives.

While carbon capture is not a standalone solution to climate change, it is crucial in reducing emissions from existing infrastructure and industries, facilitating a smoother transition to a low-carbon future. Integrated with energy efficiency, renewable energy adoption, and sustainable practices, carbon capture technologies can mitigate climate change and achieve a sustainable and carbon-neutral future.

Dr Deo Prakash Chaturvedi and Dr Sumita Kumari, Department of Biotechnology, Ministry of Science and Technology, CGO Complex, New Delhi.
Email: deo.prakash@dbt.nic.in

COP28's CALL 'Transition away' from Fossil Fuels

Anil Pratap Singh



Leaders from across the world gathered at COP28 UAE

“The United Nations Climate Change Conference (COP28) closed with an agreement that signals the ‘Beginning of the End’ of the fossil fuel era by laying the ground for a swift, just and equitable transition, underpinned by deep emissions cuts and scaled-up finance” — *UN Climate Press Release.*

THE 28th session of the Conference of the Parties (COP28) to the United Nations Framework Convention on Climate Change (UNFCCC) culminated in Dubai, UAE, in a pivotal call for a global “transition away” from fossil fuels. The 2023 UN Climate Change Conference, COP28, was attended by almost 200 countries and over 70,000 delegates from around the world. The conference offered insightful discussions and innovative exhibits and undertook diverse issues through themed days on health, energy, industry, urbanisation, transport, youth, education, nature, land use and oceans, as well as food and water.

From Kyoto’s foundation at COP3 to Paris’s ambitious pledge of limiting global warming to well below 2°C, preferably 1.5°C, COP28 moved forward with the unifying motto of uniting the world to act and deliver for a just and sustainable future. COP28, also countersigned, the decision of “loss and damage fund”, as taken during COP27, had adopted on the very first day of it, which gestured a good start.

COP28 UAE concluded with the decision to convene the next COP in Baku, Azerbaijan, in November 2024. COP30

will be held at the previously chosen location of Benin, Mexico, while India proposed to host COP33 in 2028.

First Global Stocktake (GST) under the Paris Agreement

One of the key outcomes of COP28 was the adoption of a decision by the parties on the first Global Stocktake (GST) under the Paris Agreement and reiterated the need for deep, rapid, and sustained reductions in Greenhouse Gas (GHG) emissions to stay on track for a 1.5°C future. This also encouraged parties to come forward in their next Nationally Determined Contributions (NDCs) with ambitious, economy-wide emission reduction targets by 2030, covering all GHGs, sectors and categories by aligning to limit global warming to 1.5°C.

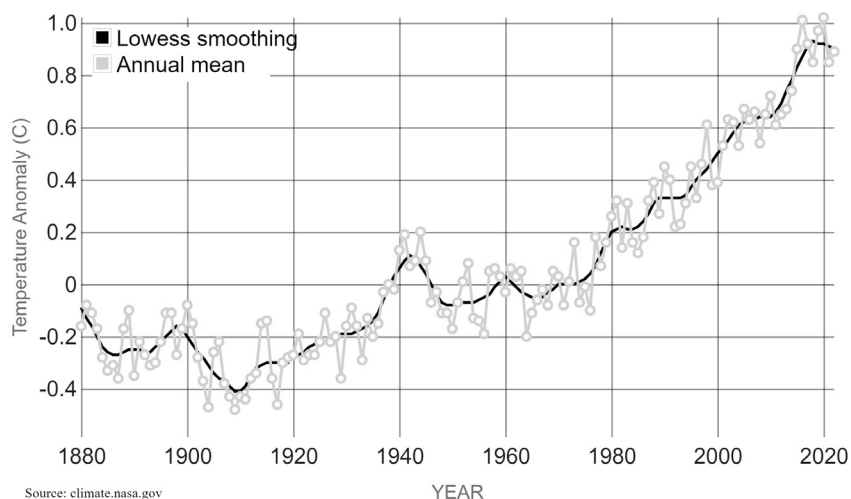
GST, a fundamental component of the Paris Agreement for monitoring its implementation and evaluating collective progress towards agreed goals, has obvious links to implementing NDCs. According to the latest NDC Synthesis Report published by the UNFCCC on 27 October 2023, 61 countries have submitted new or updated climate plans



COP28 UAE, as featured at the venue

since COP26 in Glasgow. Governments decided on the GST at COP28, leveraged to accelerate ambition in their next round of climate action plans due in 2025.

However, from the beginning of the COP28, UN Secretary-General Mr Guterres emphasised GST, wherein countries, for the first time, assessed progress on curbing global warming as he believed that this had the potential to put the world on track to achieve the temperature, finance as well as adaptation goals. After adopting the outcome document, he stressed that the era of fossil fuels must end with justice and equity.



Earth's global average surface temperature is on the rise

Climate Catastrophe Looming on the Horizon of Earth

An Analysis by the National Oceanic and Atmospheric Administration (NOAA) and other institutions mentioned that Earth's global average surface temperature continued a long-term warming trend due to human activities. The graph below also shows the change in global surface temperature compared to the long-term average from 1951 to 1980. The year 2020 statistically tied with 2016 as the hottest year since recordkeeping began in 1880.

The World Meteorological Organization (WMO) also released a report, just weeks before COP28, which says that the 2011-2020 decade was the hottest on record for both land and ocean. An alarming increase in greenhouse gases accompanied a rapid decline in land ice mass, accelerating sea level rise at a worrying pace. On the other hand, ocean warming disrupts food webs, coral reefs bleach, and coastal communities face rising tides.

These distressing findings underline the urgency of achieving the Paris Agreement's temperature targets and the SDGs' sustainability goals. COP28's agreed decision of "transitioning away from fossil fuels in energy systems, in a just, orderly and equitable manner" provides hope towards achieving a net-zero target by 2050. From Polar peaks to Himalayan heights, UN Chief Guterres, at COP28, sounded, by recalling his recent visits, the alarm on a warming world, witnessing firsthand the devastating retreat of ice in Antarctica and Nepal, a stark reminder that climate change unites every corner of our planet.

Fossil Fuels: From 'Phase-out' to 'Transition Away'

More than 100 countries called for language in the COP28 agreement to reference the "phase out" of fossil fuels. A landmark deal emerged at COP28, calling for "a just, orderly, and equitable transition away from fossil fuels in energy systems." This, in turn, is obligatory to achieve net zero by 2050 in keeping with the science.

Prior to the final negotiations, during the Energy Transition Day of COP28, the transformative shift could have been seen towards fast-tracking a clean energy future, decarbonising the present, and ensuring a just and inclusive transition.

Several new alliances mobilised \$83 billion for climate solutions to support vulnerable communities. In these earnest debates, potential economic levers like market-based coal plant closures clashed with the optimistic hum of parallel talks. These latter discussions buzzed with ideas for harnessing technological advancements and improved energy efficiency as a way to accelerate emissions reduction. Industry tackled de-carbonisation in shipping and steel, while the Breakthrough Agenda and Hydrogen Declaration spurred international collaboration for clean energy solutions for a 1.5°C future.

Sustainable Green Gains from COP28

In addition to the decision to transition away from fossil fuels, COP28 approved several other decisions contextualising climate action.

By signing the “Global Renewables and Energy Efficiency Pledge”, 117 countries at COP28 pledged to triple renewable energy and double energy efficiency by 2030. India, at COP28, made it clear that the country is among the few countries on track to meet its Nationally Determined Contribution (NDC) targets and urged, as well, towards fairly sharing the global carbon budget. Moreover, India advocated for developed nations to “make room” for carbon-neutral practices before 2050. It also invited worldwide collaboration with the country’s “Green Credit initiative,” a non-commercial effort to foster carbon sinks.

Besides, developed countries, acknowledging their role, finalised a “loss and damage fund” at COP28, pledging a combined founding contribution of at least \$700 million.

Regarding the “phase-down of unabated coal”, the previous draft text talked about limiting new coal plants, but the same was removed in the final document as adopted. With COP28’s diluted stance on coal, India’s quest for affordable power while curbing emissions demands innovative solutions. Further, 50 oil and gas producers, including Saudi Aramco, representing 40% of global production, signed a COP28 agreement for net-zero carbon (2050) and near-zero methane emissions (2030).

Countries also agreed upon the role of food systems and agriculture in carbon emissions under the “Food and Agriculture Declaration”. More than 130 countries signed this declaration on the premise that food contributes to a third of the warming gases that increase global temperatures.

What’s more, the health impacts of climate change now took centre stage for the first time in 28 years of UN climate talks, and the “Declaration of Climate and Health”, called for climate action to achieve benefits for health from deep, rapid, and sustained reductions in GHGs, including from just transitions, lower air pollution, active mobility, and shift to sustainable healthy diets. India, however, refrained from endorsing the COP28 Declaration on Climate and Health, citing concerns that reducing greenhouse gas emissions within its healthcare infrastructure might hinder its ability to meet growing demands for medical services, particularly in remote and underserved areas. In its G20 presidency, the country has already prioritised resilient health by focusing on strengthening healthcare systems, improving access to medical countermeasures, and fostering international collaboration for digital goods sharing.

Despite this, over 60 countries signed the “Global Cooling Pledge”, a new initiative launched at COP28 to reduce cooling-related emissions across all sectors by at least 68% globally by 2050 compared to 2022. It aims to do this by promoting the adoption of energy-efficient cooling technologies, reducing refrigerant leakage, and phasing out harmful refrigerants. Additionally, the pledge will provide financial and technical assistance to developing countries to help them transition to sustainable cooling technologies. On the other hand, the goal of “End

Deforestation by 2030” was initially set at COP26 and reinforced at COP28.

Essence of ‘Panchamrit’ and India’s LeadIT

Panchamrit, meaning “five nectars” in Hindi, refers to India’s five-point strategy for tackling climate change, announced during COP26 and lauded once again at COP28 for its ambitious goals and comprehensive nature. These five nectar elements included reaching net-zero emissions by 2070, increasing non-fossil fuel energy capacity to 500 GW by 2030, reducing the carbon intensity of the economy by 45% by 2030 (from 2005 levels), fulfilling 50% of energy requirements from renewable energy sources by 2030 and Lifestyle for Environment (LiFE). At COP28, LiFE resonated as an inspiration of collective action because it promotes daily sustainable practices, i.e. using public transport, choosing energy-efficient appliances, etc., living in harmony with nature, and nurturing community engagement; LiFE encourages small, impactful choices for a greener future.

Worth highlighting, in 2019, a powerful trio — Sweden, India, and the World Economic Forum (WEF) — gave birth to the Leadership Group for Industry Transition (LeadIT), a game-changer in navigating the complex landscape of industrial transition as industries share around 30% of the global Carbon Dioxide (CO₂) emissions. At the Swedish Pavilion of COP28, LeadIT 2.0 blazed a trail under India’s co-hosting banner. This bonfire of leadership gathered industry luminaries, experts, and invested stakeholders to nurture meaningful collaboration and impelled towards transformative change.

Beyond leadership talks and ministerial dialogues, India’s commitment to climate action is showcased not just through LeadIT but also by joining forces with the Solar Alliance, Coalition for Disaster Resilient Infrastructure (CDRI), the International Big Cat Alliance (IBCA), and Green Credit Initiative which is a new and exciting global platform launched at COP28 by India to incentivise and promote voluntary pro-environment actions across various sectors by individuals, communities, private companies, and even entire industries. From kitchen to community, India’s call echoed the need to reduce water waste, avoid or lessen single-use plastics, embrace sustainable food, and prioritise well-being. These everyday actions are crucial to unlocking substantial carbon reductions and environmental sustainability.

The author’s slot on “Climate Change and Role of the Ocean” at COP28, secured through a global call, epitomised the rising awareness of the ocean’s crucial role in mitigating climate change. Notably, the UN Ocean Decade and Ocean X, housed in COP28’s blue zone, facilitated dedicated “Ocean Climate Solutions Dialogues” and “Ocean Climate Spotlights” to amplify the ocean’s significance in achieving the 1.5-degree goal.

While challenges remain, COP28 witnessed cracks in the climate wall, with nations stepping up to address Loss and Damage, embrace renewables, and prioritise health and other issues of highest concern in the context of climate change.

Dr Anil Pratap Singh, General Secretary & Founder Director, Global Science Academy (GSA, www.gsaindia.org), Basti-272001, UP. Email: globalaps@rediffmail.com

Climate Change Impact on Agriculture

Jaydev Jana

*“Climate variability and extreme conditions are a key driver behind the recent rise in global hunger and one of the leading causes of severe food crisis,”
FAO.*

THE rapid growth of human civilisation is colliding with approaching limits to the supply of key natural resources. Due to climate change, the planet's life-support systems are running down, posing a threat to humanity's ability to produce even the amount of food produced today because agriculture is very sensitive to weather and climate. It also relies heavily on land, water, and other natural resources that are affected by climate change. Climate change has already affected the quantity of food produced globally, even though it is small compared to the significant increase in global food production. A study of global vegetable and legume production concluded that if Greenhouse Gases (GHGs) emissions continue on their current trajectory, food production could decline by 35 per cent by 2100 due to water scarcity, increased salinity, and topsoil depletion.

Wheat is the most important staple crop in temperate zones and is in increasing demand in countries undergoing urbanisation and industrialisation. It is one of the crops most susceptible to the effects of climate change. Studies reveal that each degree increase in nighttime temperature corresponds with a linear decrease in wheat production. The rise in mean temperature of 2 degrees Celsius to 3 degrees Celsius will reduce wheat crops in North India, resulting in a loss of 6 to 7 million tons of wheat annually. A large global review of the impact of climate change on crop yields between 1980 and 2010 showed that worldwide wheat production fell by 5.5 per cent due to climate-related factors.

Corn (maize) is the most produced crop globally, with 1.1 billion tons, followed by wheat and rice. It originated as a tropical grass and can tolerate exposure to adverse temperatures. But as temperatures continue to increase, corn appears to be the most vulnerable to heat stress. Its yields start to decrease at a range of temperatures the Earth is already experiencing regularly in summer months. Every day during the growing season — roughly from the beginning of March to the end of August — when temperatures rise above a threshold of 84 degrees F (Fahrenheit), corn yields drop by 0.7 per cent. As temperatures grow hotter than 84 degrees F, the yield declines drop further with every degree added.

Corn is the primary US feed grain, accounting for over 95 per cent of total feed grain production and use. The US is also the largest exporter of corn in the world. Indeed, nothing dominates the American landscape like corn. If temperatures in the US continue to rise as much as is now projected as global warming, by the end of the century, corn yields could fall by as much as a third from heat stress alone, with the impact of worsening droughts and the disruption of precipitation patterns taking a larger toll still. The risk is also dangerously real for the other corn exporters — Brazil, Argentina and the Ukraine. These countries are facing simultaneous crop failure. The impact on crop yields will aggravate the plight of the world's poorest and sharpen the rich/poor divide. Though soybeans have a higher threshold for heat stress than corn (86 degrees F or 30 degrees C), it has been established that higher concentrations of CO₂ level can result in soybeans deactivating genes that are crucial to the production of chemicals to defend themselves against the insects. Hence, soybeans grown in an atmosphere with high concentrations of CO₂ appear to be helpless against herbivores.

Image credit: pexels

A researcher at the International Rice Institute in the Philippines, Shaobing Peng, showed that the yields of rice declined by 10 per cent with every one degree C increase in nighttime temperatures during the dry part of the growing season, even though there were no significant drops in yield associated with increasing maximum temperatures during the daytime. Crop diseases and pests are also increasing with global warming. One of the leaders of an Asian international agricultural research group, Promod K Agarwal, said, “Warmer conditions and longer dry seasons linked to climate change could prove to be the perfect catalyst for outbreaks of pests and diseases”. Moreover, warmer temperatures and changing precipitation can affect when plants bloom and pollinators, such as bees and butterflies, come out. Pollination could decrease if mismatches occur between when plants flower and when pollinators emerge. When plants absorb large amounts of ground-level ozone, they experience reduced photosynthesis, slower growth and higher sensitivity to diseases.

Temperature is probably the most important environmental factor influencing insect behaviour, distribution, development, survival and reproduction. It has been estimated that with 20 degrees C temperature increase, insects might experience one to five additional life cycles per season. According to crop scientists, the increase in the ‘pest population’ could have a substantial economic impact through increased seed and insecticide costs, decreased yields and the downstream effects of changes in crop yields.

The major climate factor which influences crop growth is rainfall. The global water cycle gets radically intensified and accelerated by global warming. While the warmer oceans allow significantly more water vapour to evaporate into the sky, the warmer air also holds more water vapour. Scientifically, it has been established that an extra 4 per cent of water vapour in the atmosphere above the oceans significantly affects the hydrological cycle. Since storms often reach up to 2,000 kilometres, they gather water vapour from large sky areas and funnel it into regions where storm conditions trigger a downpour.

By analogy, if we put a drain into a bathtub filled with water, the water rushing down the drain does not come just from the part of the tub directly over the drain; it comes from the whole tub. In the same way, the great basins of water vapour in the sky are funnelled to the ‘drains’ opened above the land by rainstorms and snowstorms. The downpours are more intense when the basins are filled with more water vapour than in the past. The bigger downpours lead to bigger floods. The floods rush across the land, eroding the soil. And less water seeps down through the soil to recharge the underground aquifers. According to a recent analysis done by the Central Ground Water Board (CGWB), the groundwater level in some parts of the country is declining, while 89 per cent of the groundwater extracted is used in the irrigation sector of the country, and 85 per cent of rural domestic water requirements are also fulfilled by groundwater.

When temperatures rise, the warmer air holds more moisture and can intensify precipitation. Extreme precipitation can damage crops, resulting in decreased

yields. A rise in the sea level can submerge crops. Hot weather also leads to faster evaporation, drought, and water shortage. Presently, around 42.4 per cent of India is drought affected. Climate change also causes desertification by altering atmospheric circulation patterns and drying land and vegetation. The same extra heat that evaporates more water vapour from the oceans also speeds up the evaporation of soil moisture — leading to longer, deeper, and more widespread droughts. As more extended refilling of the atmospheric ‘basins’ of moisture still takes a lot of time, many areas of the world are experiencing more extended periods without rain between precipitation events, leading to more widespread and even deeper droughts. Once it is devoid of vegetation, the surface begins to absorb more heat. When the soil moisture is gone, the ground is baked, local temperatures rise, and the topsoil becomes more vulnerable to wind erosions. Topsoil regenerates naturally but at an amazingly slow rate of about 2.5 centimetres every 500 years. Many studies indicate that half of India’s geographical areas are degraded and suffer from soil erosion; each inch of lost topsoil diminishes grain yield by 5 per cent; apart from quantity, climate change can severely affect food quality.

The parching and desiccation of the world’s most highly productive agricultural breadbasket portend a future food crisis that could have humanitarian and political consequences too horrific to imagine. The consequences for food production and water availability are already extremely harsh. In 2012, mainly because of the climate-related events that reduced crop yields, the world experienced a one-month price increase for food, with additional record price hikes predicted for 2013.

More than 65 per cent of the US suffered from drought conditions in 2012. In addition to the impacts on industrial agriculture in North America, Russia, Ukraine, Australia, and Argentina, subsistence agriculture has been hit hard in many tropical and subtropical countries by considerable alternations in the timing, duration, and magnitudes of precipitations pattern due to global warming disruption of the hydrological cycle.

Climate change encompasses global warming, which is caused by the presence of invisible greenhouse gases in the atmosphere. Those gases do not stay where they are generated. They have not heard of passports and don’t know political boundaries. They are just blown by the winds and moved by the general circulation of the planet. In the words of Paul Hawken, “At present, we are stealing the future, selling it in the present, and calling it gross domestic product.”

Indeed, the planet is a unit so no single nation can solve the problem of climate change alone. All countries must sincerely work together to clean it up, be good trustees of the Earth for future generations and make it a better place for our grandchildren and great-grandchildren. If we want to save ourselves, we shall adopt — as Albert Einstein said in 1945 in a slightly different context — a new way of thinking. It is not impossibly hard to do.

Mr Jaydev Jana, IAS (Retd), Ex-Special Secretary to the Govt of West Bengal, South Breeze Residency, Bipasha, Jheel Road, Kolkata-700031.
Email: jaydev.jana@gmail.com

SNOWFLAKES

A Symphony of Nature's Design

Ajai Chawla

EVERY winter as the chill sets in, hordes of tourists from across the country flock to the Himalayas in the north to witness and experience the magnificence of snow and the fun and sports associated with it.

The beauty of snow is like magic, especially for those who have never experienced it. The quiet, slow dance of snowflakes falling through the cold winter air adds to the charm, making it seem like nature is sharing secrets in the soft snow. Each snowflake, with its special design, is like a tiny masterpiece of art, transforming the world into a living snow globe. The romance of a snowy scene makes ordinary things look amazing — trees sparkle, rooftops frost, and even simple objects become extraordinary.

Amazingly, adding to the beauty is the fact that every single snowflake is different from the other in terms of its structural formation — so, no two snowflakes are ever alike, even though to the naked eye they all seem to be the same! Why and how this is possible, is what we will explore here.

Why Study Snowflakes?

But to start with — have you ever wondered why the study of snowflakes is more than just a whimsical pursuit? Well, snow isn't just about building snowmen; it's a captivating substance with unique properties, waiting for scientists to explore its mysteries.

Snowflakes and ice aren't just frozen water; they are bona fide minerals. Studying them offers a sneak peek into the behaviour of water in its solid form. It's like unveiling the secret life of water!

Snowflakes, with their mesmerising patterns, narrate the tale of the clouds they originated from. Each snow crystal becomes a tiny storyteller, aiding us in unravelling the science of our environment. So, the next time you catch a snowflake on your glove, remember, it's not just winter's artwork — it's a microscopic marvel contributing to our scientific odyssey!

History of Snowflake Exploration

The journey of understanding the intricate world of the symmetry and complexity of snowflakes is a tale stretching back through centuries, marked by the insights of eminent scholars and the tenacity of pioneers in scientific observation. Around 135 BC, the Chinese scholar Han Yin articulated a fascinating revelation. In comparing snowflakes to the myriad flowers of plants and trees, he noted an intriguing six-pointed symmetry. This insight, well-known in ancient China, awaited recognition in Europe for many centuries.

Fast forward to 1591, Thomas Harriot, an English astronomer and mathematician, delved further. Offering a refined description, Harriot emphasised the distinct six-fold symmetry that defines snowflakes, showcasing their peculiar



Preserving snowflake with glue and observing it

variety of shapes, from crescents to hand-like formations. In 1611, the German scientist Johannes Kepler pondered on the general structure of snowflakes. Kepler, known for his celestial musings, theorised that the hexagonal arrangement of stacked cannonballs might unlock the secret behind snowflake symmetry. Limited by the scientific knowledge of his era, he left the theory awaiting further exploration. While he lacked the understanding of genetic blueprints, his notion that the complex shapes emerge spontaneously from simple origins, is in tune with contemporary scientific investigations.

The mid to late 1630's saw Rene Descartes, a French philosopher and mathematician, intensify the study of snowflakes. Even without a microscope, Descartes meticulously recorded rare forms like capped columns, pushing the boundaries of observational science.

The late 1880's introduced a revolutionary chapter with Wilson Bentley, a Vermont farmer nicknamed "Snowflake". Bentley, armed with a microscope and camera, embarked on an extraordinary quest. Enduring the winter chill, he captured over 5000 microscopic snowflake images. The Smithsonian Institution Archives proudly preserves 500 of Bentley's intricate snapshots. Bentley's technique of photomicrography, blending a microscope and camera, revolutionised the study of snowflakes.

Thousands of high-resolution images allowed scientists to make crucial generalizations about the diverse forms created under varying atmospheric conditions. Differentiating atmospheric conditions give rise to distinct snowflake patterns. The famed six-pointed structure dominates the Northern Hemisphere due to its ideal temperature-to-humidity ratio. Bentley's comprehensive collection serves as a goldmine of data, providing vital insights for mineralogists and meteorologists into the intricate formation of ice in the sky.

The saga of studying snowflakes carries on, etching new chapters in the ever-evolving narrative of scientific exploration. The complex morphologies of snow crystals also continue to be an ongoing area of exploration, highlighting the intriguing interplay of physical rules that govern their growth.

Snowflake Mysteries Unveiled

In the 1930's, physicist Prof. Ukichiro Nakaya from the University of Hokkaido in Japan, delved into the mysteries of snowflakes, employing 20th-century scientific methods.

If Cloud Temperatures Are...	Snowflake Shape Will be...
0 to -3 °C	Thin hexagonal plates and stars
-3 to -6 °C	Needle-like
-6 to -10 °C	Hollow columns
-10 to -12 °C	Sector plates
-12 to -18 °C	Star-shaped "dendrites"
-23 to -34 °C	Plates, columns

Nakaya conducted extensive observations of natural snow-crystal types and realised that laboratory experiments were essential to uncover the conditions influencing crystal shapes. Nakaya developed techniques to grow isolated snow crystals in test chambers. He discovered that a crystal's morphology and ice growth was primarily dictated by its sensitivity to air temperature and humidity.

Just below freezing, around -2 degrees Celsius, thin plate-like crystals formed. Slightly colder conditions, around -5 degrees Celsius, favoured slender needles. At -15 degrees Celsius, the largest and thinnest plate-like crystals emerged, while below -25 degrees Celsius, short columns dominated.



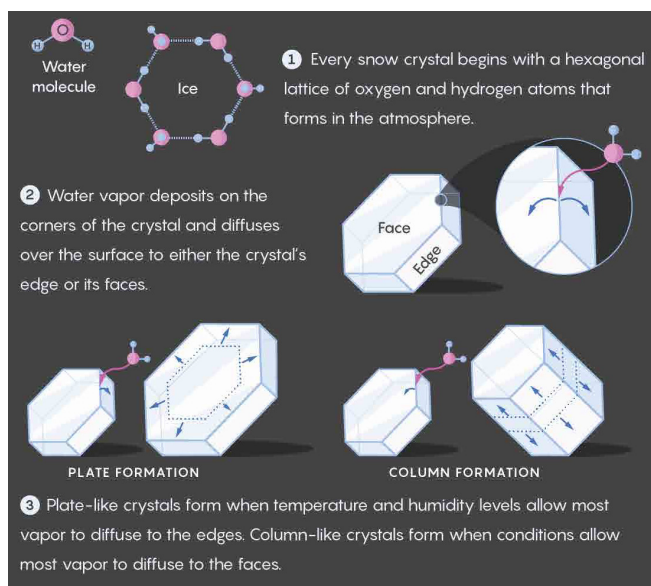
Drawings of diverse snowflakes by the Japanese physicist Ukichiro Nakaya, who conducted a decade long study on the different types of snowflakes

The snow-crystal morphology diagram, a representation of crystal shape based on temperature and humidity, was Nakaya's key contribution. Even till date, certain aspects of this diagram remain unexplained, particularly the intriguing temperature dependence oscillating between plates and columns. This morphology diagram explains two fascinating features of snow crystals: their diverse appearances and the uniformity of the six branches growing on it. As a snow crystal travels through ever-changing conditions inside clouds, variations in its local environment lead to diverse growth patterns, making each crystal unique.

The snowflake's expansion is a result of additional water molecules adhering to its surface. The manner in which these water molecules attach is dependent upon three key factors:

- 1) The adhesive quality of the surface.
- 2) The energy level of the water molecules at the surface.
- 3) The concentration of water molecules in the adjacent air.

It is fascinating to ponder how something as delicate as a snowflake crystal, with its six-fold symmetry, can emerge from a chaotic mixture of air, water vapour, and other microscopic particles. This arrangement, an intricate network of water molecules, is the result of the interplay between molecular forces. The astonishing convergence of basic physical principles and intricate symmetry accounts for the mesmerising beauty of snowflakes.



Stages of snowflake formation

The journey of a growing snowflake follows a highly random path, influenced by atmospheric chaos. Given the impossibility of two snowflakes traversing identical paths through clouds, the likelihood of finding identical snowflakes is almost non-existent. Nature's intricate dance of changing winds orchestrates the stunning variety of crystal forms observed by snowflake enthusiasts.

Beyond the morphology diagram, progress in understanding snow crystals stems from crystallography and metallurgy. In the early 20th century, X-ray diffraction techniques unveiled the six-fold symmetry of the ice-crystal lattice, laying the groundwork for crystallography. This technique was utilised, allowing scientists to peer into the interior structure of crystals, and in understanding the 3D organisation of atoms and molecules. In

the realm of snowflakes, this technique unearthed the stunning hexagonal ice crystal lattice, the common foundation for snowflake symmetry.

Meet the Snowflake Scientists

Scientists studying snowflakes are modern heroes in winter weather research who have dedicated their lives to unlock the mysteries of snowflakes, taking our understanding to new heights. They employ cutting-edge technology and deploy intricate experiments to fathom the microcosmic realm of ice crystal growth. Their work is pivotal in predicting weather patterns, enhancing our understanding of climate change, and advancing the realms of materials science.

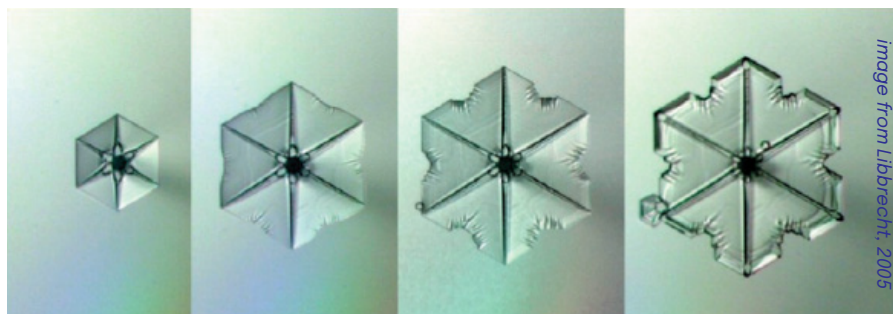
Dr Kenneth Libbrecht, a physicist at the California Institute of Technology, is one such modern snowflake scientist. He has passionately dedicated his research to understanding snowflakes and has become a prominent figure in the world of snowflake science. His enthusiasm for these icy wonders is contagious, as he captures snowflakes and shares his findings through beautiful images and accessible explanations.

Dr Libbrecht's research combines both art and science to educate the public and inspire curiosity. Using advanced equipment, he grows his own snowflakes in a lab, allowing for precise observation and the study of their intricate structures. He is part of a new generation of scientists who use a combination of traditional observation and modern technology to uncover the secrets of snowflakes. By studying their growth patterns and morphology, scientists like him contribute to our understanding of atmospheric processes, crystal formation, and meteorology.

Chasing Snowflakes

In the field of photography, capturing the elegance of individual snowflakes is both a challenge and an art form. With techniques inspired by Wilson Bentley, talented photographers such as Alexey Kljatov and Don Komarechka have elevated snowflake photography to an impressive level. Each image captures the microcosmic beauty of snowflakes, showcasing the astonishing variety in intricate patterns. These photographs reveal the complexity of ice crystals with a sense of delicacy, akin to observing a butterfly's wings or peering into the world of microorganisms.

A modern day adventure for enthusiasts, people from different walks of life pursue the elusive art of snowflake



As a snow crystal grows, its corners grow faster than the edges, until the corners start to poke out as seen in this series of images from left to right.

Snowflakes: Nature's Mini Miracles Unveiled!

Discover the enchanting world of snowflakes with these cool trivia tidbits:

Monster Snowflake Alert! In 1887, Fort Keogh, Montana, witnessed the grandeur of the largest aggregate snowflake ever reported, a colossal 15 inches wide! Imagine the snowball fights with that giant!

Snowflakes on a Slow Dance: The average snowflake descends gracefully at a speed of 1 to 6 feet per second. Their lightweight and parachute-like surface area create a leisurely fall compared to raindrops racing at 32 feet per second.

Hexagons Rule the Snow World: All snowflakes boast six sides or "arms" due to the hexagonal lattice structure of ice. It's like nature's way of saying, "Six is the perfect snowflake number!"

Math Meets Snowflakes: Mathematicians adore snowflakes for their perfect symmetry. In theory, each flake sports six identical arms, but the real ones often bear scars from their adventures in the sky.

Clear Crystals in a Blanket: Despite their collective white appearance, individual snowflakes are clear when observed up close. It's the magical teamwork of multiple ice crystal surfaces that gives us the snowy wonderland.

Snow's Silent Symphony: Ever noticed the serene hush during a snowfall? Snowflakes play maestro by trapping air between crystals, reducing vibrations. Less than an inch of snow can turn your world into a peaceful symphony!

photography. It's a magical journey, capturing the essence of snowflakes and sharing it with the world. It's an arduous task requiring patience, precision, and a keen eye. There are about 21 observation sites of snow crystals, ice crystals, and other solid precipitation particles that have been earmarked in Antarctica, Canada, Finland, Greenland, Japan, Norway, Sweden, and, USA.

Snowflake chasers often work in sub-freezing temperatures, frequently getting wet from snow, and battling frostbite for that perfect shot. Their passion for revealing the hidden beauty of snowflakes is truly inspiring. Modern snowflake chasers, equipped with advanced camera gear, have elevated snowflake photography to a fine art. They capture the unique details of each

crystal, revealing their intricacy and fragility. Every photograph becomes a testament to nature's exquisite design. Contemporary technology has made it possible for photographers to capture these wonders in unprecedented detail.

Macro lenses, focus stacking techniques, and editing tools allow for stunning close-ups of individual snowflakes. These images celebrate the artistic side of snowflakes, turning each crystal into a masterpiece of nature. It's not just the physical attributes of snowflakes that captivate people, it's also the emotions and stories they evoke. For snowflake chasers, each successful shot represents a personal triumph and an intimate connection to the winter landscape.

The act of catching these fleeting creations often leads to a sense of awe and appreciation for the world's natural wonders. A single snowflake, no bigger than a grain of sand, contains a universe of beauty and complexity, a testament to the power of nature's artistic creation.

Snowflakes, Art, and Metaphor

The wonder of snowflakes doesn't just stop at scientific fascination; it resonates deeply with human emotions. Snowflakes are often associated with art and metaphor, enhancing their appeal and charm. The unique hexagonal structure of snowflakes serves as a potent symbol for the intricate beauty in the natural world.

Its fleeting nature, transient beauty, and the knowledge that each snowflake is a unique masterpiece of nature often lead to a sense of poetic reflection. This perspective extends to the transient beauty of life, the preciousness of moments, and the awareness that every individual is unique and irreplaceable.

The metaphors associated with snowflakes are as varied as the shapes themselves. Whether it's the fragility and individuality of each flake, the idea of unity in diversity when they blanket the earth, or the calm and peace they bring when they fall gently from the sky, snowflakes hold profound symbolic power. Consider the analogy of snowflakes falling softly from the sky, covering the world in a pristine white blanket. In moments like these, nature's grandeur captures the collective human imagination.

Snowflakes, with their complex symmetry, remind us of the intricate order within the natural world. In an era marked by chaos, turbulence and unpredictability, the perfect, albeit temporary, designs of snowflakes represent a fleeting sense of order, grounding the human experience.

Snowflakes are not just frozen water; they are intricate sculptures shaped by the forces of nature and the laws of physics. They embody the charm of winter, inspire art and metaphor, and hold the potential to revolutionise science.

The next time you gaze upon a freshly fallen snowflake, take a moment to appreciate the intricate beauty, the scientific marvel, and the artistic inspiration it represents. Whether through a snowflake's journey from sky to earth, the work of modern snowflake scientists, or the artistry of snowflake chasers, there's a story waiting to be discovered in each delicate crystal.

Mr Ajai Chawla is a science communicator and directs/produces science documentaries under the banner 'Spectrum Productions' based out of Delhi. Email: ajai_c@yahoo.com

BODH TO BODHODAYA

A Transformation towards Sustainable Nation

Sushovan Ghosh



Left: Bodh is in conversation with Photon. Right: Bodhodaya is delivering speech on the Independence Day.

(self-complied, Source: Internet)

THIS is a story about “Bodhodaya”, aka “Bodh”, a boy who lives with his parents and grandmother in the village “Katundidanga”. He is now nine and a half and has just started attending high school in a nearby town. Bodh’s father is an auto-driver, and his mother is a homemaker. Earlier, his father used to sow paddy seed on their small land, but the scarcity of rain stopped that engagement.

It is around 8 pm; Bodh’s father has returned from work. The crackling sound of burning wood, the greyish smoke, and the odour of boiled rice prevailed across their premises. His grandmother is continuously coughing. Bodh’s mother comes out through the smoke and offers a glass of water to the old lady. She asks her mother-in-law to stay away from the kitchen area.

Tomorrow is 15th August. Bodh is busy drawing the tri-colour flags for his school function, and his father and the neighbours are arranging the setup to hoist the flag in their locality. They look enthusiastic about commemorating the ‘Har Ghar Tiranga’ on the ‘Azadi Ka Amrit Mahotsav’ occasion.

It is around 9.30 pm. They are having dinner. This time, Bodh used to talk about his daily activities in school. Bodh (to his parents): “Maa-Pa! You know tomorrow there will be a grand celebration in our school. Our BDO sir will come. Namita madam, our headmistress, asked us to prepare a speech.”

“So, Beta! Have you prepared any speech for tomorrow?” asks his father.

“No, Pa, I have not prepared yet. I do not know what pledge we should take for tomorrow and every day”, Bodh replies. Meanwhile, he finishes his dinner and goes to sleep.

“What shall I speak for tomorrow?” resonates in his mind.

Bodh feels that a ray of glittering light falls on his pupils. He cannot open his eyes entirely to that dazzling light. Suddenly, the beam asks, “Bodh, my friend, wake up. The time has come to become Bodhodaya from Bodh”.

“What? Who are you?” asks Bodh in complete confusion.

“I am Photon, coming from the Sun by travelling 150 million kilometres for you. It is because of me that all lives sustain on earth. Even there will be no existence of earth without me. I bring day and night, seasons and years”, the earlier voice reverberates.

Bodh is astonished and asks. “Hey, Photon, why have you come to me!”

“What do you want from me?” he adds.

“I am in big trouble, my friend, so as your earth. I need your help. I believe the day Bodh will become Bodhodaya, my worries will start to decline,” replies Photon.

Bodh is utterly perplexed and asks, “How?”.

Photon starts unfolding his story. He asks, “My little friend! Have you ever heard about Aerosols?”

“No. what are they?” Bodh replies with a lot of curiosity.

Photon says, “Aerosols are one of my enemies, so as yours. They block me and my friends from reaching the surface of your earth.”

“How can they hinder you?” asks Bodh.

Photon says, “Aerosols scatter or absorb incoming solar radiation based on their optical properties, which depend on their chemical and physical characteristics. Most of them are sub-micron to nanometers in size. The average diameter of your hair (human) is 50-70 microns. So, you think how tiny they are. But a few of them can be seen by the naked eye. When I enter through your window, you can see some of the big-sized demons (aerosols). Some are dark black, such as ‘Black Carbon’ aka ‘BC’, and completely absorb us; some are

white, such as 'Sulfate', entirely scatter, and a few possess mixed characteristics (scatter and absorb)."

"Interesting! But from where are they originating?" Bodh inquires.

"They are originating from human activities. Scientists call it '*anthropogenic*' sources, such as smoke from household cooking and lightning, fumes from industries, exhaust from vehicles, roadside dust due to construction works and many more", Photon adds.

"Do all originate from *anthropogenic* sources only?" asks Bodh.

"No, no! Natural sources include sea spray, forest fire, volcanic eruptions, and desert dust. Even the pollens and spores secreted by plants, viruses, and bacteria are on the list. They are 'Bio-aerosols,'" Photon replies.

"Okay! I have understood. What trouble are they creating for you so as on us?" Bodh's curious mind utters.

"Okay! Let me elaborate point by point. You know, we, the Photon family coming from the sun, drive the weather and climate system on your earth by interacting with various components. Few are good, like clouds and ozone at a higher level. Scientists say clouds cool your planet, and ozone at higher levels filters the lousy part of us (protecting humans from Ultraviolet). But some of them are not so good, such as aerosols and their colleagues (co-emitted toxic gasses such as carbon dioxide, methane, nitrogen oxides, sulfur oxides, etc.). However, a perfect balance exists between all of them. But, increasing human activities dump more of these demons (aerosols) and their colleagues into the atmosphere and hence block my way, perturbing the radiative balance (equilibrium between incoming and outgoing radiation at the top of the atmosphere), Photon recites.

"The news and our teacher sometimes talk about global warming, melting ice, sea level rise, extreme cold or heat waves, irregular monsoon onset and withdrawal, cyclonic storms, flashfloods, severe drought and many more. Are all these somehow linked with the manifestation of the above perturbation?" Bodh asks.

"Yes! Yes, my friend", Photon replies.

(Taking a deep breath)

Photon continues, "Even the Lilliput-sized demons (diameter less than 2.5 microns) can enter inside your body increase the risk of several diseases such as cardiovascular, lung cancer, Chronic Obstructive Pulmonary Diseases (COPD). These demons are known as Particulate Matter, aka 'PM2.5'. Infants and people of your grandmother's age are most vulnerable to this risk. Women like your mother, who used to cook using coal or wood, and the population living below the poverty line are prone to the highest level of exposure. According to the latest research, air pollution is attributable to around 7 million premature deaths (deaths before the average age of death in a certain population) worldwide. So, think how dangerous they are!"

"Yeah! I see", Bodh replies and nods in agreement.

"It is not only humans; polar bears on poles, coral in the oceans and many other animals/plant species are equally vulnerable", Photon says with a broken heart.

"So, what are your recommendations to get rid of these situations?" Bodh asks with hope.

Photon is very happy with the previous question. It looks like he finds a new ray of hope in the prevailing darkness.

Photon replies, "Thank you, my friend. Let me give you a few pathways. These actions should start with your family. From next time onwards, tell your mother to use clean fuel (take advantage of subsidised LPG), and you should use a solar lantern instead of a kerosene lamp. Ask your father and neighbour to switch from a conventional to an electric auto. Scientists have found that household emissions are among the most significant contributors to nationwide pollution, followed by industrial fumes and transport exhausts.

Using clean fuel not only eradicates pollution but also uplifts women's social status. The country you belong to has introduced a comprehensive array of schemes to curb air pollution, such as 'Pradhan Mantri Ujjwala Yojana (PMUY)' and 'Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY)', 'National Clean Air Programme (NCAP)' and many more. Transitioning to renewable energy, particularly roof-top to ground-mounted solar photovoltaic, is one of the green solutions. Even a study shows that air pollution can also affect solar renewable energy. So, I believe your nation needs to stress science and technology innovation to tackle these problems, and general awareness is urgently needed. Curbing air pollution through technology and policy can benefit public health, climate, and socio-economic livelihood. The valuation of these benefits is higher than the cost of the policies or technologies, heading towards a 'win-win' scenario, which the researchers call co-benefit opportunities."

"Wow! The solutions are impressive. I understand", Bodh replies with excitement.

"But please disclose, why do you choose me?" Bodh speaks out.

"I know you have to prepare a speech for Independence Day. I feel you have now realised the awareness required to protect your nation and Mother Earth. To me, you now become "Bodhodaya" (one who realises the true sense of humanity). You must make many more "Bodhodaya", the voice reverberates.

Birds start chirping.

"Beta, wake up", Bodhodaya's mother calls from the kitchen.

The sunrise brings new hope of light.

At school, he stands on the stage and starts his speech.

"I believe our nation has potential, and we have taken initiatives such as 'Make in India,' through which we can incubate technology and policies to tackle these issues and make our nation climate-resilient, sustainable and 'Atmanirbhar Bharat' (self-reliant India)", Bodhodaya concludes.

Mr Sushovan Ghosh is a PhD scholar at the Centre for Atmospheric Sciences, IIT Delhi. Address: Centre for Atmospheric Sciences, Block-VI, IIT Delhi, Hauz Khas, New Delhi-110016. Email: Sushovan.Ghosh@cas.iitd.ac.in
Website: sites.google.com/view/sushovanghosh/home?authuser=0

SCIENCE DIPLOMACY

A New Paradigm in the Post-truth world

Felix Bast

IN my science outreach talks, I introduce my mother as a cat; she is like Schrodinger's cat, a famous thought experiment in Physics. The experiment designed by the celebrated eponymous German physicist goes like this: place a cat in a box containing a radioactive substance and close the box; is the cat dead or alive? According to the principles of physics, the cat is in a 'quantum state', half-dead and half-alive. Such is the state of my mother; she, aged 71 years, had undergone nine open-heart surgeries in the past, living on her 3rd cardiac pacemaker, and is a cancer survivor. She is alive today thanks to a 20th century American scientist, Wilson Greatbatch, who invented the cardiac pacemaker. If her pacemaker fails, whom I call a bionic woman is dead. I am also grateful to countless scientists around the globe who have made remarkable strides in biomedical research for her life. In 1800, the mean life expectancy of the world was only 40 years; it is now around 72.6 years, thanks to the remarkable progress our scientists have made over the last two centuries.

It is becoming increasingly clear that the majority of the problems that humanity is facing at present are global and scientific, be it climate change, ecological collapse, nuclear holocaust, overpopulation, poverty, food security and so on. In addition, the world also has the multifaceted problem of Post-truth, the disappearance of shared objective standards for truth. Put plainly, post-truth or alternative facts refer to fake news, conspiracy theories and pseudoscience, which have gained an increased momentum since the turn of the millennium. Such global issues warrant global solutions; we can only strive to fight these rampant issues through international scientific collaborations.

As of today, defence expenditure eats up a significant chunk of national budgets worldwide; no country is an exception. Defence infrastructure, on the other hand, depends upon scientific research and development to a large extent. Some of the defining moments of world history can be traced to advancements in basic sciences, for example, the nuclear bombing of Hiroshima and Nagasaki to research in particle physics. Inversely, through global scientific partnerships and dialogues, one can expect global harmony and a gradual reduction of warheads channelling economic resources to meet the nation's education and health sectors. International scientific partnerships and dialogues are crucial in conflict resolution and our march towards a more peaceful tomorrow.

The use of scientific collaborations and dialogues among nations to address the common problems facing humanity and to build constructive, knowledge-based international partnerships is known as Science Diplomacy. Alternative terms for science diplomacy include 'soft power' and 'smart power.' Over the years, Science Diplomacy has tremendously increased; as of today, the term is not only used to refer to 'actions to advance cross-border interests' but also to 'actions designed to directly advance a country's national needs'. The field of science diplomacy is still fluid and emerging, but its impact is profound and can be felt across all domains of human existence. It is becoming increasingly conspicuous that science plays a decisive role in international conflict resolution and in fostering new coalitions. Three cardinal attributes of science are rationality, universality and transparency; all countries can use these attributes to foster national and international dialogues to find optimal solutions for global challenges.

While diplomacy, the non-violent approach for conflict resolution between countries via dialogue, negotiation, and compromise, had traditionally been under state monopoly, with only the foreign ministry authorised to deal with representatives from other countries, the situation has changed dramatically over the last three decades. Large technological multinational companies can initiate international-level dialogues in seconds. Scientific communities are increasingly becoming ambassadors of their respective nations to foster international cooperation and dialogues. Today, scientists and diplomats play pivotal roles in international diplomacy, albeit their approach is different.

Science diplomacy is crucial in managing and governance of international spaces, including Antarctica, high seas, deep-sea and space, including the moon and other planets. As an expedition scientist of the Indian Antarctic Mission 2016–17, I found Antarctica a continent devoted only to scientific research without national borders. Thanks to that, Antarctica remains the only continent without war or major conflicts. The Antarctic Treaty System, a global framework of Antarctic policies, governs Antarctica. Antarctica has several international collaborative research stations; Concordia Station was established in 2005 by France and Italy, for instance.

There are three basic premises of science diplomacy outlined by the American Association for the Advancement of Science (AAAS) and the Royal Society: Science in diplomacy, diplomacy for science and science for diplomacy. The first premise is that science can improve the nation's foreign policy by making objective and rational recommendations. As stated previously, a majority of the problems that humanity is facing are global and scientific, especially climate change and ecological deterioration; science plays a prominent role in recommending foreign policies of governments worldwide along these lines. The term 'diplomacy for science' refers to furthering international scientific collaborations and coalitions. 'Science for diplomacy' refers to fostering new scientific collaborations to improve global relationships. One example is the Apollo-Soyuz space docking that happened in 1975. Amid the US-USSR Cold War, both countries agreed to dock their respective space capsules to ease the tensions between these two rival countries: Apollo of the US and Soyuz of the USSR.

Science diplomacy is still in its infancy in India. In 2016, the Department of Science and Technology established a Centre for Policy Research on the campus of the Indian Institute of Science, Bengaluru, to work on Science Diplomacy in the Indian context. The centre "attempts to question the concept of science diplomacy from an Indian perspective, trying to understand the existing role of S&T in India's foreign policy and frame a more suitable definition in the Indian context." Yet another initiative by the name of Forum for Indian Science Diplomacy (FISD) was established in 2018 by the New Delhi-based Research and Information System for Developing Countries (RIS), partnered with the Bengaluru-based National Institute of Advanced Studies (NIAS). Key objectives of this project, as listed on the website, are: Capacity building in science diplomacy, Developing networks, and Science diplomacy for strategic thinking. Several short-term

training programmes were conducted by RIS, principally for participants from developing countries.

An example of Science Diplomacy in action from an Indian perspective happened way back in October 2008 when a civil nuclear deal was signed between India and the US, opening up a nuclear corporation between these two countries for the first time in thirty-five years. Science literacy and science diplomacy have played crucial roles in the underlying Indo-US nuclear negotiations leading to the final deal, entirely transforming the geopolitical association to a new dimension. India has a large number of international collaborative research programmes. In total, 37 Indian scientists, of which 12 were from the Pune-based Inter-University Centre for Astronomy and Astrophysics (IUCAA), were authors of the scientific paper revealing the discovery of gravitational waves published in *Physical Review Letters* in 2016 that won the Nobel Prize for physics in 2017. India is also home to at least two well-known international research institutes: the New Delhi-based International Centre for Genetic Engineering and Biotechnology and the Hyderabad-based International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

The role of national science academies in promoting science diplomacy worldwide is unequivocal, and India is no exception. India has three well-established science academies: the Indian Academy of Sciences (IASc) in Bengaluru, the Indian National Science Academy (INSA) in New Delhi and the National Academy of Sciences of India (NASI) in Allahabad. Science diplomacy perfectly complements public engagement of science and science communication; through wider social outreach, science gets into the general public.

Public engagement in science has been one of the principal priorities of all three science academies of India. The Bengaluru-based IASc focuses on supporting Science Education, especially Refresher Courses for faculties and lecture workshops for students. New Delhi-based INSA's priorities have been to support bilateral exchanges with foreign countries, while Allahabad-based NASI focuses on rural outreach activities.

Science diplomacy is relevant for young scientists worldwide, as effective science diplomacy policies can bring scientists across borders, fostering long-lasting international collaborations. In addition, science diplomacy enables young scientists to act as global ambassadors representing their nations, an opportunity that can transform their professional arena. However, young scientists are traditionally left out of policy-making processes altogether. In 2015, INSA established India's first science academy for young scientists, the Indian National Young Academy of Sciences (INYAS), in line with Die Junge Akademie of Germany. Public engagement in science remains the major priority of INYAS as well. It is expected that three science academies in India, as well as INYAS, play a larger role and complement the Principal Scientific Advisor's office, spearheading India's efforts to leverage the power of science diplomacy that will ultimately bridge the world through science.

Mr Felix Bast, Associate Professor, Department of Botany, Central University of Punjab, Mansa Road, Bathinda, Punjab-151001. Email: felix.bast@gmail.com

National Quantum Mission

Image credit: dst.zixwer.online/mission-dashboard

INDIA is recording numerous innovative achievements in the fields of science and technology. Be it the establishment of the National Research Foundation, research, or the field of space explorations such as Mangalyaan, Chandrayaan, Aditya L1, and Gaganyaan. These critical research achievements have demonstrated India's scientific and technological capabilities to the world. Consequently, India has become one of the few selected countries globally, marking it a remarkable achievement.

National Quantum Mission is also one such technological breakthrough being implemented in the country. The Union Cabinet, chaired by the Hon'ble Prime Minister Shri Narendra Modi, approved the National Quantum Mission (NQM) at a total cost of Rs 6003.65 crore from

2023-24 to 2030-31, aiming to seed, nurture and scale up scientific and industrial R&D and create a vibrant & innovative ecosystem in Quantum Technology (QT). This will accelerate QT-led economic growth, promote the ecosystem in the country and make India one of the leading nations in the development of Quantum Technologies & Applications (QTA).

The mission objectives include developing intermediate-scale quantum computers with 50-1000 physical qubits in 8 years on various platforms like superconducting and photonic technology. Satellite-based secure quantum communications between ground stations over a range of 2000 kilometres within India, long-distance secure quantum communications with other countries, inter-city quantum key distribution over 2000 km and multi-node quantum networks with



Image credit: www.needpix.com/photo/1174187/

quantum memories are also some of the deliverables of the mission.

The NQM will focus on developing magnetometers with high sensitivity in atomic systems and Atomic Clocks for precision timing, communications, and navigation. It will also support the design and synthesis of quantum materials such as superconductors, novel semiconductor structures, and topological materials to fabricate quantum devices. Single photon sources/detectors and entangled photon sources will also be developed for quantum communications, sensing, and metrological applications.

Mission implementation includes setting up four Thematic Hubs (T-Hubs) in top academic and National R&D institutes in the domains — Quantum Computing, Quantum

Communication, Quantum Sensing & Metrology and Quantum Materials & Devices. The hubs will focus on generating new knowledge through basic and applied research and promote R&D in the areas that are mandated to them.

NQM can potentially elevate the country's Technology Development ecosystem to global competitiveness. The Mission would greatly benefit various sectors, including communication, health, finance, and energy, with applications in drug design, space, banking, security, etc. The Mission will also boost National priorities like Digital India, Make in India, Skill India and Stand-up India, Start-up India, Self-reliant India and Sustainable Development Goals (SDG).

Source: Science Media Communication Cell (SMCC), CSIR-NIScPR.

LOVE: *Unravelling the Biochemistry behind it*

Soumik Goswami



“EVERYTHING is fair in love and war”, “Love is blind”, “To be loved is the ultimate need of every living being”, etc. are some quotes which make this behaviour very popular and often puzzling to us. Love is not only about romanticism, songs in movies or going on a date with an individual to whom one feels attracted. It is one of organisms’ most complex and less studied behavioural expressions. What most people think of love as being an action or feeling governed by the small fist-shaped organ pounding against the left side of one’s chest is not the actual description of what it is.

Love is more of a behaviour significantly regulated by the brain, specifically by areas of the limbic system, pituitary and prefrontal cortex. The heart is merely an organ that reacts to the consequences of brain activity. Hence, the next time you find someone who has experienced a failed love, you are sure to blame the brain and spare the heart. Love is a biological phenomenon that is experienced deeply by all individuals. The existence and expression of love have created cultural and historical manifestations in monuments, art, poetry and music.

On the contrary, failing to reciprocate a love feeling, commonly denoted as “failed love”, can be

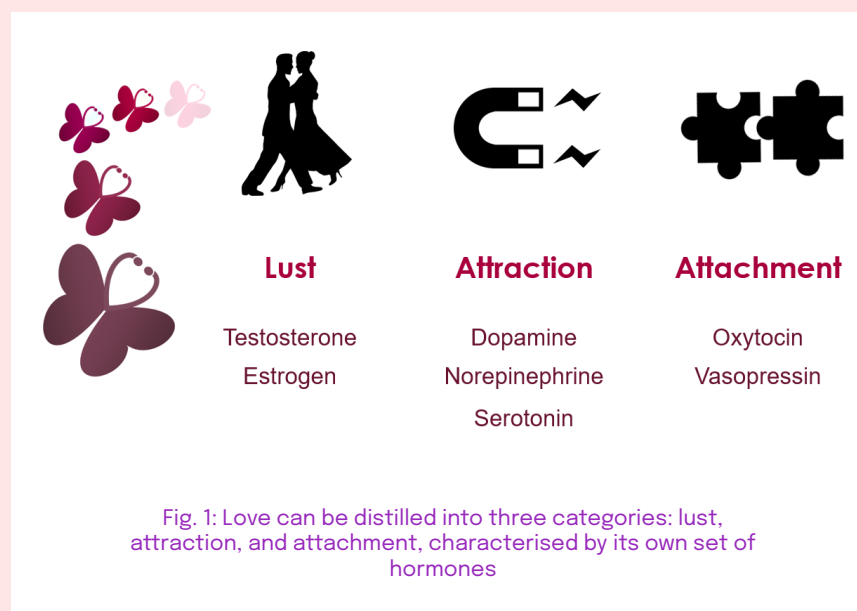
hazardous for an individual. The loss of loved ones forms an indelible imprint to carry with us for the rest of our lives. Most people do not realise that love is not just an emotional attachment or feeling towards someone or something. However, it underlies a complex biochemical and bio-physiological network of events that ultimately orchestrates the series of signalling molecules, culminating in the good feeling of love.

There should be a clear distinction between attraction, attachment and

lust, although each is associated with a pattern of behaviour called love. All the manifestations mentioned are governed by different brain areas and respective hormones, which profoundly affect the patterns of behaviour evoked by each. Attraction is a preliminary feeling that one experiences towards any individual, animal, place, etc., which should not be simulated with the much broader feelings of love and attachment.

The primary hormone that elevates when a person experiences a feeling of attraction is dopamine. Dopamine is released from the area of the brain called the hypothalamus, and its release is associated with the reward areas of the brain termed ventral tegmental area and caudate nucleus. Interestingly, the surge in dopamine negatively correlates with serotonin levels. It has been experimentally revealed that serotonin levels go down during periods of attraction. Dopamine is a magical hormone because it can make us do things which we otherwise may not consider doing. Hence, the initial period of an affair, which primarily involves attraction as the prime behavioural pattern, shows such frenzy and energetic behaviour that does not include the areas of the brain associated with critical thinking, reasoning, arguing, etc.

Norepinephrine or Noradrenaline, a hormone from the adrenal medulla categorised as catecholamines and primarily related to emergency



responses, also increases as a positive feedback response to dopamine release. The catecholamines are associated with exerting critical effects like increased heart rate, insomnia, lack of appetite, etc. Hence, during the early days of courtship, when a couple experiences mere attraction, they experience all these physiological functional changes and reside in utopia. Lust is an expression of sexual desire or libido, which is predominantly governed by the gonadal steroid hormones — testosterone and estrogen. These gonadal steroids are under strict regulation by the hypothalamo-hypophyseal-gonadal axis.

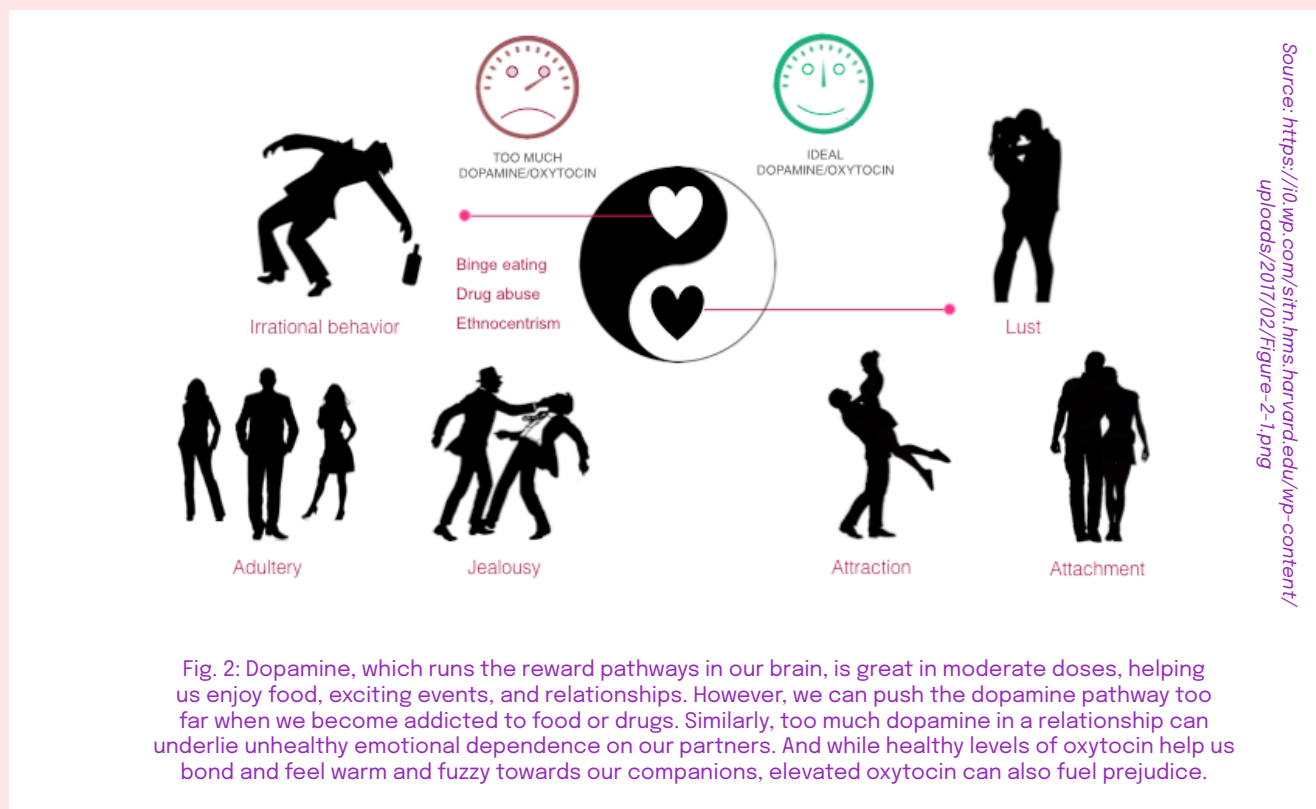
The broader aspect of love involves a long-term association, denoted as — attachment, a behavioural pattern governed by oxytocin and vasopressin. Attachment should not be meant only for couples. Moreover, this is also evidenced in sibling bonding, mother-child bonding, father-child bonding, owner-pet bonding, etc. Oxytocin is a neuropeptide released from the hypothalamus via the posterior pituitary during intense activities like sexual activities, breastfeeding, childbirth and labour. Therefore, it can be understood

that oxytocin is associated with a more pronounced long-term consequence of love, ‘referred to as attachment’. However, these hormones have negative aspects as well. Dopamine stimulates the reward areas of our brain, and this is also common in people addicted to narcotics or alcoholics. Experimental evidence and brain scans have depicted an extensive surge in dopamine levels in people exposed to party drugs. Hence, dopamine and oxytocin, if present in extensively high concentrations, can lead to irrational and irresponsible behaviour.

Love is not just an emotion; it is a far more complex behavioural expression governed by signalling pathways triggered by hormones. Theodosius Dobzhansky said, “Nothing in biology makes sense except in the light of evolution”. The statement is true for love also. During evolution, life on this planet was initiated from simple unicellular organisms, but the common attribute to all life forms was that life was always social. Different dynamic interactions between organisms have always existed and have been exhibited to promote mutual homeostasis, species growth and reproduction. Human

interaction with other organisms has also been observed in behavioural studies conducted amongst pet owners. Different groups of animals have evolved different degrees of sociality, and love is intricately related to social interactions. Love towards a dog or elephant is well reciprocated by both partners, as evidenced in the Oscar-winning documentary *The Elephant Whisperers*. However, the same reciprocation might not be true for a pet turtle or snake. This shows a diversified expression of emotional and behavioural patterns, which results from the evolution of brain areas that regulate them.

The principal centre of the brain, controlling the emotional core of the human brain, evolved far before the cerebral cortex, which serves as the area primarily involved in critical thinking, rationalising, reasoning and thinking. Hence, the cerebral cortex often fails to understand the impulses pertaining to emotions received from various peripheral cues. The cortex interprets the messages as a narrative, which is the main reason for confused stimuli because the reality is that the cortex does not understand the visual, auditory



or other stimuli that the emotional brain conveys. Social behaviour, the basis of love, is chemically documented as an elevated level of oxytocin.

Establishing bonding between a mother and her child is attributed to elevated levels of circulatory oxytocin during lactation. Some studies also show that even mothers who undergo caesarean sections or fail to breastfeed also exhibit high oxytocin levels. The attachment between a father and his offspring is also due to oxytocin. Hence, just the mere presence of an infant evokes the body to produce more oxytocin, further strengthening the relationship between parent and offspring.

Human experiments have shown that intra-nasal administration of oxytocin positively triggers social behaviours like eye contact and cognitive abilities. These are exclusive features of love. It would be rather too ambitious to say that love is the emotional equivalent of oxytocin. Oxytocin is a chemical message the body secretes when an individual emotionally attaches to another. The oxytocin receptors are also regulated by other hormones and epigenetic factors. Therefore, these show plasticity in their presence and functioning. Hence, emotions change over time depending on the experiences an individual is exposed to.

Vasopressin is associated with physical and emotional mobilisation and supports behavioural patterns like vigilance, mate protection, or territorial defence. *Prairie voles*, very social organisms, depict high levels of social behaviour in the colonies — however, the entire pattern of behaviour changes once they successfully mate. The voles become more aggressive towards an intruder, which is related to their elevated vasopressin levels. Oxytocin, on the other hand, is a relatively stabilising factor that minimises anxiousness and tension. Hence, the significant rise in oxytocin levels during parturition and lactation makes a woman more emotionally stable while dealing with the challenges of motherhood.

Love is epigenetic; hence, it is regulated by genes associated with the

production of several hormones. Sudden abrupt and adaptive changes in the hormones are triggered by alterations of gene functions which govern social behaviours, emotional attachment and long-term reciprocal behaviours experienced by married couples. Pre and post-natal exposure to these hormones significantly alters offspring's behavioural patterns. Traumatic and anxious situations, if frequently experienced during pregnancy, can lead to the exposure of the fetus to elevated levels of vasopressin, most of which are either through the placenta or during breastfeeding. It has been observed that children born under such circumstances overreact to situations of fear and anxiety; they also tend to react defensively to situations triggering anxiety and fear. Experiments in rats have shown that early life exposure to stressors causes an upregulation of vasopressin receptors, making the organism increasingly sensitive to stressors.

What comes with a benefit also often has consequences, which is true for love. The feeling of being loved emotionally attaches us to an individual so intricately that we create a utopic world encompassing everything by imagining that individual as the protagonist. These figments of imagination ultimately bind us so strongly that the utter imagination of getting away devastates us. All experience the feeling of being “heartbroken”, and this is where sociality acts like a balm or emotional support that sustains life. Recent advances in technology, social media, new world parenting, job patterns, etc., have hindered the behavioural practice of sociality among human beings. We have, unknowingly and sometimes out of compulsion, created small cubicles which we have learned to imagine as our world.

Unfortunately, this has jeopardised our ability to deal with stress, which is a primary consequence of the feeling of betrayal in love. Our bodies are gifted with a beautifully engineered hormonal network to combat stress. Hormones that help our body cope with chronic and acute stress also make us more adaptable to challenging

situations in life. It has been confirmed by psychological tests that individuals raised in a social environment and those who have not experienced unusual vasopressin and oxytocin exposure during pre- or post-natal life have better adaptability to stressful situations.

Interestingly, a “broken heart” can be healed by the hormone oxytocin. Oxytocin receptors have been experimentally localised in the cardiac tissues, and the precursors of oxytocin synthesis have also been reported to play a crucial role in fetal cardiac development. In the complex signalling that ultimately converts pluripotent stem cells into cardiomyocytes, oxytocin is a significant molecule that thoroughly exerts its effect. Scientific reports also depict that advanced neurogenesis required for recovery from stressors is also stimulated by oxytocin.

Hence, much has been studied regarding the enigmatic feeling called love; however, many lacunae remain unanswered to date. We cannot think of a world without love, as it is required for successful individual interactions, which become the basis of ecosystems. There is still much to be amazed at as future research might unravel some more mysteries, which will probably open up more avenues for a better understanding of the biochemically regulated epigenetically controlled behavioural pattern called “love”.

Therefore, let's prepare ourselves and dive into the abyss of available data, making love, more abstract to be understood rather than felt. Unless we understand this phenomenon, we can never share it with others. The world needs socialism, altruism, emotional bonding and, most importantly, the feeling of getting and spreading “LOVE”. This article presents just the tip of the iceberg for making love more comprehensible for readers. We have a long way to go to understand this phenomenon better. We have a lot to realise from love and a lot to understand about love.

Dr Soumik Goswami, Assistant Professor, Department of Zoology, Sunbeam Women's College Varuna, 904/1, Central Jail Rd, Sikraul, Varanasi, UP-221002.
Email: soumik.goswami911@gmail.com

INTELLIGENCE

Myths and Measures

Govind Bhattacharjee



WITH an *IQ (Intelligence Quotient)* between 250 and 300, William James Sidis was a genius. Born of Jewish-Russian immigrants in New York on 1 April 1898, an 18-month old could already read *The New York Times*. At the age of eight, he was fluent in French, German, Russian, Turkish, Armenian, and Latin, besides his mother tongue language, English. At the age of nine, he created a new language called “Vendergood”, which was certified by linguists to be complete, correct, and fascinating. Little wonder that the child prodigy would have lost his precious childhood; instead, at the age of nine, he was accepted into Harvard University. At the age of twelve, he gave his first lecture about the fourth dimension to the scientific community, an event covered extensively by the press. His parents, a famous Russian psychologist and one of the first female medical doctors of that time, wanted only to raise a genius. They did. Boris Sidis, his father, used hypnosis on the young boy to hone his son’s mental abilities from an early age. Sidis was called “the most intelligent man in the world”. He, indeed, was a linguistic genius.

Only four years later, at the age of 16, he got tired of his fame, felt he had had enough and began what he called his “pilgrimage to the abyss.” He rebelled against everything, was jailed and released for protesting and recruiting people for the communist movement, and imprisoned again for two years. After his release, he changed his name and embarked on a nomadic life, moving from job to job, occasionally publishing using pseudonyms on various subjects. All the while, though, he was being pursued by a heartless and ruthless press who never stopped maligning him: “The child genius who never amounted to anything now cries as he works as a stock boy”, “the most intelligent man in the world has a miserable life”, “the math and linguistic genius has burnt out”, “William J Sidis is tired of thinking”. A person who wanted to “live the perfect life is through seclusion”, was never let

alone. Tired of society, family, academia and life, tired of his fake identity, the most intelligent man died a lonely death from a stroke at the age of only 46. The only thing found in his clothes was the photo of an Irish activist lady, Martha Foley, with whom he had a complex relationship. His extraordinary intelligence could not get him much happiness in life.

Geniuses like Sidis, who score very high on *IQ* or *Intelligence Quotient*, a measure of the intelligence possessed by a human being, are not at all rare. In fact, the list of child prodigies in the world is endless. Einstein was estimated to have an *IQ* of 160; there are many with *IQ* scores higher than that. Terence Tao, a 1975-born Chinese-Australian mathematician with an *IQ* of 225-230 and now a celebrated Mathematics teacher at the University of California at Los Angeles (UCLA), was also a child prodigy. At 13, he was the youngest winner of the gold medal at the International Mathematical Olympiad. He won the Fields Medal — the equivalent of the Nobel Prize in Mathematics in 2006. Unlike Sidis, he, however, is happily settled in life with a family. When he was young, his parents were advised by some great mathematicians to let him go slow. Still, he completed his PhD from Princeton University when he was only 21 and was appointed as a full professor at UCLA at 24, the youngest person in history to hold that post at the University.

Jacob Barnett, with an *IQ* score of 170, was diagnosed with moderate to severe autism at the age of two years. Defying all doctors’ predictions that he would not be able to live life on his own, the American child prodigy finished grades six through twelve in less than a year and went to college at ten. He was already publishing papers on physics at 13 and is currently working on his PhD on quantum gravity. Ainan Cawley, with an *IQ* score of 263, was already taking third-year chemistry courses at Singapore Polytechnic at eight years. By the time he was nine, he’d memorised the first 518 decimal places of Pi.



William J Sidis



Jacob Barnett

Nathan Leopold, with an *IQ* score of 200, at the age of 18, could speak nine languages but ended in jail only a year later on murder charges after trying to commit the “perfect crime”. After spending 33 years in prison before being released on parole, he died in 1971. Again, intelligence has nothing to do with how one conducts oneself.

The standard definition of a prodigy is a child who, by age 10, “displays a mastery of a field usually undertaken only by adults”. They stand out in terms of accomplishments, and their precociousness is too obvious not to be noticed. Prodigies like Sidis or Tao are not only not rare but are found in every corner of the earth, regardless of ethnicity, geography, history, genetics, or income. Wunderkinds can materialise anywhere under any condition. Such geniuses, children endowed with extraordinary intelligence, blossom regardless of their parent’s income, profession or situation. They are found in all countries, and India also has its share of such prodigies.

In January 2020, 50 child prodigies were given the Global Child Prodigy Awards, “a global initiative to provide child prodigies with the stage they deserve”, in a public function presided over by the Indian Noble Laureate Kailash Satyarthi. They included talents from myriad backgrounds such as martial arts, painting, modelling, writing, entrepreneurship, social work, acting, etc., and from different corners of the country, like Ramesh Pragganandhaa from Chennai, who became the youngest Chess International Master in human history at the age of 10 in 2015 and just missed the World Cup title losing to Magnus Carlsen in 2023. Lydian Nadhaswaram was a

young Indian Pianist from Chennai who won the CBS talent show “The World’s Best” in 2019 with a prize of \$1 million. Fourteen-year-old Yatharth Murthy from Bengaluru can sing 260 national anthems from memory and has a Limca Book of World Records. Nihal Raj, also known as Little Chef Kicha, is one of the youngest chefs in the world who has appeared on the top-rated American Television Talk show, “*The Ellen DeGeneres Show*”, to teach Ellen how to cook Kerala’s popular breakfast “Puttu”. A six-year-old Mozart was placed on a pedestal to perform before Austria’s Archduchess Maria Theresa in 1762. Ten-year-old Abigail Sin is Singapore’s most celebrated young pianist, with a coveted Associated Board of the Royal Schools of Music diploma in piano performance. She is also a math prodigy, but her passion is in music. Prodigies, indeed, don’t follow any rules. Many of them also yield to incredible pressures from their parents to demonstrate their superior intellect, who sometimes drive them out of their minds.

Tathagat Avatar Tulsi from Bihar was called one of the seven gifted youngsters in the world by *Time magazine* in 2003. He passed the matriculation examination in 1997 at the age of nine. He obtained a Bachelor’s degree from Patna University at the age of 10, being the youngest matriculate and youngest graduate in the country. He received a Master’s degree at the age of 12 and later finished his PhD on the generalisations of the quantum search algorithm from the Indian Institute of Science, Bengaluru, in 2009. At 22, he became the youngest-ever teacher at IIT-Bombay when he joined it as a temporary



Ramesh Pragganandhaa



Lydian Nadhaswaram



Yatharth Murthy



Nihal Raj

(Images credits: Global Child Prodigy awards, gopawards.com)

assistant teacher in 2010. He has never attempted to crack the tough IIT entrance exam. However, when controversy arose upon his unsubstantiated claim to have discovered a new particle to explain the presence of dark matter in the universe, sceptics started calling him a “fraudigy”. Tathagat suffered from depression for a few years before he could finally complete his PhD. Not everyone is as lucky. Parents often love their children’s geniuses more than their children and drive them to the extremes by becoming over-demanding. Child prodigies not only struggle under the massive burden of expectation, but most cannot enjoy their childhood like an ordinary child does.

The cybernetics-inventor mathematician Norbert Wiener had earned a PhD from Harvard doctorate at 18 years of age. He described his otherwise gentle father as a tyrannical “avenger of the blood” whenever he made a calculation mistake. Sufiah Yusof gained admission to Oxford College to study mathematics at the tender age of 13. But, just after her 3rd-year master’s exams, she disappeared, accusing her Pakistani father and Malaysian mother of making her life a “living hell” from 15 years of physical and emotional abuse, including long study sessions in a house deliberately kept ice-cold, supposedly to improve concentration. She never used mathematics to earn a living.

Prodigies are indeed different from ordinary children in many ways. Research seems to show that genetic factors indeed influence their basic cognitive abilities. Tests conducted on them indicate that their working memory, which is responsible for executing complex mental tasks such as problem-solving and language comprehension, is very highly developed. Working memory is measured by tests that involve recalling information after a short interval of time and manipulating that information. For example, a subject may be asked to read a sequence of random digits, such as 8 3 2 9 5 1 3 7 5 0, and then instructed to recall the digits in reverse order — 0 5 7 3 1 5 9 2 3 8. Ordinarily, people differ greatly in their working memory capacity — some people have much “bigger” working memory than others. Prodigies also exhibit an unusual commitment to their domain area of “giftedness”, usually enjoying the activities related to these areas so much that it is often difficult to tear them away. Research also points to the possibility that a common set of genes may influence both the aptitude in domain areas as well as the propensity to cultivate through practice, which may combine with environmental factors to produce prodigies.

The correlation between high intelligence and prodigious behaviour is not certain; even people with low intelligence can possess unusual mastery of specific skills; they are not called prodigies because of their low intelligence. We know about autistic savants, like the unforgettable character of Raymond Babbitt, played by Dustin Hoffman in the Barry Levinson movie *Rain Man*; it was inspired by a real person named Kim Peek. Kim had a rare condition called “Savant Syndrome,” which gave him amazing gifts, including a phenomenal memory. However, prodigious behaviour seems more a trait connected with childhood only; when the prodigies grow into

adulthood, by and large, they cease to be as prodigious as they were in childhood, and their performance as adults rarely matches their extraordinary childhood achievements. Some burn themselves out, some slow down, some get bored with their pursuits, some seek solace and happiness in an ordinary vocation and family, and some live miserable lives. It seems the other kids catch up with them when they grow. Usually, intelligence alone does not carry them too far in their lives.

It is difficult to define intelligence. Only a general and subjective definition is possible, and most agree that intelligence is “a very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience... it reflects a broader and deeper capability for comprehending our surroundings.” Mental ability is not something that can be narrowed down to a single thing but manifests itself in many ways in different individuals. Intelligence has been reckoned as “the default yardstick of genius”. If you can measure intelligence, you can probably identify a genius. Measurement is fundamental to any science. One way of measuring intelligence is the



Alfred Binet



Théodore Simon

(Images credits: Wikipedia)

standard *IQ* tests, which attempt to measure the intelligence of a subject based on their responses to some standard questions.

In 1905, the French psychologists Alfred Binet and Théodore Simon were working together to identify the mentally retarded among school children requiring special attention. This needed them to measure children's mental development through a test. Noticing that fast learners could answer questions that only older children (e.g., studying in higher grades) would ordinarily be able to answer, while slow learners answered questions that were more typical of younger children, they used this knowledge to devise a test. This is how the famous Binet-Simon Intelligence Test was devised. The Binet-Simon test was easy to administer, and the score on the Binet-Simon scale could be used to calculate a child's mental age, which reflects a child's mental development in relation to the environment in which the child lived. The test aimed to determine the mental age of a child — the average age at which a child is expected to answer a certain set of questions reflecting the learning outcome appropriate to that age, like naming objects, defining words, drawing pictures, completing and constructing sentences, comparing items, etc. It was one of the first tests of *IQ*, *Intelligence Quotient*, a term coined by the German psychologist William Stern.

As the Binet-Simon Test became popular, its fame spread beyond the borders of France and ultimately reached America, where it attracted the attention of a Stanford psychologist, Lewis Terman. Terman revised the Binet-Simon Test to devise the Stanford-Binet Intelligence Test in 1916, which became and remained the most widely used test for intelligence in the USA for decades. The test compared a child's or anyone's mental age to her biological or chronological age — the number of years since her birth — to derive her *Intelligence Quotient (IQ)* by using the simple formula: $IQ = (\text{Mental Age} / \text{Chronological Age}) \times 100$. If the mental age equals the chronological age, the *IQ* would be 100; if it exceeds the chronological age, the *IQ* score would be higher. A five-year-old child who achieved the same level as his peers would score 100. Thus 100 reflects the average

score of any human and is reckoned as such even today. If she performed at the same level as an average eight-year-old, her mental age would be eight, reflecting an *IQ* score of 160, an Einstein-like genius (Fig. 1).

Tests show a remarkable diversity in intelligence measured by *IQ* scores, with about two-thirds of the population scoring between *IQ* 85 and *IQ* 115. About 2.5 per cent of the population scored above 130, and 2.5 per cent below 70. Fitted into a graph, they represented the classic Bell Curve, what statisticians call the Normal distribution. A score of less than 70 indicates impaired intellectual functioning. A score above 140 indicates a potential genius. Binet understood the limitations of his scale; he correctly thought that intelligence depends on many factors and stressed the need to use qualitative methods to arrive at the correct score. A bewildering variety of intelligence tests — as bewildering as the variety of theories of intelligence — developed subsequently. They test a subject's general intelligence, verbal reasoning, abstract or visual reasoning, quantitative reasoning, and short-term memory. Typically, it takes about 45 minutes to administer a test. The test has undergone five subsequent revisions in 1911, 1937, 1961, 1972, and 1986.

In 1904, the British psychologist Charles Spearman observed a positive correlation between children's school grades across seemingly unrelated subjects; if one scored high grades in one subject, one was more likely to score high grades in other subjects as well. He reasoned that underlying disparate cognitive tasks is a single factor he called the general intelligence factor, *g*. Generally, *g* and *IQ* are roughly 90 per cent correlated, which means that the *IQ* scores could be used as a proxy for *g* and vice versa. In fact, the two terms are often used interchangeably, though the correct relationship is shown in the Fig. 2.

If intelligence is a measure of mental abilities, then it is only a subset of the total mental abilities, and it is more than what the *IQ* measures. *IQ* tests capture only a small part of the many intelligences a human possesses, as we shall see later, and the *g* factor is common to all mental abilities, which

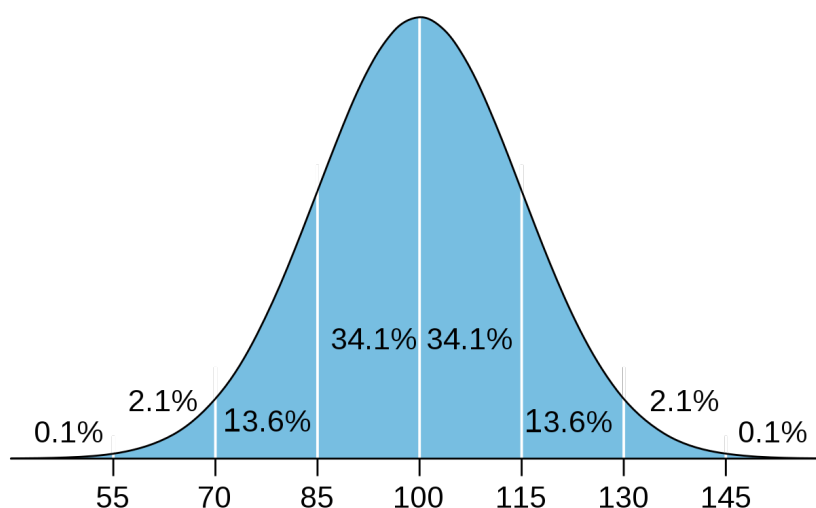


Fig. 1.

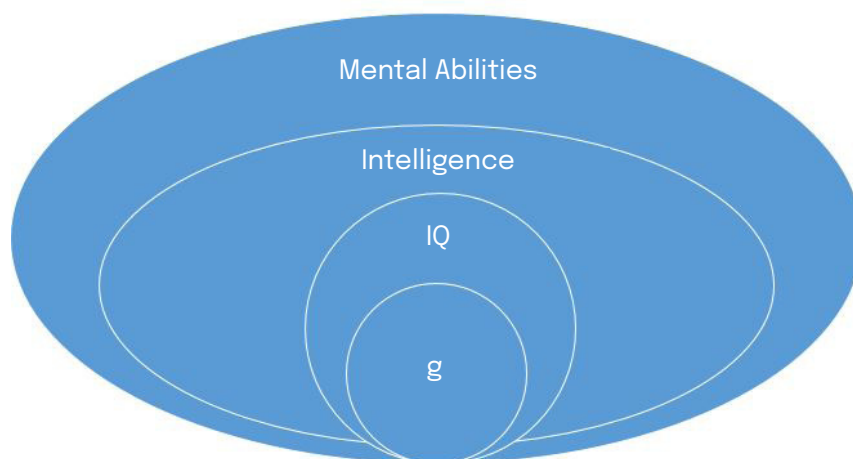


Fig. 2.

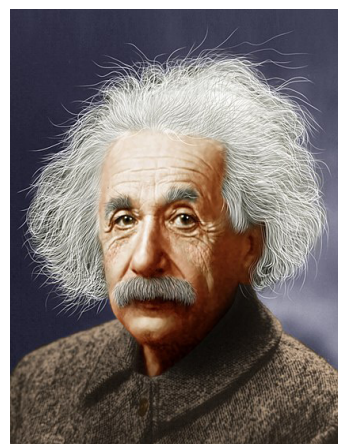
can be social, cultural and biological, that is, genetic. Another psychologist, Jim Flynn, noticed that the average *IQ* score tests tend to rise over the decades, warranting recalibration of the *IQ* tests every few years. Despite the popularity of the tests, there is danger in taking the test scores as the ultimate declaration of one's intelligence. There are always factors that are not measurable by these tests and are equally important in determining a person's overall cognitive and adaptive abilities.

Since a genius is reckoned to have extraordinary intelligence, it was believed that the *IQ* tests that captured intelligence could also identify a genius. Thus, starting with the 1920s, Terman began to track some 1,500 school kids between the ages of 8 and 12 in California with *IQ* scores above 140 — the threshold he labelled as a “near genius or genius” — to see how they fared in life later; 80 of these kids had *IQ* scores over 170. The poor kids, nicknamed “Termites” for their lifetimes, had their successes and failures captured in a series of reports called “Genetic Studies of Genius” over the next 40 years. While most were successful in their careers and well-adjusted in society, there were also remarkable exceptions.

Even after Terman's death in 1955, other researchers carried out the study, and it continues even now. The study found that the average income of these “gifted” individuals was an impressive \$33,000 compared to a national average of \$5,000 in 1955. Two-thirds had earned college degrees, and many had carried on further higher studies. Many became scientists, politicians, doctors, professors, musicians, doctors, lawyers, business executives, and scientists. But many others had struggled to thrive; many flunked or dropped out of college, while those who were not followed since their low *IQ* scores had shined. Two of such kids were Luis Walter Alvarez and William Bradford Shockley, both later won a Physics Nobel each for inventions that would change the course of science — Alvarez invented the hydrogen bubble chamber used to detect subatomic particles and later joined the Manhattan project, while Shockley, along with John Bardeen and Walter Brattain, discovered the transistor.

Indeed, many great scientists and thinkers were considered academically very ordinary and with below-average intellect at their early age — Darwin, Einstein, and Tagore are some glaring examples. In fact, the biggest pitfall of *IQ* tests is that they cannot measure creativity that makes a genius, not simply intelligence. No rulebook makes a creative person; the process of creativity cannot be explained by anyone other than creative people and is very difficult to emulate or replicate.

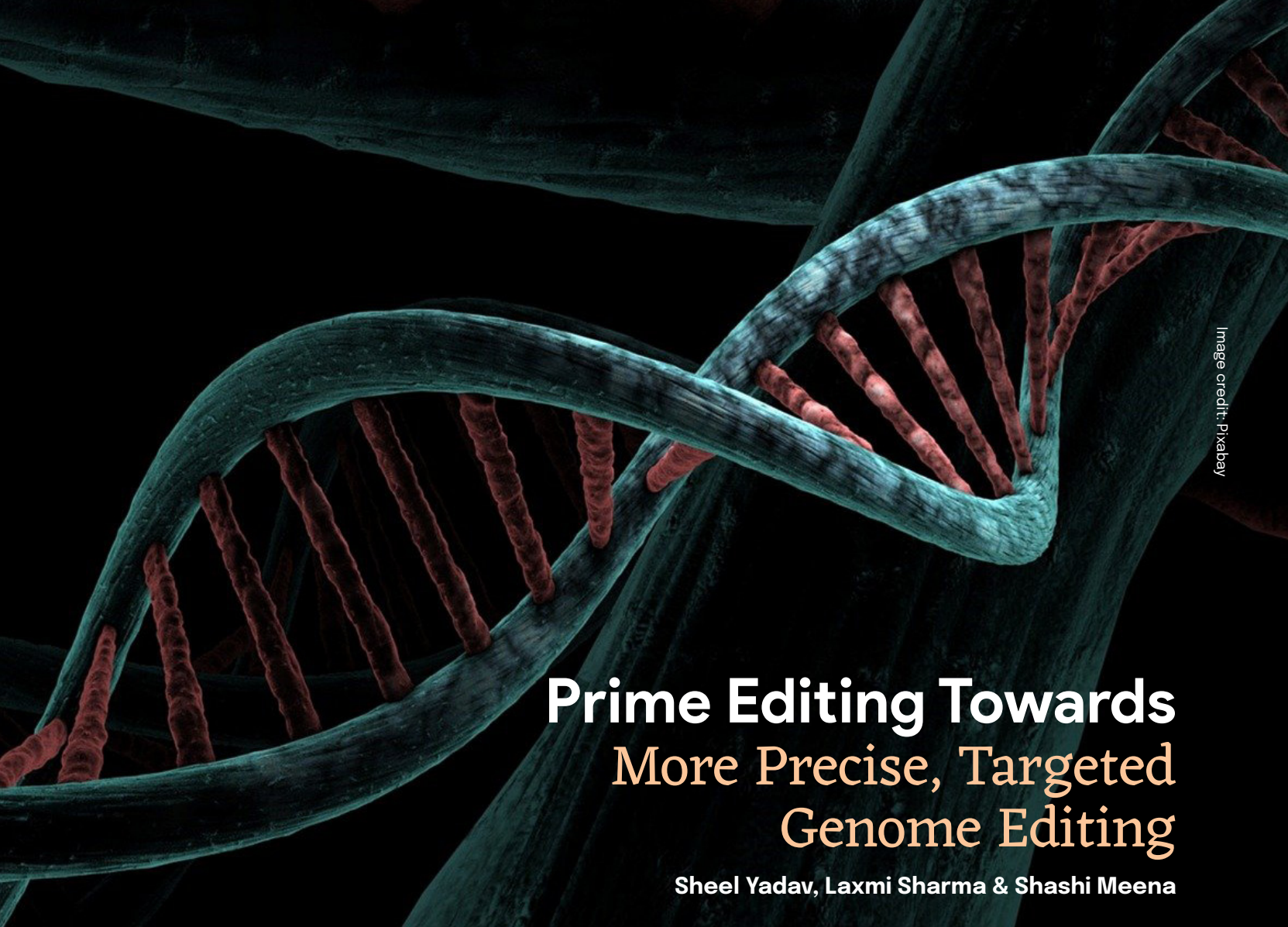
Maybe they even do not know the process. Many great ideas that changed the world came by following what Einstein called an intuitive leap, not by any defined process. “The intellect has little to do on the road to discovery. There comes a leap in consciousness, call it intuition or what you will, the solution comes to you, and you don't know how or why”, Einstein had said. Credited with the discovery of many “elemental” laws of nature, he has admitted, “There is no logical way to the discovery of these elemental laws. There is only the way of intuition, which is helped by a feeling for the order lying behind the appearance.”



(Image credit: Wikipedia Commons)

Albert Einstein

Dr Govind Bhattacharjee is a retired bureaucrat currently engaged in academics and a popular science writer. Email: govind100@hotmail.com



Prime Editing Towards More Precise, Targeted Genome Editing

Sheel Yadav, Laxmi Sharma & Shashi Meena

OVER the past decade, there has been a lot of scientific experimentation to develop crop varieties that are more adapted to the rapidly changing climatic conditions. With the advent of NGS (Next-Generation Sequencing) technology, the breeding process to develop improved, climate-resilient crop varieties has become more precise and much faster than ever anticipated. The availability of whole genome sequences of most crop species has allowed crop breeders and molecular biologists to target precise regions in the genome and attempt gene modification to bring about desirable changes in the genome and, consequently, the phenotype. Genome editing, a non-transgenic method of genetic modification, has been made much easier and feasible with the recently developed CRISPR-Cas9 system owing to its simplicity. The

potential of this technology in genetic improvement was realised as soon as the first reports of successful genome editing started appearing. Due to its profound applicability, this technology was hailed as a breakthrough in 2015.

An advancement of this technique called 'Prime Editing', published in the journal *Nature* in October 2019, allows 'search-and-replace' genome editing. What sets prime editing apart from traditional CRISPR is that it enables targeted editing without generating double-stranded DNA breaks. Moreover, targeted insertions can be achieved without the need for donor DNA templates. It was observed that this technique has a similar efficacy to CRISPR-Cas9 but causes much fewer off-target effects. In simpler terms, this technology enables editing just one or a few bases. It also expands the limited scope of current base editing abilities

(4 possible combinations $C > T$, $G > A$, $T > C$, and $A > G$) to all 12 combination swaps. Though in its infancy, this technology holds immense promise and has garnered much attention (already cited >250 times) due to its potential uses, especially in medical genetics. Since the first report that appeared in 2019, this technology has captured the interest of molecular biologists across the world who are trying to overcome the hurdles (particularly the off-target effects) they face using the CRISPR-Cas9 system. It is widely believed that this technology will, in no time, overtake CRISPR for genome editing.

Components of Prime Editing

The two basic components of prime editing include:

- A guide RNA (pegRNA) consisting of an extended single guide RNA (sgRNA) containing a Primer

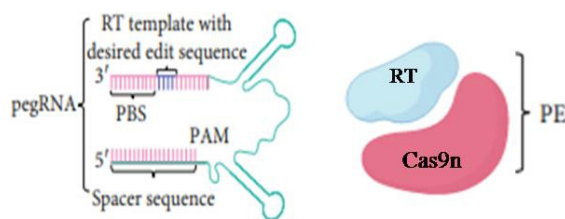


Fig.1: The components of prime editing “editosome” (Source: Hassan et al., 2020). RT: Reverse Transcriptase; PBS: Primer Binding Site; pegRNA: prime editing guide RNA; sgRNA: single-guide RNA; PE: Prime Editor; Cas9n: Cas9 nickase; PAM: Protospacer Adjacent Motif.

Binding Site (PBS) and a Reverse Transcriptase (RT) template sequence (Fig. 1).

- A fusion protein consisting of a Cas9 H840A nickase fused to a Moloney Murine Leukemia Virus (M-MLV) reverse transcriptase.

Prime editing in plants

In one of the first reports on the application of prime editing in plants, a prime-edited herbicide-tolerant rice plant was developed by editing the rice *OsACCI* gene. A suitably designed pegRNA construct along with Cas9 nickase and RT, were used to transform embryonic calli obtained from the variety Nipponbare. It was shown that base transitions, transversions and 1- to 3-bp insertions could be introduced in the rice genome by the synthetic pPE2 system, indicating the versatile applications of prime editing in plants. However, the pegRNA design for each target has to be optimised for factors like nick positions and lengths of PBS and RT templates to achieve higher efficiency.

In another report published in *Nature Biotechnology*, at almost the same time by the same group of researchers who first published the seminal paper on prime editing, a suitably optimised PE system was devised to edit six selected rice and wheat genes. A range of gene edits in the form of point mutations, insertions and deletions were created in the gene sequences on the transformation of the constructs in rice and wheat protoplasts. The frequency of regenerated prime-edited rice plants could be increased up to 21.8%.

Future Perspective for Development of Climate-resilient Crops

Due to the high precision of this technology, prime editing can provide new, hitherto unexplored opportunities for precision crop breeding for enhanced tolerance to both abiotic and biotic stresses. The different kinds of genetic modifications that can potentially be created through prime editing are given in Table 1.

Table 1: The range of potential genetic modifications using prime editing (Source: Hassan et al., 2020, BioDesign Research)

Gene knockout	Gene correction	Protein engineering	Contribution to molecular evolution
Introduction of premature stop codon	Correction of undesired mutation	Introduction or replacement of desired amino acid	Introduction of multiple point mutations
Introduction of single-point mutation	Small segment substitution		
Deletion of small segment			

Biotic Stress: Plant disease resistance genes are mostly allelic. These alleles vary only in a Single or a Few Nucleotides (SNPs). Loss-of-function mutants generated due to missense mutations because of SNPs lead to susceptibility alleles. If the function of these alleles can be recovered by reversion of the SNP, such alleles might be able to confer disease resistance in crop plants. In another mode of action, prime editing can also be used to introduce premature stop codons or nonsense mutations in the coding sequences of the S (Susceptibility) genes, which could provide a powerful approach for inactivating them.

Abiotic Stress: As prime editing can precisely generate all types of base conversions and small indels, this technology is ideal for editing the Cis-regulatory Elements (CREs). CREs are noncoding DNA regions known as promoters and enhancers, which regulate the transcription of genes. These contain binding sites for different Transcription Factors (TFs) or other regulatory proteins. Mutations in the CREs can thus alter gene expression levels, reshaping the transcriptome, which can lead to speeding up the evolutionary process of crop domestication. For example, the putative TFs *OsERF922* (rice) and *GhWRKY17* (cotton) bind to the CRE sequences GCC box (AGCCGCC) and W-box (TTGACC), respectively, resulting in the susceptibility to abiotic stress such as drought and salinity. It has been anticipated that if the binding sites of these TFs at the GCC-box and W-box could be altered, generating novel drought and salinity-tolerant crops might be possible.

Based on this progress, we envision that prime editing would go on to strengthen both basic plant research and

Dr Sheel Yadav (Sheel.Yadav@icar.gov.in) and Dr Laxmi Sharma are with the Division of Genomic Resources, ICAR-National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi-110012. Ms Shashi Meena is with the Division of Plant Physiology, ICAR-Indian Agricultural Research Institute, Pusa Campus, New Delhi-110012.

10th Anniversary of Heidelberg Laureate Forum

HS Fatesingh & RC Parida

THE Heidelberg Laureate Forum Foundation (HLFF) has been organising the Heidelberg Laureate Forum (HLF) annually since 2013, an international networking event for mathematicians and computer scientists. German physicist Klaus Tschira Stiftung (1940-2015) laid the forum's groundwork. The scientific partners of the HLF are the Heidelberg Institute for Theoretical Studies (HITS) and Heidelberg University. The HLF is strongly supported by award-granting institutions such as the Association for Computing Machinery (ACM), the International Mathematical Union (IMU) and the Norwegian Academy of Science and Letters (DNVA). The HLF provides the platform and time for leading researchers in their fields to interact, share ideas, network and form lasting connections that promise to develop into fruitful collaborations.

The 10th HLF took place in the University of Heidelberg, Germany, from 24-29 September 2023 and brought together 32 laureates of the most prestigious prizes in mathematics and computer science, such as recipients of the Abel Prize, Field Medal, Navenlinna Prize, ACM Prize, as well as 200 bright young researchers of the next generation from over 60 nations around the world. Besides, 20 alumni from past HLFs were invited to share their experience and expertise. The weeklong event featured a host of fascinating Laureate Lectures, Lindau Lecture, Laureate Discussions, Panel Discussions, Scientific Interactions and other formats. The event discussed some of the timeliest issues relating to mathematics and computer science. In honour of its tenth anniversary, the HLF featured several notable additions of new formats, such as Lightning Talks and Spark Sessions, which provided participants with more dynamic ways to engage with contemporary scientific issues. Eleven young researchers from different institutes and universities in India participated in this event.

In his welcome address during the opening ceremony, Jens Brandenburg, Parliamentary State Secretary to the German Federal Minister of Education, lauded the efforts of the HLFF to organise such an event to bring together prestigious laureates of mathematics and computer science and young researchers of the disciplines. Rafel Lang, Chairperson, HLFF, encouraged all young researchers to seize the unique opportunity of the week. He said, "You have been selected for



Laureates of the 10th HLF

your talent, for your knowledge, for your potential This meeting is for you!". Petra Olschowski, Minister of Science, Research and Arts, Baden Wuttemberg; Bernhard Eitel, Director of Heidelberg University; Eckart Wurzner, Mayor of Heidelberg; Patrick Cramer, President of the Max Plank Society; and Anna Wienhard, Scientific Chairperson, HLFF, graced the occasion and expressed their valuable views.

Representatives of the award-granting institutions, such as Yannis Ioannidis, President, ACM; Hiraku Nakajima, President, IMU; and Lise Ovreas, President, DNVA, were also present to encourage the young researchers. On this occasion, the signatories of the HLF charter, Vinton Gray Cerf, former president of ACM; Ingrid Daubechies, former president of IMU; Nils Christian Stenseth, former president of DNVA, introduced the alumni of the last HLFs. During this auspicious ceremony, a saxophone quartet presented music.

The first day of HLF featured two major talks: In the morning, Robert Metcalfe, inventor of the Ethernet technology, gave an insightful talk on "Connectivity is a Thing, is THE Thing". Afterwards, Louis J Ignarro, a Nobel Prize recipient in Psychology or Medicine 1998, delivered the Lindau Lecture on "Nitric Oxide: The Miracle Molecule of Health and Longevity". The Lindau Lecture is held yearly at



Workshop by the laureate Leslie Lamport

the HLF to mark the strong connection between the HLF and the Lindau Nobel Laureate Meetings.

An alumna of the Forum, Jie Li, presented a fabulous birthday cake to commemorate the event. Finally, all attendees received ample opportunity to meet and interact with each other, first through a rapid speed-networking session and later in the poster flash. During the poster session, 30 pre-selected young researchers had the opportunity to present their research in a condensed poster format, presenting their work in rapid-fire two-minute presentations.

On the second day, participants had a deep pool of engaging lectures, inspiring rapid-fire talks, and insightful panel discussions by and with some of the foremost luminaries of mathematics and computer science. At first, Dennis Parnell Sullivan, a recipient of the Abel Prize 2022, delivered an insightful lecture on “Three-Dimensional Space and Fluid Motion”. Spark session included several short plenary Spark Talks of 15-20 minutes by laureates. The young researchers also had the opportunity to dive deeper into more unique topics by attending various workshops and master classes offered by the laureates.

In the afternoon, two panels closed the day, focusing on “Synergies in Research”. At the same time, the other invited the audience to share in a “Conversation with Ingrid Daubechies, Karen Uhlenbeck and Maryna Viasovska”. During Lightning talks, laureates gave short, rapid-fire, one-slide talks recalling the last ten years in computer science and mathematics or even risked a glimpse into the future. The evening programme featured a perennial favourite, the “Bavarian Evening”, in which attendees celebrated their cultural heritage and diversity by donning the traditional clothing of their home countries.

The third day of the HLF was traditionally reserved for laureates to visit local schools to speak directly in the classrooms. At the same time, the young researchers attending the HLF spent their mornings visiting various prestigious institutions in the region; among them were the German Cancer Research Center (DKFZ), the European Molecular Biology Laboratory (EMBL) as well as the Heidelberg Institute for Theoretical Studies (HITS). The day capped off



Exhibition “MAINS on Tour”

with attendees taking a leisurely boat cruise along the Neckar River, followed by a boat party against the backdrop of the historical old town of Heidelberg.

The morning of the fourth day featured a rich array of spark talks by laureates. Later, there was a Laureate Discussion where a panel seeking to answer the question, “Why Do So Many People Hate Mathematics?”. In the afternoon, attendees dove into more detail on their favourite subjects with another round of workshops and master classes. Finally, attendees gathered at the Speyer Museum of Technology in the evening and dined amid impressive plane, automobile and space shuttle exhibits.

On the final day, the attendees travelled to the SAP campus in nearby St Leon-Rot for a day packed with an exciting lecture and panels. Fields Medalist (2022) Hugo Duminil-Copin started the day with an engaging lecture on “Critical Phenomena through the Lens of the Ising Model”. Following this, two panel discussions focused on one of the most pressing topics in computer science: AI. The first examined generative AI, such as Large Language Models (LLMs), in greater detail, while the second dove into ethical ramifications surrounding the technology.

The afternoon brought together young researchers with computer scientists and mathematicians from business and academia to gain valuable insights into career paths available for the future and guidance on how to achieve their goals. To close out the final day of the 10th Heidelberg Laureate Forum, the attendees arrived at Heidelberg Castle for a guided tour and the traditional Farewell Dinner.

Each year, the HLFF showcases an exhibition centred on mathematics or computer science as part of the HLF programme, and this year also featured a curated selection of previous exhibits entitled “MAINS on Tour” and two additional visiting exhibitions.



Laureate Discussion on “Why Do People Hate Mathematics”

Mr Himansu Sekhar Fatesingh, Freelance Science Writer and Teacher, DAV Public School, Unit-VIII, Nayapally, Bhubaneswar-751012. Email: himansu1972@gmail.com
Mr Fatesingh received the fellowship to cover the 10th HLF as a science writer.

Dr Ramesh Chandra Parida, Retired Professor, Odisha University of Agriculture & Technology, Usha Nivas, 124/2445, Khandagiri Vihar, Bhubaneswar-751030.
Email: paridanana47@gmail.com

Science Reporter's **SCIENCE FICTION COMPETITION 2023!**

Here are the Results!

Second

*Bounty by
Aryan Menon*

First

*Jordan by
Amaan Tariq*

Third

*In the Quest of Truth
by Nandini Killa
A Piece of Moon by
Monalisa Paul*

Congratulations to all Winners!
Winning entries will be published In Science Reporter

The other entries that have been found worth publishing are:

1. *Cosmic Convergence: The Tale of Dr Carter and Dr Reed* by Akanksha Upadhyay
2. *The Phantom of the mind* by Sanah Kumar
3. *Fates Intertwined* by G Srivani
4. *The Glitch!* by Pooja Virmani
5. *BLEACHED* by Chabungbam Priya Devi
6. *Whispers of the Abyss: Reclaiming Earth's Destiny* by Ankit Pratap Singh
7. *The Quantum Breakthrough* by Shakunthala Natarajan
8. *AI Guru at Digital Ashram* by Little Raghav and Prashant Raghav



Bounty

Aryan Menon



MY mud-caked boots sat in the corner of the room, decorated with brown cracks that spread around the sole like a fungus. The sight of my possessions lying undisturbed often induced this state of thoughtlessness. It was comforting, juxtaposed to the constant drone of industrial and mechanical noises that continued outside the tinted window of my apartment. The days were long and draining. Being on alert throughout took a toll on your mind, although it prevented any potentially fatal slip-ups. Moments of tranquillity like this were rare and treated like a luxury. There were people everywhere, inhabiting every corner of the vacant earth, reducing the concept of privacy to a myth. It disgusted me.

I heard the ping from my target disc and saw the holograph of my next target. I let out a sigh of defeat muddled with frustration, and headed for the door. I collected my keys, my HUD watch and my gun. The cold metal of the barrel comforted me to a degree that helped me stay sane during the toughest parts of my job. I holstered it and stuffed the armour disks in my clothes. This small practice had evolved into a routine after countless bounties and granted me the peace of mind required to focus on myself to ensure no anomalies during the job.

My target's name was [Redacted], whose most well-known alias was the Stinger. Head narco in The Galley, whose infestation was plaguing the entire city. His supply routes ran deep in the city's veins and covered every square foot. Of course, with such a big name from the criminal underbelly, many had taken up the bounty to either make a massive dent in the rampant crime in the city or make a small fortune. I didn't bother to differentiate between which would benefit what more, and I found it hard to care at this point. It was a job like every other, and it didn't matter whether it was Stinger or any other pathetic felon who considered himself to be a big-shot criminal.

After the War, the ruins of the city, Evergreens, were restored, but this time, the scorched soil was too infertile to replace the green cover that gave it its name, so it was substituted with the dark, glossy surface of reinforced metal. Now, the name was a cruel reminder that before everybody here breathed in filtered air or looked up to watch the animated dome of the city, there was a prosperous, green community destroyed purely by the greed and mercilessness of humankind. With the gentrification of the Upper-East side of the city, the South was left derelict, a breeding ground for larceny, gun violence and narcotics. It grew to be called

The Galley, a place where the scum accumulated to an interminable level.

The first pinged site was an old production warehouse, which Stinger used as a front to transport contraband. I pulled out my proximity scanner and watched as it hovered around the dilapidated hall, flashing red at any signs of potential evidence. I scoured every square inch of the hall but was still left empty-handed until I reached the main office area. In the corner of the room was a corpse that had a bullet hole in his forehead.

I scanned him from head to toe and found concrete evidence pointing to the man being one of Stinger's employees. The badge of a matte black scorpion on the arm of his jacket was pretty much a giveaway. Why kill him, though? Business gone sour or some more concerning matter? Maybe he was the inside man who pinged the location in the first place. Anyway, I had to leave some work for the detectives; my job was to find and exterminate Stinger, not ponder upon the tense relations within his own gang.

One other thing... His clothes and primarily his jacket were coated with a thick smell of some chemical. Yes, it was sarium gas. Sarium gas was a hazardous byproduct of the element Sarimidium that has been used for energy production ever since we discovered it after intensive drilling on the lunar surface. There was only one plant in the city, located in a fairly isolated section of The Galley. The perfect spot for a potential hideout. No one would go close to ingest the toxic fumes expelled from the plant, not from that close.

Walking down the streets next to the Sarimidium plant was not how I expected it to be. Silence festered, allowing only my wet footsteps, the whirring of the distant Sarimidium reactors and the crackle of my oxy-mask to interrupt it. I kept my hand firmly on my gun holster, but even that could not comfort me to the level I needed. I felt my stomach churn, and my mind flood flooded with doubt. Abandoned buildings from the Old Evergreens projects surrounded me, each one more elevated than the other, almost as if they were stairs ascending to the very surface of the dome.

A sense of unease overcame me as I approached the doorway of one abandoned apartment complex. The door creaked open slowly, finally revealing the shabby living area of the apartment. The paint was peeling off the walls, and a heavy, musty scent permeated throughout. I raised my pistol and covered the entirety of the room through the sights. As I held it up, I noticed the barrel shake very subtly. The floorboards creaked with every step, and beads of sweat stung the edges of my eyes, partially blinding me, which were wiped off promptly to ensure maximum alertness. I turned the corner, and the flashlight from my pistol lit the otherwise pitch-black room.

I repeated this process through every building that would have been close enough to allow that strong scent of Sarium to remain on that jacket. Each building was as tense as the one before, if not even more so. It was a dead end for sure. Another attempted capture of the infamous Stinger failed

because he was too smart not to catch on. I had three houses left on one block when I entered the two-storey building. I held the door half open as I peered in, pointing my pistol at any unfortunate individual who might have crossed my line of sight. As I entered the room, deciding that the room was safe enough to enter, I heard the door thud behind me and the sharp crack of the hard stock of a rifle on the back of my head.

I awoke disoriented and light-headed as I felt the cold trickle of what I assumed was blood down the side of my face. My hands were bound, and I was being dragged somewhere. It looked like a butcher shop. I was dragged all the way into a cold room, which I assumed was the walk-in freezer. That's when I saw him. Black hyper-cotton t-shirt, a carbon mesh jacket and an unmistakable scorpion tattoo on his hand. Stinger.

"I heard you were looking for me," he said. A combination of rage and fear made my face look rather dour. "Many men have tried and failed, and yet you still tried. Admirable, maybe, but foolish. This greed that drives you people disgusts me. You take and take and take, and it's never enough for you, and it will indefinitely be the end of you," he continued. "I apologise to you as I know you're a victim of this system, but I cannot allow this to be tolerated; I hope you will understand. You were brave, my friend," he said, as he raised my own pistol against my head. There was no countdown, no flashing of my life before my eyes, no sudden jolt of adrenaline to counter it. It just happened. One pull of the trigger.

I couldn't be the hero of this story, and I am not even sure if I should've been. This city is a glaring reminder to humanity that our faults have consumed us. Turns us into beasts fascinated with power and control. The interstellar colonialism, the subsurface excavation projects on the other planet colonies, and the overexploitation of our own planet are just testaments to man's evil greed. What the city considers criminals are just people who don't want to go with society's conformities.

The bounty hunters that the law enforcement assigns are just people too desperate to try to comprehend the difference between right and wrong. The people that we've put in power cover the eyes of the gullible with promises of peaceful interstellar unilateralism and lounge about in their Sarimidium-powered cars and carbon mesh mansions while the people they chose to uplift stoop and are forced to resort to extreme measures to survive. Perhaps that wasn't the world I wanted to live in. Maybe that wasn't the job I wanted. The fact of the matter is that I had been doing it for so long that I forgot about everything else. It was the curse, the cruel world I knew bestowed upon me, and it was the curse that died with me.

Mr Aryan Menon, Grade 11 student, Sharada Mandir School, Goa. Address: H4 Devashri Enclave Annexe, Alto Bella Vista, Sangolda, Goa-403511.
Email: aryan07.menon@gmail.com

Lake Natron

Tanzania's Hypersaline Red Lake

Sidra Kazmi

Its most striking feature is high alkalinity, letting cyanobacteria thrive, which produces a vibrant, deep-red hue to the lake.



Image credit: Wikimedia Commons

THE salinity of lakes, seas, and oceans is one of the common characteristics that we usually come across. But Lake Natron is so deadly and beautiful that one cannot imagine dipping into it. Lake Natron in the north Ngorongoro District of the Arusha Region in Tanzania is a unique and phenomenal natural wonder. The lake is relatively shallow, with an approximate depth of less than 3 metres, which may vary depending on the water level. The striking features of Lake Natron are its hypersaline conditions due to its high alkaline concentration, distinctive deep red or orange colour, and unique ecosystem.

The hypersalinity of the lake attracts salt-loving organisms, including some cyanobacteria, halophilic, salt-loving, blue-green algae with red pigments, that depend on photosynthesis to flourish. The red pigment in these bacteria gives the lake an eye-catching deep red colour. Over thousands of years, Lake Natron has sustained very high evaporation, as it has no significant outflow and rarely receives rainfall. As a result, trona (sodium sesquicarbonate dihydrate) and natron (hydrated sodium carbonate) in the residual water become highly concentrated, producing a toxic brine. The lake's water temperature ranges from 40 to 60°C, and its average alkalinity measures 10.5, with a pH above 12. Consequently, animals are not adapted to their caustic nature and can experience skin and eye burns when exposed to Lake Natron's alkaline water.

However, the uniqueness and beauty of this lake are beyond its physical appearance. It serves as the exclusive breeding ground in East Africa for the lesser flamingo. Due to the high salinity of the lake, these elegant birds are attracted to its blue-green algae for food. Moreover, the harsh and alkaline nature of the lake is a natural shield, keeping predators at bay and protecting their nests. These species of flamingos are considered “near threatened” due to their dependence on this specific location for breeding. Thus, the lake's high salinity levels play a crucial role in the proliferation of cyanobacteria, which supports an increased number of nesting sites for the flamingos.

Besides, Lake Natron is also home to a diverse array of wildlife, attracting other bird species, such as pelicans and cormorants, which find suitable habitats. Additionally, certain species of alkaline tilapia, a member of the cichlid family, have adapted to survive in the cooler regions of the lake. Its magnificent view serves as a paradise to photographers, presenting them with mineral deposits along the shoreline that contrast sharply with the red water, creating a striking visual capture.

Contributed by Ms Sidra Kazmi.
Email: kazmisidra18@gmail.com



WHAT'S NEW

Sensor for Rapid Water Quality Monitoring



Representational concept of a bioelectrochemical sensor designed for water quality monitoring, featuring electroactive microorganisms

RESEARCHERS from IIT Delhi's Department of Biochemical Engineering and Biotechnology have developed a sensor for real-time water quality monitoring using electricity-generating microorganisms. Known as "electroactive microorganisms", these microbes generate an electrical current and are widely researched for power generation but can also be used for biosensing.

The sensor uses "weak electricigen", a category of electroactive microbes, known for generating low levels of electricity. When the weak electricigens encounter a pollutant, their current output decreases. By measuring their extracellular current continuously, the approach facilitates real-time monitoring of water quality.

Such technology could act as an early-warning system to be used in tandem with conventional monitoring methods that can be expensive or not amenable to 24/7 operation. The paper was published in *ACS Applied Bio Materials*.

Source: IIT Delhi Press Release

Virtual Reality Goggles for Mice



VR setup, with an "overhead threat" projected into the top field of view

RESEARCHERS from Northwestern University have developed new Virtual Reality (VR) goggles for mice called Miniature Rodent Stereo Illumination VR (iMRSIV). According to researchers, these miniature goggles provide more immersive experiences for mice living in laboratory settings. By more faithfully simulating natural environments, the researchers can more accurately and precisely study the neural circuitry that underlines behaviour.

Additionally, researchers used the goggles to simulate an overhead threat — something that had been previously impossible with current systems. The system comprises two lenses and two screens — one for each side of the head to separately illuminate each eye for 3D vision, which provides each eye with a 180-degree field-of-view that fully immerses the mouse and excludes the surrounding environment. The research was published in the journal *Neuron*.

Source: Northwestern University News Release

New AI noise-cancelling headphone



Pictured is co-author Malek Itani demonstrating the system

RESEARCHERS at the University of Washington have developed deep-learning algorithms to help filter out unwanted sounds while using headphones in real-time. The system is called “semantic hearing”, enabling users to pick the sounds that filter through their headphones in real-time.

Using smartphones, users can cancel out all environmental sounds using the app or voice command. Users can select sounds they want to include, which will be played via headphones.

Source: University of Washington News Release

New Conductive, Cotton-based Fiber for Smart Textiles



Hang Liu examines fibre samples developed at her lab

RESEARCHERS from Washington State University developed a single strand of fibre that has the flexibility of cotton and the electric conductivity of a polymer, called polyaniline. The newly developed material showed good potential for wearable e-textiles. The WSU researchers tested the fibres with a system that powered an LED light and another that sensed ammonia gas, detailing their findings in the journal *Carbohydrate Polymers*.

According to researchers, further development in the field could lead to the integration of fibres like these into apparel as sensor patches with flexible circuits. These patches could be part of uniforms for firefighters, soldiers or workers who handle chemicals to detect hazardous exposures. Other applications include health monitoring or exercise shirts that can do more than current fitness monitors.

Source: Washington State University Press Release

TEST YOUR KNOWLEDGE

BASICS OF PLANT TAXONOMY

Pooja Gupta

1. Who is known as the 'Father of Plant Taxonomy'?
 - (a) Theophrastus
 - (b) Carolus Linnaeus
 - (c) Armen Takhtajan
 - (d) JP de Tournefort
2. Angiosperms are thought to have originated from a perennial rhizomatous small plant rather than a tree. This is known as _____.
 - (a) Euanthial theory
 - (b) Anthocorm theory
 - (c) Genophyll theory
 - (d) Herbaceous origin hypothesis
3. Scientific names of plants are treated as _____ irrespective of their source.
 - (a) English
 - (b) Latin
 - (c) Greek
 - (d) Roman
4. Which of the following is considered as the basic unit of plant taxonomy?
 - (a) Specimen
 - (b) Variety
 - (c) Cultivar
 - (d) Species
5. The taxonomic characters that help in distinguishing a plant taxon from other such closely related taxa and identifying it is termed as _____.
 - (a) Homologous characters
 - (b) Analogous characters
 - (c) Diagnostic characters
 - (d) None of the above
6. The size of a standard herbarium sheet is
 - (a) 29 x 41.5 cm
 - (b) 11.5 x 16.5 cm
 - (c) 15.5 x 30 cm
 - (d) 20 x 40.5 cm
7. The taxonomic keys help in the quick identification of plants. These are _____.
 - (a) Always single access
 - (b) Always multi-access
 - (c) Either single or multi-access
 - (d) Neither single nor multi-access
8. An inventory of all the plants of a defined geographical area is known as _____.
 - (a) Herbarium
 - (b) Monograph
 - (c) Flora
 - (d) Journal
9. The nomenclature of plants follows a code published by the International Association of Plant Taxonomy. It is now known as _____.
 - (a) International Code of Botanical Nomenclature (ICBN)
 - (b) International Code of Nomenclature (ICN)
 - (c) International Code of Nomenclature of algae, fungi and plants (ICN)
 - (d) International Code of Nomenclature of Plants (ICNP)
10. Botanical names published before which date are not considered as valid?
 - (a) 1 January 1953
 - (b) 1 January 1753
 - (c) 1 May 1973
 - (d) 1 May 1753

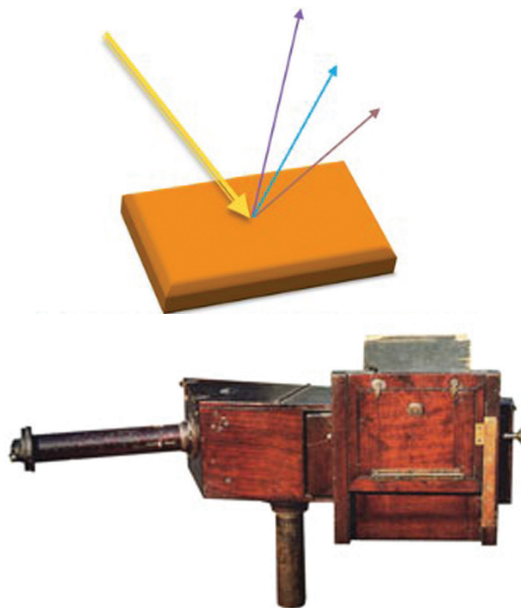
11. According to the principles of plant taxonomy, it is essential to designate a particular specimen or illustration as the type of the species by the original author at the time of publication of a new species. It is referred to as _____.
- Holotype
 - Paratype
 - Lectotype
 - Neotype
12. A classification system of plants utilising general similarity in grouping taxa based on morphology, anatomy, embryology, cytology, etc. and all other available fields of taxonomic information would be called _____.
- Artificial system
 - Sexual system
 - Phenetic system
 - Phylogenetic system
13. A group of closely related genera of plants represents a _____.
- Species
 - Genus
 - Family
 - Order
14. Utilising phytochemical information for understanding phylogenetic relations and classification of plants is _____.
- Chemotaxonomy
 - Chromotaxonomy
 - Phylotaxonomy
 - Phylochemotaxonomy
15. The most well-developed natural system of plant classification published in *Genera Plantarum* in the 19th century, which has great practical utility even today, was given by _____.
- Carolus Linnaeus
 - Jean BP Lamarck
 - George Bentham & JD Hooker
 - Adolph Engler & Karl A Prantl
16. In a taxonomic hierarchy, taxa of successively higher rank contain successively _____.
- Less members and more features in common
 - More members and less features in common
 - Less members and less features in common
 - More members and more features in common
17. OTUs are very important in the data analysis of plant taxa. It refers to _____.
- Operational Taxonomic Units
 - Ordered Transformative Units
 - Operative Transitional Units
 - Ordered Taxonomic Units
18. The primitive characters or character-states possessed by a plant that determine its phylogenetic status are also known as _____.
- Plesiomorphic characters
 - Apomorphic characters
 - Evolutionary characters
 - Derived characters
19. A branching tree diagram constructed based on evolutionary the history between several species depicting ancestor-descendant relationship is known as _____.
- Cluster diagram
 - Venn diagram
 - Cladogram
 - Phenogram
20. In the present times, plant taxonomy follows the APG system of a classification that combines traditional morphological taxonomic data with molecular and genetic data of plants. It stands for _____.
- Advanced Paraphyletic Group
 - Angiosperm Phylogeny Group
 - Advanced Phylogeny Group
 - Angiosperm Paraphyletic Group

Answers

1.b	2.d	3.b	4.d	5.c	6.a	7.c	8.c
9.c	10.d	11.a	12.c	13.c	14.a	15.c	16.b
17.a	18.a	19.c	20.b				

Contributed by Dr Pooja Gupta, Assistant Professor in Botany, Ramjas College, University of Delhi, Delhi-110007.
Email: poojagupta@ramjas.du.ac.in

**TAKE A LOOK AT THE PICTURE AND
IDENTIFY THE SCIENTIST'S NAME**



He was an eminent physicist known for his work in light scattering, which earned him the most prestigious Nobel Prize in Physics in 1930. February 28 is celebrated as National Science Day every year to mark the discovery of the scattering of light. Take a look at the picture and identify the scientist's name.

Answer

Guess Who I am?



I am India's first Marine National Park, situated in the country's westernmost state in one of the famous Gulfs. The area under me covers the archipelago of 42 tropical islands. I am famous for my rich diversity of coral reefs, mangroves, bird breeding grounds, and numerous other eye-catching flora and fauna. My stunning beauty and thriving ecosystem make me a must-visit destination for nature enthusiasts and wildlife lovers. Can you guess me?

SOLUTIONS TO THE PUZZLES PUBLISHED IN JANUARY 2024

Earth's Largest and Smallest Mammals

- a) *Balaenoptera musculus*
- b) Blue Whale
- c) Kitt's hog-nosed bat (Bumblebee)
- d) *Craseonycteris thonglongyai*

Pollution Language Unscramble the Scrambled

- a) Aerosol
- b) Hygroscopicity
- c) Micropollutants
- d) Inversion
- e) Smog

SCIENCE CARTOON

Theme — “Conserve Biodiversity to Preserve Humanity”

Group II (Class IX-XII)





Abhayraj Hada
hadaabhayraj08@gmail.com



Ayanna Chanda
chanda1974@gmail.com