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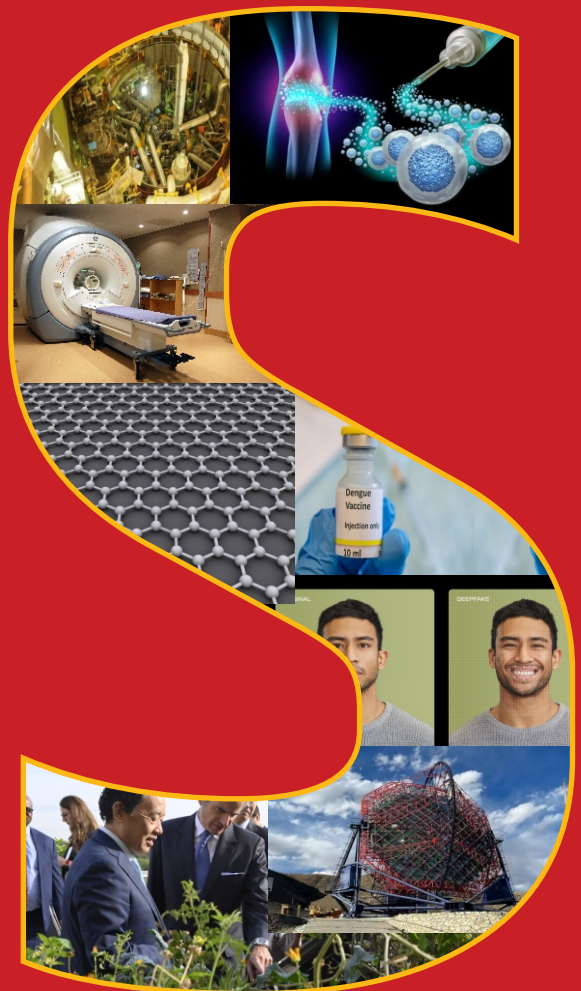
FOR UPSC CSE 2025



CAPSULE MODULE FOR
**LAST MINUTE
REVISION**

Topics covered:

- Biotechnology, Medical Science & Genetic Research
- Material Science and Chemistry
- Emerging Technologies and AI
- Nuclear Science & Energy
- Energy Storage Technologies
- Fundamental Physics, Space Science & Technology
- Space Missions in News
- Telescopes in News
- Diseases in News
- Health & Pharmaceuticals
- Computing & Electronics
- Other Concepts in News



SCIENCE & TECHNOLOGY AND HEALTH

Prelims Express 2025: Maximize Your Score with High-Probability Topics

As you gear up for **UPSC CSE Prelims 2025**, **Prelims Express 2025** is your strategic companion, meticulously crafted to give you an edge in the final leg of your preparation. It is not a compilation of current affairs or textbook summaries, but **a focused resource covering high-probability topics**. Designed to **plug critical gaps**, it brings together scattered yet essential content into one accessible guide. Use it as **a smart supplement** that strengthens your preparation to **boost your score** and **move closer to your goal**.

Wishing you all the best!





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AND HEALTH**

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BIOTECHNOLOGY, MEDICAL SCIENCE & GENETIC RESEARCH

■ Heritable Human Genome Editing (HHGE)

➤ South Africa has become the first country to allow Heritable Human Genome Editing (HHGE).

Heritable Human Genome Editing (HHGE) modifies germline cells (sperm, eggs, or embryos), making genetic changes inheritable by future generations. It can prevent genetic

disorders like Huntington's disease and enhance IVF. Ethical concerns: unforeseen risks and fears of designer babies.

■ One Day One Genome

➤ Department of Biotechnology and Biotechnology Research and Innovation Council launched the 'One Day One Genome' initiative.

One Day One Genome releases a daily annotated microbial genome, enhancing research access and showcasing unique bacterial species. Microbial

genomics studies microorganisms' genetic material, structure, function and evolution, covering microbes like bacteria and algae.

■ Recombinant Proteins (RPs)

➤ Researchers have developed a new process for production of recombinant proteins.

Recombinant Proteins (RPs) are artificially engineered proteins produced using recombinant DNA (rDNA) technology, which combines DNA from different sources to create new functions. RPs, including monoclonal

antibodies (mAbs), are mass-produced in bioreactors using modified bacterial, viral, or mammalian cells. mAbs mimic natural antibodies, aiding in medical and research applications.

■ RNA Editing

➤ The first successful clinical demonstration of RNA editing in humans was conducted.

Wave Life Sciences utilized this technique to treat Alpha-1 Antitrypsin Deficiency (AATD), a genetic disorder affecting the liver and lungs. The process involved the use of Adenosine Deaminase Acting on RNA (ADAR) along with guide RNA (gRNA) to enable precise modifications. RNA editing alters genetic information by inserting, deleting, or substituting nucleotides in RNA sequences. The

gRNA directs the editing machinery by base-pairing with mRNA at specific regions. Unlike DNA editing, which is permanent and involves bacterial proteins, RNA editing is temporary and flexible, relying on naturally occurring ADAR enzymes in the human body. This reduces risks associated with genetic modifications, making RNA editing a promising therapeutic approach.

■ TDP1 (Tyrosyl-DNA Phosphodiesterase 1)

➤ Scientists discovered that cancer cells use TDP1 to repair DNA damage during cell division, making them resistant to chemotherapy.

TDP1 aids cancer cell survival by repairing DNA damage from chemotherapy drugs like camptothecin. It removes damaged DNA bases, preserving genetic integrity. As DNA repair ensures genomic stability in all organisms, targeting TDP1 could help develop new cancer treatments to combat drug resistance.

DNA	RNA
DNA is Deoxyribonucleic Acid	RNA is ribonucleic acid
It is made up of Adenine, guanine, cytosine, and thymine	It is made up of Adenine, guanine, cytosine, and uracil
Very stable structure	Comparatively less stable structure
Less prone to mutations	More easily prone to mutations
Present in Nucleus and mitochondria.	Present in the Cytoplasm, ribosomes, and nucleus
It is Self-replicating.	Most of the RNA is dependent on DNA for its synthesis.
It is the genetic material of most organisms and helps in the transfer of information from one generation to another.	It is most essential component during protein synthesis .
3 forms of DNA are B-DNA, A-DNA and Z-DNA.	3 types of RNA are found: m-RNA, r-RNA and t-RNA.
Contains a Deoxyribose sugar	Contains a ribose sugar

■ ISDRA2TNPB

➤ ICAR recently developed a miniature plant genome editing tool ISDra2TnpB.

TnpB proteins, evolutionary ancestors of Cas12 nucleases, are derived from *Deinococcus radiodurans*, a bacterium known for extreme survival. As part of **jumping genes**, TnpB can **target unique genome regions** inaccessible to

Cas9 and Cas12. It also enables the creation of **fusion proteins (chimeric proteins)** by joining multiple genes. Cas9 and Cas12 are both CRISPR-associated proteins (Cas proteins) that are used to edit genes and regulate genomes.

■ CAR-T therapy

➤ India's first homegrown gene therapy, **NexCAR19 CAR-T Cell Therapy**, has been launched.

CAR-T therapy modifies T-cells by adding a **chimeric antigen receptor (CAR)** to help them **identify and destroy cancer cells**. Known as a "living drug", it offers a **potential cure** for certain cancers with **short treatment durations** and **fast recovery**. T cells are white blood cells that help protect the body from infection and cancer. They

are also known as T lymphocytes and thymocytes. T cells start in the bone marrow as hematopoietic stem cells. These cells mature in the thymus, an organ in the upper mid-chest. There are two main types. Cytotoxic T cells destroy infected cells. Helper T cells send signals that direct other immune cells to fight infection.

■ Mitochondria

➤ Researchers studied **mitochondrial dynamics** to explore treatments for **Parkinson's disease**.

Parkinson's disease is a **neurodegenerative disorder** caused by the death of brain cells. Inhibiting **Dynamin-related protein 1 (Drp1)** could restore **mitochondrial function**, offering a potential treatment. Drp1 helps mitochondria divide into smaller units for **mobility and quality control**.

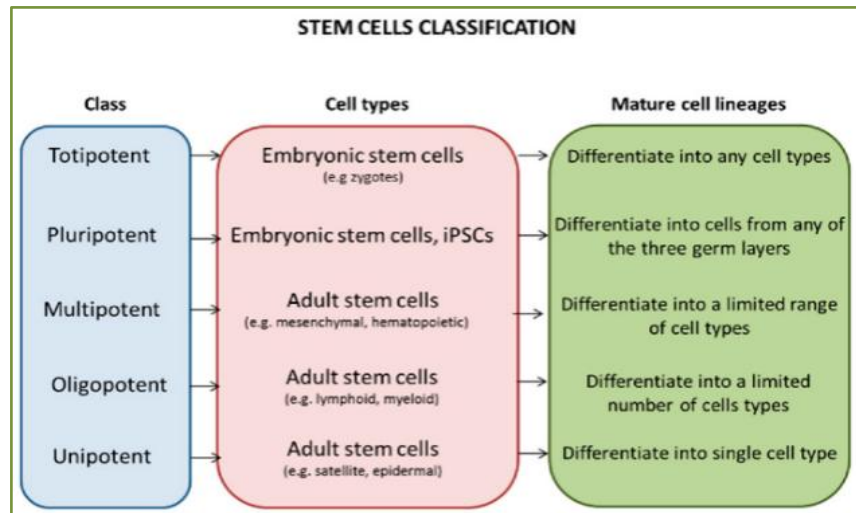
Mitochondria: Membrane-bound organelles that generate ATP, earning the title "**powerhouse of the cell**." They contain **mitochondrial DNA (mtDNA)**, which is **maternally inherited**.

Mitogenome: A **small circular chromosome** inside mitochondria, composed of **double-stranded DNA**.

■ Stem Cell Therapy

➤ For the first time, a Type 1 diabetic woman was treated using reprogrammed stem cells derived from her own body.

In **allogeneic stem cell transplantation**, donor stem cells are used for treatment. **Type 1 diabetes** occurs when the immune system destroys **insulin-producing islet cells**, while **Type 2 diabetes** results from insufficient **insulin production**. **Stem cells** are **unique cells** capable of **self-renewal** and **differentiation** into specialized cells, sourced from **embryos** and **adult tissues**.



■ Xenotransplantation

➤ Recently, the first human recipient of a genetically modified **pig kidney** transplant passed away.

Xenotransplantation involves transplanting live non-human animal cells, tissues, or organs into humans. Using **CRISPR-Cas9** gene editing, specific pig genes that trigger immune responses are eliminated and human genes are introduced for better organ compatibility. It offers an alternative organ supply and helps reduce the transplant shortage. **Pigs** are preferred due to their similar organ size, metabolism and immune system.

In India, the **Transplantation of Human Organs and Tissues Act (THOTA)**, 1994 (amended in 2011), governs organ transplants, with **National Organ & Tissue Transplant Organisation** overseeing regulations. Organ donation is based on the donor's physical condition (not age) but both living must be at least 18 years of age and **family consent** is required for deceased donors.

■ mRNA Vaccine

➤ The world's first mRNA lung cancer vaccine trials, BNT116, have commenced in Europe, targeting non-small cell lung cancer.

mRNA vaccines work by introducing messenger RNA into cells, prompting them to produce viral proteins that activate the immune system. This process generates antibodies, enhancing immunity. Unlike traditional vaccines, mRNA

vaccines do not use live or weakened viruses, making them safer and faster to develop. The success of mRNA technology in COVID-19 vaccines has paved the way for exploring its potential in treating cancer and other diseases.

■ New Dengue Vaccine TAK-003

➤ WHO Prequalifies New Dengue Vaccine TAK-003.

It is the **second dengue vaccine to achieve this status after CYD-TDV**. Dengue is a **viral infection transmitted by the Aedes mosquito** and can lead to severe conditions like

hemorrhagic fever and shock syndrome, for which no antiviral treatment is currently available in India.

■ R21/Matrix-M Malaria Vaccine

➤ Serum Institute of India (SII) has begun exporting the R21/Matrix-M malaria vaccine.

This vaccine targets *Plasmodium falciparum*, the parasite responsible for malaria, transmitted by the **Anopheles mosquito**.

Both, Malaria cases and deaths have dropped by around 80% from 2015-2023. The National

Framework for Malaria Elimination (NFME), launched in 2016, provided a clear roadmap for achieving zero indigenous malaria cases by 2027.

■ Codon De-Optimisation Technology (CDT)

➤ India developed a needle-free intra-nasal booster vaccine for SARS-CoV-2 using CDT.

CDT adjusts the **genetic code to reduce underrepresented codon pairs without altering amino acid sequences**, making the virus less virulent. This technology enhances vaccine safety

and efficacy, enabling faster production. It is an **innovative strategy to improve virus attenuation** and offers a safer, more efficient solution for vaccine development.

■ Thrombocytopenia Syndrome (TTS)

➤ AstraZeneca's COVID-19 vaccine (Covishield) has been linked to rare side effects, including **Thrombocytopenia Syndrome (TTS)**.

TTS occurs when a person develops **blood clots (thrombosis)** alongside a **low platelet count (thrombocytopenia)**. This rare condition can

cause **clots** in unusual places such as the **brain, abdomen and lungs**.

■ Ferroptosis

➤ A new study by researchers at **Columbia University** found that **Ferroptosis** is a major **cell death mechanism** that underlies **COVID-19 lung disease**.

Ferroptosis is an **intracellular iron-dependent form of cell death**, typically marked by the accumulation of **iron** and **lipid peroxidation** during the process. Research suggests that

ferroptosis is linked to various **pathophysiological processes**, including **tumors, nervous system diseases** and **kidney injury**.

■ Tmesipteris oblancoolata

➤ Scientists discovered that **Tmesipteris oblancoolata**.

Tmesipterisoblancoolata, a species of **fork fern**, holds the record for the **largest genome**, with **160 billion base pairs**—over **50 times larger** than the

human genome. It belongs to an **ancient plant group** that predates dinosaurs.

■ Unified Genomic Chip

➤ India launched **Unified Genomic Chip** and **indigenous sex-sorted semen technology** to enhance livestock breeding in India.

The **Unified Genomic Chip** is an **SNP chip** for profiling **Indian cattle breeds**, enhancing their **genetic potential** using **DNA technology**. It includes **Gau Chip (for cattle)** and **Mahish Chip (for buffaloes)**, developed by **DAHD** and partners.

SNPs

Single Nucleotide Polymorphisms (SNPs) are **genetic variations** where a **single DNA nucleotide differs**, acting as **biomarkers** for disease-linked genes.

Sex-Sorted Semen Technology: An AI method ensuring 90% female calf births, boosting dairy

productivity by reducing male calves. Developed by National Dairy Development Board.

■ BioE3 Policy

➤ Cabinet has approved the BioE3 Policy to foster high-performance biomanufacturing in India.

The BioE3 Policy aims to drive **biomanufacturing** by utilizing **engineered microbial, plant and animal cells** to produce valuable products. Implemented by the **Department of Biotechnology (DBT)**, it targets a **\$300 billion bioeconomy by 2030** through the **sustainable use of biological resources**. Key features include

support for R&D and entrepreneurship across six sectors and the establishment of **Bio-AI and Biomanufacturing Hubs**.

The **Bio-RIDE Scheme**, under DBT, fosters **biotechnology research, industrial development and biomanufacturing**, aligning with the **Circular Bioeconomy and LiFE Mission**.

■ Hayflick Limit

➤ Leonard Hayflick, who introduced the **Hayflick limit**, recently passed away.

The **Hayflick Limit** is the maximum number of times a cell can divide before stopping due to **cell cycle arrest**, governed by **telomere length**. **Telomeres**, protective DNA sequences at

chromosome ends, **shorten with each division**, limiting lifespan. In humans, this limit suggests a **theoretical lifespan of around 125 years**.

■ Organ-on-Chip (OoC) Technology

➤ OoC technology could support BioE3 (Biotechnology for Economy, Environment and Employment) policy by advancing personalized medicine.

A **micro-scale system** that mimics the **human body environment**, **Organ-on-Chip (OoC)** is a **3D culture model** under **New Approach Methods (NAMs)**. It enables researchers to **recreate human organs and diseases in a dish** using **channels, chambers and membranes** to regulate cell behaviour and material flow. **Cells are placed on a chip** and grow into **3D structures** using a **polymer** that mimics real tissue. **Tiny fluid channels** simulate **blood flow, oxygen delivery and nutrient transport**, enabling the creation of

miniature organ models (e.g., lung, heart) on a **chip-sized device**.

The **New Drugs and Clinical Trials Rules 2019** allow the use of **human organs-on-chips**. The **Genome India Project (GIP)**, launched in 2020, aims to create a **10,000-genome database**, supported by the **Indian Biological Data Centre (IBDC)**. The **Phenome India Project (CSIR)** focuses on building a **comprehensive phenome database** to map **observable traits** in biological systems.

■ Bridge Recombinase Mechanism (BRM) and Jumping Genes

➤ Scientists have discovered a naturally existing **DNA editing tool** called the **BRM**, which utilizes **jumping genes** for genetic modifications.

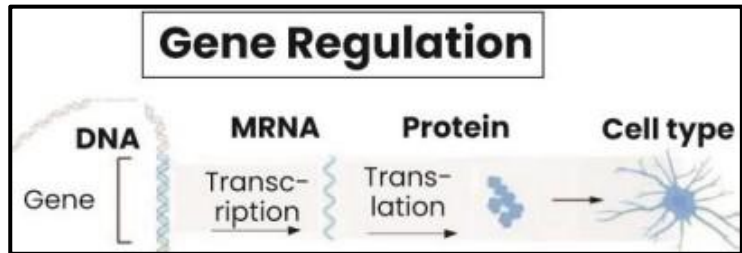
BRM works by using **extra DNA at the ends of jumping genes** to convert the **DNA double helix** into a **single-stranded RNA molecule**. This **bridge RNA** binds to two DNA segments—**donor and target**—allowing for flexible modifications. **Jumping genes, or transposable elements**, are DNA sequences that move within the genome

and contain **recombinase enzymes** and extra DNA segments that aid in DNA binding and manipulation. These genes play a crucial role in **self-replication, insertion at new locations, genetic mutations and genome evolution**, making them fundamental to genetic diversity and adaptability.

■ Nobel Prize in Medicine

➤ The **2024 Nobel Prize in Medicine** was awarded to **Victor Ambros and Gary Ruvkun** for their discovery of **microRNA** and its role in **post-transcriptional gene regulation** in *C. elegans* nematodes in 1993.

Previously, gene regulation was thought to be controlled solely by **transcription factors** binding to DNA. **microRNA** is a small, non-coding RNA that regulates gene expression by binding to mRNA, either blocking translation or triggering degradation, functioning in the **cytoplasm** unlike transcription factors in the **nucleus**. Gene regulation determines when, where and how much genes are expressed, enabling specialized protein production in different cells despite identical



Transcription	Translation
1. In the process of Transcription, the sequence of nucleotides present on the DNA molecule is copied and carried to the cytoplasm by m-RNA.	1. In the process of translation, the specific amino acids are picked up according to the codons brought by m-RNA.
2. The process of Transcription takes place in nucleus.	2. The process of translation takes place in ribosomes located in cytoplasm.
3. During Transcription, RNA is produced from DNA.	3. During translation, proteins are produced with the help of RNA.
4. Only m-RNA takes part in transcription.	4. m-RNA, t-RNA and r-RNA take part in translation.

DNA. This discovery has profound implications in **cell development**, including **stem cell renewal and differentiation**, **immune response regulation** and **cancer prevention**, making it crucial for disease diagnosis and treatment.

■ Magnetic Resonance Imaging (MRI)

➤ The world's most powerful (MRI) machine, named '**Iseult**', has recently captured the first images of the human brain.

Magnetic Resonance Imaging (MRI) is a non-invasive imaging technique that uses **radio waves** and powerful magnets to create detailed images of the body's internal structures. MRI does not

involve X-rays or the use of ionizing radiation, which distinguishes it from computed tomography (CT) and positron emission tomography (PET) scans.

■ Radiation therapy

➤ **Delhi's Lady Hardinge Medical College** has recently opened a **Radiation Therapy facility**

Radiation therapy, or **radiotherapy**, is a treatment method that uses ionizing radiations like **X-rays**, **gamma rays**, **high-energy electrons**, or **heavy particles** to destroy cancerous cells. It is particularly effective in treating cancers of the **brain**, **breast**, **head and neck** and **cervix**, while minimizing harm to healthy tissues. However, it

can have potential side effects, including **fatigue**, **nausea**, **hair loss** and **loss of appetite**. Additionally, **Proton therapy**, an advanced and precise form of radiotherapy, is becoming increasingly popular for treating cancer due to its high accuracy in targeting cancer cells.

■ Hepatitis A Vaccine

➤ Indian Immunologicals Limited has launched India's first indigenous pediatric Hepatitis A vaccine, Havisure.

Hepatitis A is a liver inflammation caused by a viral infection, typically spread through contaminated water or food. While Hepatitis B and C are more commonly associated with liver cirrhosis and cancer, Hepatitis A primarily causes

acute symptoms. India's National Viral Hepatitis Control Program aims to eliminate Hepatitis C by 2030, with vaccines being an essential tool in preventing viral hepatitis.

■ Ultrasound Technology

➤ Scientists have mapped brain activity using Functional Ultrasound Imaging (fUSI), an emerging technique offering high-resolution neural imaging.

Ultrasound technology uses high-frequency sound waves to visualize the internal organs of the body. This non-invasive technique does not

use radiation, making it a safe and effective imaging tool in diagnostic medicine, sonar and non-destructive testing.

■ Coalition of Epidemic Preparedness Innovations (CEPI)

➤ Asia's first Pre-clinical Network Facility was inaugurated in Faridabad (Haryana) under the CEPI.

Launched in 2017 by partners such as Norway, India, the Bill & Melinda Gates Foundation and the World Economic Forum (WEF), CEPI's goal is

to accelerate vaccine development against emerging infectious diseases and ensure equitable access to these vaccines.

■ Global Alliance for Vaccines and Immunization (GAVI)

➤ A recent study highlighted the role of GAVI, launched in 2000.

GAVI aims to improve vaccination coverage, particularly in poorest countries and includes

core founding members like WHO, UNICEF and the Bill & Melinda Gates Foundation (BMGF).

■ Endosymbiotic Theory

➤ Researchers have discovered a new organelle called nitroplast in the marine algae *Braarudosphaera bigelowii*, capable of nitrogen fixation.

Braarudosphaera bigelowii: A Nitrogen-Fixing Eukaryote

Previously, only bacteria and archaea were known to fix nitrogen, but *Braarudosphaera bigelowii* is the first known eukaryote with this ability, reviving interest in the Endosymbiotic Theory.

About Endosymbiotic Theory

It suggests that mitochondria and plastids in eukaryotic cells evolved from free-living prokaryotes. Eukaryotic cells have a membrane-bound nucleus, while prokaryotic cells store DNA in the nucleoid region without a nuclear membrane. The theory proposes that some eukaryotes engulfed prokaryotes, forming symbiotic organelles over time.

MATERIAL SCIENCE AND CHEMISTRY

■ Thermite

➤ "Dragon Drone," has been reportedly used in the Russia-Ukraine war. This drone is equipped with **thermite-based incendiary payloads**

Thermite, a mixture of **aluminum and iron oxide**, is known for its **high-temperature exothermic reaction** that is self-sustaining and nearly impossible to extinguish. It is widely used in **welding, metal cutting and military applications**. While not banned internationally, its use in warfare raises **legal and ethical concerns**. The UN's **Convention on Certain Conventional Weapons** prohibits incendiary weapons in civilian areas, though military targets remain lawful under international law.

■ SEBEX 2

➤ The Indian Navy has certified **SEBEX 2**.

SEBEX 2 is a **highly potent non-nuclear explosive** based on **High-Melting Explosives (HMX)**, offering **2.01 times the lethality of Trinitrotoluene (TNT)**. TNT, a **yellow, odorless solid**, is widely used in **military shells, bombs, grenades and industrial blasting**.

■ Carbon Fiber

➤ The Vice President of India inaugurated the **Centre for Carbon Fiber and Prepregs**

Carbon fiber is a **lightweight, strong polymer with high strength, chemical resistance and thermal stability**. **Prepregs, or resin-impregnated reinforcing fabrics, are key to high-performance composites**. Widely used in **aerospace, defense, automotive and sports equipment**, carbon fiber is crucial for **missiles, satellites, aircraft, EVs and sporting gear**.

■ Graphene

➤ India Graphene Engineering and Innovation Centre (IGEIC) was launched.

Graphene, a **2D crystalline carbon allotrope**, is the **building block of graphite**. **200 times stronger than steel yet six times lighter**, it absorbs only **2.3% of light**, making it ideal for **touchscreens and solar cells**. With **~5000 W/m/K thermal conductivity**, it excels in **heat dissipation**. Its **impermeability** blocks even the lightest gases. It has **Quantum Hall effect** that is critical for **quantum computing and advanced electronics**.

■ Goldene

➤ Scientists have developed a sheet of Gold, called Goldene, which is just one atom thick.

Goldene is an **ultrathin gold sheet, just one atom thick**, created by replacing **silicon with gold atoms in a silicon-titanium carbide sandwich**. It is **400 times thinner** than the **thinnest gold leaf** and has potential applications in **electronics, catalysis, CO₂ conversion and hydrogen generation**.

■ Fluorescent Nanodiamonds (FNDs)

➤ Scientists recently spun **fluorescent nanodiamonds** at extreme speeds to study the **Berry phase effect** on spin qubits.

Fluorescent Nanodiamonds (FNDs) are **carbon nanoparticles** that emit **lower-frequency light** when irradiated with **higher-frequency light**. Produced under **high temperature and pressure**, they are **stable under light, non-toxic** and used in **high-resolution imaging, temperature sensing, correlative microscopy and long-term cell tracking**.

■ Piezoelectric Polymer nanocomposites

➤ Researchers developed a security alert system using Piezoelectric Polymer nanocomposites.

Piezoelectric Polymer nanocomposites generate electric charges under pressure or strain, converting mechanical energy into electrical energy. Their flexibility, lightweight nature and ease of processing make them ideal for sensors, wearables, medical implants and consumer electronics.

■ Calcium Carbide

➤ The FSSAI has warned fruit traders to comply with the ban on calcium carbide in fruit ripening.

Calcium carbide, which releases acetylene gas, contains harmful traces of arsenic and phosphorus. The use of calcium carbide for ripening fruits is prohibited under the Food Safety and Standards Regulations due to its health risks.

■ Ethylene Oxide

➤ The Singapore Food Agency ordered a recall of India's Spice products due to the presence of ethylene oxide.

This colorless, flammable gas is used in the production of chemicals like antifreeze, plastics and detergents. Ethylene oxide is also a sterilizing agent for medical equipment and is linked to eye and skin irritation as well as cancer with long-term exposure.

■ Methanol

➤ Deaths have been attributed to methanol (methyl alcohol) poisoning, often from illicitly produced hooch or spurious liquor.

Methanol is a colorless liquid used in various industries as a solvent in paints, varnishes and the production of formaldehyde. Even small quantities can cause blindness and large doses can be fatal, highlighting the dangers of methanol poisoning.

■ Liquid Nitrogen

➤ The FSSAI has issued an advisory regarding the unauthorized use of liquid nitrogen in food preparation by food-serving establishments.

Liquid nitrogen (-196°C), an inert cryogenic fluid used in the food industry. It serves as a freezing agent for rapid chilling, a propellant in food packaging, a packaging gas to prevent oxidation and a foaming agent in molecular gastronomy. Liquid Nitrogen could cause frostbite and burns due to extreme cold, asphyxiation risks in poorly ventilated areas and severe internal organ damage if ingested improperly. The Food Safety and Standards Regulation, 2011, permits nitrogen as a Good Manufacturing Practice (GMP) additive, but its use must adhere to strict safety guidelines to prevent direct ingestion hazards.

EMERGING TECHNOLOGIES AND AI

'Vishvasya: National Blockchain Technology Stack'

'Vishvasya: National Blockchain Technology Stack' was launched.

Vishvasya: National Blockchain Technology Stack offers Blockchain-as-a-Service (BaaS) with a geographically distributed infrastructure for permissioned blockchain applications. It is part of the National Blockchain Framework (NBF) under the National Strategy on Blockchain.

Key Features: Rapid development & deployment of permissioned blockchain applications; pre-audited blockchain containers for secure production setups.

Brain-Computer Interface (BCI)

Brain-Computer Interfaces (BCIs) are gaining significant attention

A BCI is a system designed to translate brain signals into commands that control external devices. It consists of a **headset** to detect brain activity, a **computer** to process these signals and an **application/device** that executes the desired action. **Feedback** allows users to adjust actions for better control. BCIs are of 3 types: **invasive**, involving implants directly into the brain; **non-invasive**, using surface sensors like EEG or fMRI; & **partially invasive**, placed under the skull but outside brain tissue. BCIs hold potential for healthcare, particularly for individuals with disabilities, enabling new forms of communication, mobility and sensory experiences such as restoring sight to the blind.

Network as a Service (NaaS)

The NaaS market in India is poised to grow significantly, expanding from **\$1.18 billion** in 2024 to **\$7.32 billion** by 2029.

NaaS is a cloud service model that enables customers to **rent networking services** from cloud providers. This model offers **flexibility** by allowing customers to pay based on usage and scale their networks according to business requirements.

Li-Fi Technology

Li-Fi Technology has recently gained attention as the Ministry of Defence funds a start-up under **Innovations for Defence Excellence (iDEX)** to secure its integration into the Indian defence sector.

Li-Fi (Light Fidelity) is a bidirectional wireless communication system that uses visible light, infrared and near-ultraviolet light to transmit data instead of traditional radio frequency waves. The technology works through the on/off activity of a **Light Emitting Diode (LED)** transmitter, enabling data transmission via binary codes.

Comparison Wi-Fi, Li-fi and Gi-Fi			
Characteristics	Wi-Fi	Li-Fi	Gi-Fi
Frequency	24GHz	Up to 10THz	60GHz
Range	Varying	100 meters	10 meters
Operation	Data transmission by radio waves	Data transmission by light of LED blubs	Data transmission by 5mm chip
Data transfer rate	11Mbps	1Gbps	5Gbps
Power consumption	10mw	No additional Power needed.	2mw
Data Density	Very low	High	Very high
Cost	High	low	Very low
Security	Less secure	High Secure	Less secure

3D Hologram Technology

Japan introduces 3D hologram banknotes to combat counterfeiting.

Hologram technology is a **photographic pattern** that produces a **three-dimensional image** when exposed to **coherent light** like a laser. In banknotes, holograms enhance security by displaying **different images and colors** based on the viewing angle, making counterfeiting highly challenging. Their creation is based on **interference and diffraction**, forming intricate patterns that are difficult to replicate.

Digital Twins

The use of digital twins is growing in India.

Digital Twins are virtual replicas of physical objects, systems, or processes that simulate real-world counterparts in real-time. By integrating data from sources, they enable real-time monitoring, analysis & optimization. They rely on Internet of Things, Extended Reality, Cloud Computing and AI to create digital representations, collect data & generate insights.

Facial Recognition Technology

NITI Aayog released the 'White Paper: Responsible AI for All (RAI) on Facial Recognition Technology (FRT)'.

Facial Recognition Technology (FRT) is an AI-based system that identifies or verifies individuals using images or video data. It operates in two modes: **1:1 Verification**, which matches a facial map to a single stored image (e.g., phone unlocking) and **1:N Identification**, which compares a face against a database (e.g., mass surveillance). **Key applications** include security uses like law enforcement (identifying persons of interest/missing persons) and crowd control (e.g., Divya Drishti). **Non-security uses** involve identity verification (Aadhaar-based authentication), airports (contactless boarding via Digi Yatra) and banking (password-free authentication for enhanced security).

Deepfakes

Election Commission of India has warned against misuse of Deepfakes in elections.

Deepfakes are AI-generated synthetic media, often in the form of altered images or videos, created using deep learning techniques. Unlike **Shallowfakes**, which rely on conventional editing tools, deepfakes use **Generative Adversarial Networks (GANs)** to manipulate audio and visual content.

BharatGen Programme

The Ministry of Science & Technology launched BharatGen, a pioneering initiative in Generative AI.

The **BharatGen Programme** is a multimodal LLM project designed for text, audio and imagery generation in Indian languages to enhance public service delivery and citizen engagement while preserving India's linguistic and cultural diversity. It is implemented by **TIH-IoT** under **NM-ICPS**, with completion targeted by **July 2026**. A key component, **Bharat Data Sagar**, will serve as an **India-centric AI data repository** for improved contextual accuracy. Under the **National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS)**, approved in 2018 and implemented by **DST**, India is advancing **Cyber-Physical Systems (CPS) research**. Other AI initiatives include the **IndiaAI Mission** (under Digital India Corporation), **National AI Portal (INDIAai)**, **AIRAWAT** (AI research platform) and participation in **Global Partnership on Artificial Intelligence**. Additional programs include the **National AI Skilling Program**, **YuvaAI** and **Srijan (GenAI Centre of Excellence)**.

S.A.R.A.H

WHO unveiled S.A.R.A.H., a Generative AI-powered digital health promoter for public health.

S.A.R.A.H. is a **Generative AI-powered digital health promoter** unveiled by **WHO** to enhance public health awareness. It provides information on major health topics, including healthy habits and mental well-being and helps in understanding risk factors for leading causes of death like cancer, heart disease, lung disease and diabetes.

NUCLEAR SCIENCE & ENERGY

■ Small Modular Reactors (SMRs)

➤ The Union Budget 2024-25 announced a partnership with the private sector to develop Bharat Small Reactors (BSRs), a shift in India's nuclear policy.

BSRs, based on Small Modular Reactors (SMRs), will use **Pressurized heavy water reactor (PHWR) technology** and aim to boost nuclear energy's share in India's energy mix, **currently at 1.6%**. SMRs are small, factory-assembled reactors with a **capacity of up to 300 MW(e)**, offering a **modular approach to nuclear energy generation**.



■ Tokamak

➤ The Korea Superconducting Tokamak Advanced Research (KSTAR) fusion reactor recently set a world record by achieving **temperatures seven times that of the Sun's core**.

A **tokamak** is a **donut-shaped reactor that mimics the Sun's nuclear fusion process**. International Thermonuclear Experimental Reactor (ITER), currently under construction in France, will be the **largest tokamak globally**. India also contributes to fusion research with its tokamaks, ADITYA and SST-1 (or Steady State Superconducting Tokamak in Gandhinagar), while the International Thermonuclear Experimental Reactor (ITER) progresses as a global collaborative project.



■ Criticality

➤ The Atomic Energy Regulatory Board granted permission for the First Approach to Criticality of India's 500 MWe sodium-cooled Prototype Fast Breeder Reactor (PFBR) located at Kalpakkam, Tamil Nadu, commissioned by BHAVINI.

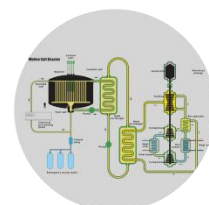
Criticality refers to initiating a **self-sustaining chain reaction in the reactor and core loading marks this first step**. The PFBR is significant as it will operate using **Uranium-Plutonium Mixed Oxide (MOX) fuel, with the Uranium-238 "blanket" transmuting into fissile fuel**. It marks the beginning of India's Stage II of its three-stage nuclear power program, eventually utilizing Thorium as fuel in the third stage, leveraging India's abundant Thorium reserves. The AERB, established in 1983, ensures the safe use of nuclear energy in India. **India's reserves of Thorium, approximately 25% of the world's total**, are mainly found in Kerala, Tamil Nadu, Odisha and other coastal states.



■ Thorium Molten Salt Nuclear Plant

➤ China plans to launch the world's first **Thorium Molten Salt Nuclear Power Plant** in the Gobi Desert by 2025.

This reactor uses **thorium as fuel and liquid salt or carbon dioxide for heat transfer**, reducing meltdown risks compared to traditional water-



cooled reactors.

■ Atoms4Food

➤ Bhabha Atomic Research Centre participated in the International Atomic Energy Agency (IAEA) Scientific Forum 'Atoms4Food'.

Atoms4Food is a joint initiative by the International Atomic Energy Agency and the Food and Agriculture Organization that leverages nuclear techniques to enhance agriculture and livestock productivity. It focuses on crop improvement through mutation breeding, sustainable soil and water management, nuclear-based disease detection in livestock and food preservation via irradiation.



ENERGY STORAGE TECHNOLOGIES

■ Battery Energy Storage System (BESS):

➤ India's Battery Energy Storage System (BESS) ecosystem is set to receive ₹3.5 lakh crore in funding by FY2032. BESS, which includes technologies like lithium-ion and sodium-sulfur batteries, stores electricity through electrochemical reactions and is essential for stabilizing renewable energy grids. The government supports BESS with initiatives such as the Viability Gap Funding scheme and Production Linked Incentive schemes.

■ Sodium-Ion Battery

➤ South Korean scientists have developed a high-power, rapid-charging sodium-ion battery, a potentially cheaper and more feasible alternative to lithium-ion batteries, especially in large-scale energy storage.

■ Hydrogen-Fuel Cells

➤ The MV Sea Change, the world's first commercial passenger ferry powered entirely by zero-emission hydrogen fuel cells. Hydrogen fuel cells produce electricity through an electrochemical reaction between oxygen and hydrogen, emitting only water vapor.

■ Zinc Air Batteries

➤ CSIR has developed durable zinc-air batteries designed to function in extreme cold, featuring a zinc negative electrode and an oxygen positive electrode, making them ideal for energy solutions in remote, sub-zero conditions.

■ Triboelectric Nanogenerator (TENG) Technology

➤ IIT Indore has developed footwear for military personnel using TENG technology, which converts the mechanical energy from walking into electrical energy. This energy can power small devices, wearable technology and IoT applications, providing a sustainable energy source from everyday motion.

FUNDAMENTAL PHYSICS, SPACE SCIENCE & TECHNOLOGY

■ Higgs boson

➤ **Peter Higgs**, the Nobel Laureate physicist, who recently passed away, is renowned for proposing the **Higgs field** and the associated **Higgs boson** in 1964.

The **Higgs field** is a universal field that permeates the entire cosmos and particles acquire mass through their interaction with this field via the **Brout-Englert-Higgs mechanism**. This interaction explains how elementary particles, initially massless, gain mass—stronger interactions with the field result in heavier particles. The **Higgs boson**, often called the "God particle," is an elementary particle associated with the Higgs field and it is the only elementary particle with **no**

spin (spin = 0). With a mass of **125.35 GeV**, it has a very short lifetime, decaying quickly into other particles. The Higgs boson cannot be directly detected but is identified by observing the particles it decays into. The theory was experimentally confirmed in **2012** by scientists at the **Large Hadron Collider (LHC)** at **CERN**, validating the **Standard Model** of particle physics and establishing the Higgs field's vital role in the mass generation of particles.

■ Neutrinos

➤ **New findings on Neutrinos.**

Neutrinos, often called "ghost particles," are subatomic particles with no electrical charge and negligible mass. They pass through matter almost undetected, with trillions of them passing through the human body every second. High-energy neutrinos, released from cosmic sources like supernovas, black holes and active galactic nuclei,

provide valuable insights into astrophysical events. Key observatories dedicated to studying neutrinos include the **Indian Neutrino Observatory (INO)** in Tamil Nadu, **China's TRIDENT and JUNO** and the **IceCube Observatory**, the world's largest neutrino detector.

■ Gravitational Waves (GW)

➤ **Recently, GW230529, was detected by the LIGO-Virgo-Kagra collaboration in 2023.**

Gravitational Waves (GW) are ripples in space-time caused by highly energetic processes like the collision of cosmic objects. Gravitational waves, predicted by **Einstein's General Theory of Relativity (1916)**, travel at the speed of light and were first detected in 2015 by the **LIGO** observatory. LIGO, or Laser Interferometer Gravitational-Wave Observatory, is a facility that detects gravitational waves from space.

How does LIGO work

The LIGO is a giant L-shaped instrument. Each arm of the L is 4 Km long. Two laser pulses are shot through each arm at the same time, and they bounce off a mirror at the end to return to the vertex.



A detector checks whether the pulses return at the same time. When a gravitational wave passes through the detector, the pulses are slightly out of time. Researchers use this and other signal to detect, record and study gravitational waves.

■ Antimatter

➤ Scientists discovered the heaviest antimatter nucleus, **anti-hyperhydrogen-4**, in the **Relativistic Heavy Ion Collider**. This antimatter nucleus consists of an **antiproton**, **two antineutrons** and an **antihyperon**.

Antimatter is a form of matter composed of particles that have the same mass as their matter counterparts but opposite electrical charges. For instance, the **positron** is the antiparticle of the negatively charged electron and the **antiproton** is the antiparticle of the proton. Antimatter

particles, like positrons, antiprotons and antineutrons, are always produced in pairs and, when they come into contact with their matter counterparts, they annihilate each other, releasing pure energy. This annihilation process is a key feature of antimatter.

■ Synchrotrons

➤ China is constructing the **High Energy Photon Source (HEPS)**, set to be Asia's **brightest synchrotron X-ray source**.

Synchrotrons are circular particle accelerators that use electricity to produce highly intense beams of light—**more than a million times brighter than the sun**. These intense beams of light allow researchers to explore matter at the

smallest scales, including **molecules, atoms, electrons and spin**, providing insights into the nature of materials across **space, time and energy**. India's first synchrotron was **Indus-1**.

■ Giant Radio Sources (GRSs)

➤ Indian astronomers discovered **34 new Giant Radio Sources (GRSs)** using the **Giant Metrewave Radio Telescope (GMRT)** near Pune.

GRSs are among the **largest objects in the universe**, with a **supermassive black hole** at their

core. The black hole generates **jets of hot plasma**, leading to massive **radio emissions**.

■ Hydrogen Line

➤ **Hydrogen line** was in the news.

The **hydrogen line**, also known as the **21 cm line**, is a spectral line emitted by **atomic hydrogen** when an electron in a hydrogen atom transitions from a higher energy level to a lower one, releasing energy in the form of light with a

wavelength of approximately **21 centimeters**. This phenomenon has applications in **radio astrophysics**, such as studying the **composition & evolution** of the **solar system** and the **universe**.

■ Space docking

➤ India has become the **4th country** to successfully conduct **space docking** with the launch of the **Space Docking Experiment (SPADEX)** by **ISRO** using the **PSLV-C60**.

Space docking is the precise connection of two spacecraft to operate as a single unit, enabling critical tasks such as **refueling, repair** and **crew exchange**, essential for building facilities like the **International Space Station (ISS)**. SPADEX consists of two satellites, **Chaser** and **Target**, which will dock autonomously at an altitude of about **700 km**. The experiment demonstrates autonomous docking, **formation flying**, **remote**

operations and the use of robotic arm technologies. It is vital for **space exploration** missions such as **sample return** from the Moon and **building and operating space stations**. The mission will also contribute to innovations like **POEM-4**, a cost-effective platform for **on-orbit experiments**, benefiting **startups** and **space technology development** in India.

■ Bharatiya Antariksh Station (BAS)

➤ India's **Bharatiya Antariksh Station (BAS)** is a planned space station for scientific research as part of the extended **Gaganyaan Programme**.

BAS will include the development of **first module of BAS** and 4 missions for technology validation by **2028**. The **Next Generation Launch Vehicle (NGLV)**, capable of carrying **30 tonnes to Low Earth Orbit (LEO)**, will support **BAS** construction. The **Gaganyaan Programme** aims to transport astronauts on India's first **human space flight** mission, with a **reconfigured LVM3** for crew

safety. The **BAS** will consist of five modules, with the **Base Module** set for launch in 2028.

Upcoming:

Gateway Space Station: NASA-led. To create a space station around Moon as part of **Artemis campaign**.

Axiom Station: World's first commercial space station, being developed by Axiom Space to operate in LEO.

■ Brown Dwarf

➤ Recent observations by the **James Webb Space Telescope** have helped map the weather patterns on brown dwarf stars.

The **Brown Dwarf** is a celestial object that lies between a giant planet, like Jupiter and a small star. Brown dwarfs do not have sufficient mass to

sustain nuclear fusion like regular stars, leading to their nickname "failed stars."

■ White Dwarf Star

➤ **Speedy white dwarf planets are more likely to be habitable.**

A **White Dwarf Star** is the remnant core of a star that has exhausted its nuclear fuel and shed its outer layers, forming a planetary nebula. It is a dense, burned-out star with a limited lifespan.

The **Chandrasekhar limit** is the maximum mass (1.44 times the mass of the Sun) that a white dwarf can have before it collapses into a neutron star or black hole.

■ Plunging Region

➤ **New study has provided the first observational proof of a prediction from Einstein's theory of gravity regarding the existence of "plunging regions" around black holes.**

Plunging Region refers to an area around a black hole where matter ceases to orbit and falls directly into the black hole. This phenomenon, predicted by **Einstein's theory of general relativity**,

demonstrates the impossibility of maintaining stable orbits near the black hole, where some of the strongest gravitational forces in the galaxy exist.

■ Super Blue Moon

➤ **Super Blue Moon on Raksha Bandhan.**

A **Super Blue Moon** occurs when a **Supermoon** and a **Blue Moon** happen simultaneously. A **Supermoon** is when the Moon is at or near its closest point to Earth (perigee) during a full moon. A **Blue Moon** has two types: a **monthly blue moon**, which occurs when two full moons

are visible in a single month and a **seasonal blue moon**, which happens when there are four full moons in a season instead of the usual three. Super Blue Moons happen, on average, every 10 years.

■ Trojan Asteroids

➤ The **Lucy mission** (2021) was the first to explore the Jupiter Trojan asteroids, offering insights into the solar system's evolution.

Trojan Asteroids are celestial bodies that share an orbit with a planet, located at stable Lagrange points, usually L4 and L5. The discovery of a

Trojan asteroid around **Saturn** highlights the presence of such bodies alongside other giant planets like Jupiter, Neptune and Uranus.

■ RHUMI-1- India's first reusable hybrid rocket

➤ RHUMI-1, developed by Space Zone India was launched to carry Cube and Pico satellites for climate change data collection.

It features a hybrid rocket engine combining solid and liquid propellants and is 100% pyrotechnic-

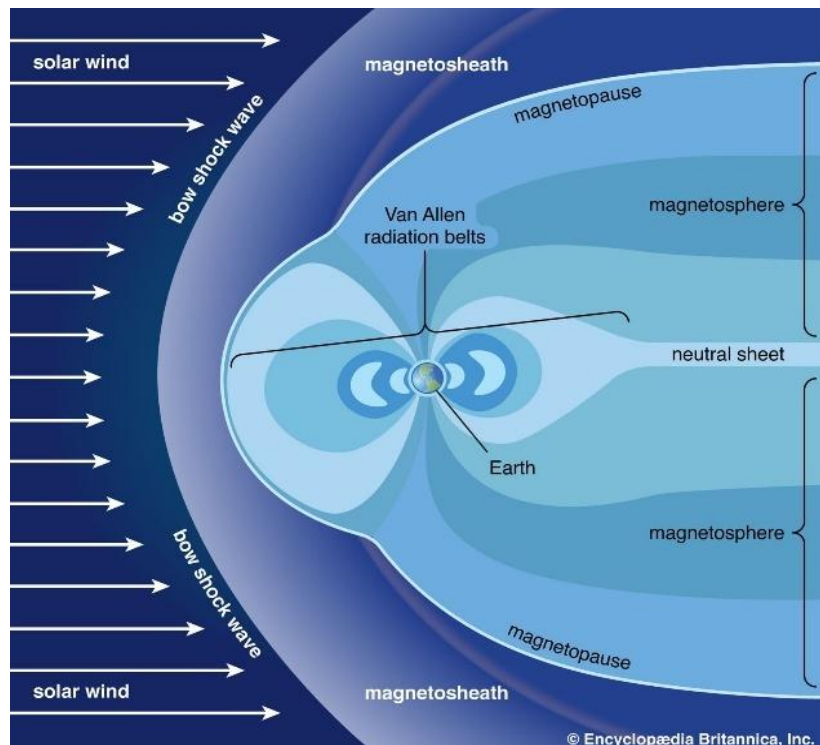
free, promoting environmental friendliness and cost efficiency through its reusability.

■ Van Allen Radiation Belt

➤ Trillions of charged particles in Earth's radiation belts interact with lightning, impacting space weather and spacecraft design.

The Van Allen Radiation Belt, discovered by James Van Allen in 1958, traps high-energy particles in Earth's magnetosphere, shielding us from solar storms.

It consists of two belts—an inner belt from cosmic ray interactions and an outer belt made of high-energy solar particles. Spacecraft must pass through these belts quickly to limit radiation exposure.



■ Space Debris

➤ The **Indian Space Situational Assessment Report (ISSAR)** for 2023, released by ISRO, highlighted the increase in space debris

Space debris, consisting of non-functional artificial objects and fragments, is primarily concentrated at altitudes of 800-1000 km and near 1400 km in Low Earth Orbit (LEO). It originates from **on-orbit break-ups, collisions, defunct satellites, spent rocket stages** and space-based weapons. The **Kessler Syndrome** describes a chain reaction where the growing density of

debris in LEO causes collisions, leading to more debris. To mitigate space debris, global initiatives like the **Inter-Agency Debris Coordination Committee (IADC)** and the **UN Space Debris Mitigation Guidelines** have been established. India is also working on **Debris Free Space Missions (DFSM) 2030**, the **Space Situational**

■ Universe's Expansion

➤ Recent research revealed that Universe is expanding at a rate of **68.5 (±0.6) kilometers per second per megaparsec**, with data from the **Dark Energy Spectroscopic Instrument (DESI) located in the USA**.

DESI, located in the USA, measures the effect of **dark energy** on the expansion. Key theories explaining the expansion include the **Big Bang Model**, which suggests the universe originated from a dense singularity **13.8 billion years ago** and the **Lambda CDM Model**, which describes how both **matter** and **dark energy** influence the universe's expansion in opposing ways. The **Hubble Constant** is used to measure this expansion.

The **Hubble constant** is calculated by analyzing changes in the **Cosmic Microwave Background (CMB)** and using the **Cosmic Distance Ladder**, which involves measuring distances to objects through **redshift** (when moving away) and **blueshift** (when moving towards Earth).

Property	Dark Matter	Dark Energy
Composition	Unknown subatomic particles	Unknown form of energy
Density	About 5 times the density of normal matter	Very low density, much less than density of dark matter
Gravity	Attracts other objects	Opposes the force of gravity
Effect on the universe	Slows the expansion of the universe	Accelerates the expansion of the universe
Amount in the universe	-27%	-68%
Distribution in the universe	Concentrated in galaxies and galaxy clusters	Uniform throughout space
Evidence for existence	Gravitational lensing, galaxy rotation curves, and the cosmic microwave background	Accelerated expansion of the universe
Proposed particles	WIMPS, axions, and sterile neutrinos	Cosmological constant, quintessence, and phantom energy

■ Solar storms

➤ Recently, Earth experienced a **G5-level solar storm**, the strongest in two decades.

Solar storms are massive bursts of energy from the Sun, occurring when large eruptions on the Sun's surface, often with **solar flares** and **coronal mass ejections (CMEs)**, accelerate charged particles to extremely high speeds. Solar storms are classified from **G1 (Minor)** to **G5 (Extreme)**, with **high-speed solar winds** causing geomagnetic storms. These storms occur during the **Solar Maximum**, a period of peak solar activity. A **solar flare** is an intense burst of radiation, while **CMEs** are vast clouds of plasma (hot, ionized gas) and magnetic fields ejected from

the Sun near **sunspots**. During a **solar storm**, ejected particles from the Sun can travel at over a million miles per hour, interacting with Earth's magnetic field and causing disturbances. **Sympathetic Solar Flares** result from multiple eruptions across the Sun's magnetic field. The Sun experiences **11-year activity cycles**, alternating between high and low activity. The **solar maximum**, the peak phase, brings frequent solar storms and sunspots due to the Sun's complex and twisted magnetic fields.

■ National Space Day (NSD)

➤ India celebrated its maiden **National Space Day (NSD) on 23rd August 2024.**

National Space Day (NSD) commemorates achievement of India's **Chandrayaan-3 mission**, which marked the soft landing of the **Vikram Lander** on the lunar surface on **August 23, 2023**. This mission, a follow-up to **Chandrayaan-2** (2019), made India the **fourth country**, after the **US, Russia and China**, to soft-land on the Moon. The landing site is called named '**Shiv Shakti**'.

Following the landing **Pragyan Rover** was successfully deployed, further advancing lunar exploration. The mission utilized the **Geosynchronous Satellite Launch Vehicle Mk III**, with key payloads like the **Chandra's Surface Thermophysical Experiment (ChaSTE)** and the **Alpha Particle X-ray Spectrometer**.

■ Air Breathing Propulsion Technology

➤ ISRO carried out the **second experimental flight** for the demonstration of **Air Breathing Propulsion Technology**.

Air Breathing Propulsion Technology uses atmospheric oxygen for combustion, eliminating the need for an oxidizer. This reduces vehicle mass, enabling **low-cost space transportation** and improving **payload fraction**. The three main types

are **Ramjet** (efficient at **Mach 3**), **Scramjet** (efficient at **hypersonic speeds**) and **Dual Mode Ramjet (DMRJ)** (operates in both **subsonic** and **supersonic** modes).

■ RLV LEX

➤ ISRO has successfully completed its **Reusable Launch Vehicle (RLV) technology demonstrations**.

The **RLV LEX** is part of the **RLV-Technology Demonstration Programme**, designed to develop key technologies for a fully **reusable launch vehicle** to enable low-cost access to space. **RLV LEX-03** mission simulated **high-speed landing**

conditions for a vehicle returning from space. The test was conducted with a winged vehicle, named '**Pushpak**', which is designed to glide horizontally, unlike SpaceX's Falcon 9 that lands vertically.

SPACE MISSIONS IN NEWS

■ Venus Orbiter Mission (VOM)

➤ The Union Cabinet has approved the **Venus Orbiter Mission (VOM)**. The VOM, set for launch in **2028** aboard the **Launch Vehicle Mark-3 (LVM-3)**, is India's first mission to Venus. It aims to examine dust in Venus' atmosphere and its **airglow**, map the planet's surface topography, study the **solar X-ray spectrum** and investigate its sub-surface characteristics. The mission will demonstrate cutting-edge technologies such as **aerobraking** and **thermal management techniques**. Key payloads include **Venus Advanced Radar for Topside Ionosphere and Subsurface Sounding (VARTISS)** and the **Venus**

Orbit Dust Experiment (VODEX). Venus, Earth's **nearest planetary neighbor**, is often called "**Earth's twin**" due to its similar size and shape. It has an orbital period of **224.7 Earth days** and is located **108.2 million km** from the Sun. The planet experiences a **runaway greenhouse effect**, making it the hottest in our solar system, with an atmosphere filled with **sulfuric acid clouds**. **Phosphine**, a potential sign of microbial life, has been found in its clouds. Venus rotates **east to west**, unlike most planets. Past missions to Venus include **Mariner 2** (1962), **Venera 7** (1970) and **Magellan** (1990), with future missions like

NASA's **DAVINCI** and **VERITAS**, as well as the

ESA's **EnVision**.

■ **Daksha project**

➤ **IIT Bombay** is leading the **Daksha project**. The project aims to build two **high-energy space telescopes** to study **explosive astrophysical sources**. Key objectives include detecting,

localizing and characterizing high-energy counterparts to **gravitational wave sources** and conducting **high-sensitivity studies of Gamma-Ray Bursts (GRBs)**.

■ **OSIRIS-REx (NASA)**

➤ Studied asteroid **Bennu**. Returned a sample from **Bennu**, thought to be a "time capsule" from the birth of our solar system.

■ **Lunar Trailblazer & PRIME-1 (NASA)**

➤ To look for **water** on the Moon, with **PRIME-1** drilling.

■ **Psyche (NASA)**

➤ Aims to explore the origin of planetary cores. **Psyche** is believed to have a high metal content.

■ **MMX (JAXA)**

➤ To study Mars moon **Phobos** and **Deimos**.

■ **Shenzhou 16 (China)**

➤ Sent 3 humans to **Tiangong** space station. Created a world record with **17 humans** in orbit, 6 aboard **Tiangong** and 11 on the **ISS**.

■ **Hera (ESA)**

➤ To study the **Didymos-Dimorphos** asteroid system.

■ **Chandrayaan-3 (ISRO)**

➤ Made a soft landing on the **Moon**. India became the 4th country to soft-land a spacecraft on the Moon. 1st spacecraft to land near the **South Pole** of the Moon.

■ **DART mission**

➤ NASA's mission to the **Didymos-Dimorphos** asteroid system in 2022, successfully changed **Dimorphos's** orbit to test a planetary defense technique called **kinetic impact**.

■ **Aditya L1 (ISRO)**

➤ India's 1st mission to study the **Sun** and **space weather**. Will travel 1.5 million kilometers to the 1st **Lagrange point (L1)** between the Sun and Earth.

■ **Europa**

➤ A moon of **Jupiter**, smaller than Earth's Moon, with a surface made of ice and a likely saltwater ocean beneath.

■ **Europa Clipper (NASA)**

➤ To explore **Europa**, **Jupiter's** moon.

■ **Volatiles**

➤ Molecules that easily vaporize (like water and CO₂) at lunar temperatures, which may provide resources for future human exploration.

■ **Artemis II (NASA)**

➤ To send 4 humans to the Moon for 10 days.

■ **SIMPLEx**

➤ **Small, Innovative Missions for Planetary Exploration** - NASA's low-cost planetary missions program.

■ **VIPER (NASA)**

➤ To survey **water** at the south pole of the Moon.

■ **Luna-25**

➤ Russia's 1st independent lunar mission, which crashed onto the Moon near its **South Pole**.

■ The Hakuto mission

➤ The 1st privately-led lunar mission (Tokyo-based), which also crashed on the Moon after 5 months in space.

■ Juno Mission (NASA)

➤ The mission's goals include understanding how Jupiter formed and how it contributed to the formation of the solar system.

■ PACE Mission (NASA)

➤ PACE satellite aims to study the impact of climate change on the ocean and atmosphere, focusing on plankton, aerosols, clouds and ocean ecosystems.

■ NASA MAVEN mission

➤ Studies Mars' upper atmosphere to understand the loss of the planet's atmosphere over time.

■ Aditya-L1

➤ Launched in 2023, **Aditya-L1** was successfully inserted into its **halo orbit** around the **Lagrange L1 point** in early 2024, with a full revolution taking **178 days**. **Aditya-L1** is India's first space mission dedicated to studying the Sun. The mission's primary objectives are to study the **Sun's upper atmosphere**, including the **chromosphere** and **corona** and to explore the dynamics behind **solar flares** and **coronal mass ejections (CMEs)**.

Halo orbits are three-dimensional, periodic orbits created through the interaction between gravitational forces of two large bodies and the centrifugal force on a spacecraft. These orbits,

■ Earth Observation Satellite EOS-08

➤ ISRO launched the **Earth Observation Satellite EOS-08**. ISRO launched the **Earth Observation Satellite EOS-08** under the **SSLV-D3/EOS-08 mission** using the **Small Satellite Launch Vehicle (SSLV)-D3** from the **Satish Dhawan Space Centre**, Sriharikota. The satellite is set to operate

■ Dragonfly mission

➤ A NASA mission to explore Saturn's moon Titan. It will use a rotorcraft-lander to study the moon's surface and subsurface and search for signs of life.

■ EUROPA CLIPPER

➤ NASA's Europa Clipper is a mission to Jupiter's moon Europa to study its icy shell, ocean and geology and determine if Europa could support life.

■ EarthCARE

➤ A satellite mission that studies clouds and aerosols to improve climate change predictions. It's a collaboration between the European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA).

linked to points like **L1**, **L2**, or **L3**, provide stable positions with minimal fuel consumption, with **L1** offering continuous solar observation without interruptions. **Lagrange points** are positions where gravitational forces of two bodies balance the necessary centripetal force for a smaller object to stay in orbit. There are **five Lagrange points** (L1 to L5), with **L4** and **L5** being stable. Other missions studying solar activity include NASA's **Parker Solar Probe**, the first human-made object to fly close to the Sun and the **Interface Region Imaging Spectrograph**, which investigates solar atmospheric dynamics and eruptions.

in a **circular Low Earth Orbit**. EOS refers to **Earth remote sensing satellites**, which are designed to observe and collect data about Earth from space. **Earth Observation (EO) satellites** provide real-time data for disaster management, climate studies etc.

■ TRISHNA Mission (Thermal Infra-Red Imaging Satellite for High-resolution Natural Resource Assessment)

➤ The TRISHNA mission is a collaborative effort between ISRO and CNES (French Space Agency). TRISHNA Mission aims to monitor the energy and water budgets of the continental biosphere in detail, with a focus on quantifying terrestrial water stress and water use, as well as providing high-resolution observation of water

quality and dynamics. TRISHNA will operate in a Sun-synchronous (SSO) orbit, which is a specific type of polar orbit where satellites are synchronized to remain in the same position relative to the Sun, ensuring consistent illumination for observation.

■ National Information System for Climate and Environment Studies programme

➤ Operated by ISRO and the Department of Space, in collaboration with other ministries, the NICES programme is a key initiative under the National Action Plan on Climate Change. The main objective of NICES is to generate and

disseminate long-term Essential Climate Variables (ECVs) derived from Indian and other Earth Observation satellites, helping in climate monitoring and action.

■ AstroSat

➤ AstroSat observations have led to the discovery of irregular emission of high-energy X-ray photons from a Black Hole X-ray binary system. Launched by ISRO in 2015 using PSLV-C30, AstroSat operates in Low Earth Orbit. As India's first dedicated multi-wavelength space observatory, it aims to study celestial sources

across X-ray, optical and UV spectral bands simultaneously. Its key objectives include understanding high-energy processes in binary star systems, detecting new transient X-ray sources and studying star birth regions. AstroSat is equipped with five payloads for multi-wavelength observations.

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TELESCOPES IN NEWS



MACE

The Major Atmospheric Cherenkov Experiment (MACE) Observatory, inaugurated by the Department of Atomic Energy (DAE) at Hanle, Ladakh, is the largest imaging Cherenkov telescope in Asia and the second largest globally. Located at an altitude of approximately 4,300 m, it is the highest of its kind. MACE aims to observe high-energy gamma rays to study energetic phenomena like supernovae and is indigenously built by the Bhabha Atomic Research Centre (BARC).



SKA

The Square Kilometer Array (SKA), which recently became partially functional, is set to become the world's largest radio telescope. With over a square kilometer of collecting area, SKA will operate from two large telescopes in South Africa and Australia. Its objectives include understanding the universe's birth, detecting gravitational waves and exploring dark matter and cosmic magnetism. India joined the SKA Organization in 2012 and has been actively involved in its pre-construction phase.



TAO

The University of Tokyo Atacama Observatory (TAO) project, is located in the Atacama Desert of Chile. It aims to construct an optical-infrared telescope at the summit of Cerro Chajnantor. This site, the highest astronomical location in the world, offers exceptional observing conditions due to its high altitude, thin atmosphere and arid climate, enabling nearly full-range near-infrared observations.

DISEASES IN NEWS

Tuberculosis

Global TB Report 2024 highlights that India accounts for 26% of the global TB burden and is the leading country in multidrug-resistant (MDR) and Rifampicin-resistant TB.

- TB is a bacterial infection that usually affects the lungs.
- **TB Types:** Pulmonary (affects lungs) and Extrapulmonary (affects other body areas like gastrointestinal and liver).
- **Transmission:** Airborne, primarily through coughing, sneezing, or speaking.
- **Symptoms:** Prolonged cough, chest pain, weakness and sometimes blood.

India's Initiatives:

- **National Tuberculosis Elimination Programme (NTEP)**
- **Pradhan Mantri TB Mukht Bharat Abhiyan**
- New BPaLM regimen reducing treatment time to 6 months.
- Additional support through **Nikshay Poshan Yojana** and **National TB Call Centre**.

WHO Initiative: End TB Strategy, aiming for an 80% reduction in TB incidence by 2030.

Monkeypox (MPOX)

WHO Declared Monkeypox a Public Health Emergency
due to its spread and global concern.

- Mpox is an illness caused by the monkeypox virus.
- **Transmission:** Zoonotic, from animals to humans, mainly in central and western Africa.
- **Symptoms:** Rash, fever and swollen lymph nodes.
- **Vaccine:** MVA-BN vaccine, prequalified by WHO.
- **India's Response:** Serosurvey by ICMR to monitor spread.

Neglected Tropical Diseases (NTDs)

India has eliminated **Trachoma**, becoming the third country in
South-East Asia to do so after **Nepal** and **Myanmar**.

- **NTDs:** Conditions such as **hookworm**, **dengue** and **lymphatic filariasis**.
- **Trachoma:** An eye disease caused by bacterium **Chlamydia trachomatis** that can lead to blindness if untreated.

Antimicrobial Resistance (AMR)

Jeddah Commitments focus on **One Health** approach to combat AMR.

- **Global Initiatives:** WHO's **Global Action Plan** and **Global AMR Surveillance System (GLASS)**.
- **India's Response:** **National Action Plan on AMR (NAP-AMR)** and the introduction of **Nafithromycin** for resistant infections.
- **Dysbiosis:** Imbalance in the body's microbiome caused by the irrational use of antibiotics.

Avian influenza

Avian influenza, caused by **Type A** viruses, has led to the death
of over 300 million birds worldwide.

- These viruses are classified based on two surface proteins, hemagglutinin (H) and neuraminidase (N), with 18 H and 11 N subtypes identified.
- Birds typically carry 16 H and 9 N subtypes, with additional subtypes found in bats. The disease is classified **into low pathogenic (LPAI) and highly pathogenic (HPAI) strains**, like H5N1, which causes severe outbreaks.
- HPAI can impact human health, though bird-to-human transmission remains limited. Vaccine: No.

Zika Virus

Cases of Zika Virus was in news.

- Zika virus, spread by **Aedes** mosquitoes, is non-fatal but poses risks, especially for pregnant women, causing microcephaly in newborns.
- It can also lead to **Guillain-Barré syndrome** and other neurological disorders.
- Detection is via RT-PCR, a cost-effective method.

- Currently, no vaccine or specific treatment exists. Preventive measures focus on controlling mosquito populations.

Chandipura Virus

WHO warned that India's current Chandipura virus outbreak is the largest in 20 years.

- Chandipura virus, part of the Rhabdoviridae family, causes outbreaks of acute encephalitis syndrome (AES) in India.
- It is transmitted by **vectors like sandflies and mosquitoes**. Symptoms include fever, vomiting and neurological issues.
- **No vaccine or specific treatment is available**. Preventive efforts focus on vector control and public awareness.

HEALTH & PHARMACEUTICALS

■ Fixed-Dose Combination (FDC) Drugs

➤ The Ministry of Health and Family Welfare has recently banned 156 Fixed-Dose Combination (FDC) medicines, raising concerns about their safety and regulation.

FDCs are pharmaceutical products containing two or more active ingredients in a single dosage form, such as tablets, capsules, or injectables, commonly used to treat ailments like cough, cold, fever and infections. These drugs, often called cocktail drugs, require approval under the **Drugs and Cosmetics Act, 1940**, as they are classified as **New Drugs** by the **Central Drugs Standard Control Organisation (CDSCO)**. The CDSCO, under the Ministry of Health and Family Welfare, ensures the quality, safety and efficacy of drugs,

medical devices and cosmetics, while **State Drug Regulatory Authorities (SDRAs)** oversee drug manufacturing licenses and prevent the sale of spurious drugs. Additionally, the **National Pharmaceutical Pricing Authority (NPPA)**, established in 1997 under the Department of Pharmaceuticals, regulates drug pricing, revises the cost of controlled drugs and enforces the **Drugs (Prices Control) Order, 2013** to ensure affordability.

■ Trans-fat Elimination

➤ **Trans-fat Elimination** is in the news as the **World Health Organization (WHO)** published its report on progress toward global trans-fat elimination, covering 2018-2023.

Trans fats (or **trans-fatty acids**, TFA) are unsaturated fatty acids that have been partially hydrogenated, making them the worst type of fat. There are two types: **natural trans fats**, found in small amounts in meat and dairy products, which are not considered harmful and **artificial trans**

fats, also known as **industrial-produced trans fats**, formed when hydrogen is added to vegetable oil, turning it into solid **partially hydrogenated oil (PHO)**. PHO contains 25-45% trans-fat on average and is commonly used in processed foods, offering no nutritional benefits.

■ Omega-3 Fatty Acids

➤ A study shows that regular use of **fish oil supplements** might increase the risk of **stroke**.

Omega-3 fatty acids, including **eicosapentaenoic acid (EPA)**, **docosahexaenoic acid (DHA)** and **alpha-linolenic acid (ALA)**, are essential fats that

reduce inflammation and lower **triglyceride** levels. Key sources include **nuts, seeds, plant oils** and **seafood**.

■ Glycemic Index (GI)

➤ Recent studies have linked **GI** to an increased risk of **Type II diabetes** and **cardiovascular diseases**.

Glycemic Index (GI) measures how quickly carbohydrate-rich foods raise blood sugar levels. Foods are ranked on a scale from **0 to 100**, with **glucose** having a GI of 100. Additionally, **Glycemic Load (GL)** combines the GI with the total carbohydrate content in a serving to estimate how much and how quickly blood sugar will rise after consuming a particular food.

GI	GI rating	Blood glucose level	A few examples
High	Over 70	Increases rapidly	<ul style="list-style-type: none"> • White rice • White bread • Baked potato • Water melon
Medium	56 to 69	Increases moderately	<ul style="list-style-type: none"> • Brown rice • Oatmeal • Macaroni cheese • Sugar
Low	Less than 55	Increases slowly	<ul style="list-style-type: none"> • Chickpeas • Bean sprouts • Spaghetti • Carrots

■ Probiotic

➤ Scientists have uncovered a new strain of **lactic acid bacterium** that could serve as a promising **probiotic** for the **food** and **pharmaceutical industries**.

Probiotics are live microorganisms, such as **bacteria** and **yeasts**, that provide health benefits when consumed. A common example, **Lactobacillus acidophilus**, is found in the human

gut and helps in the breakdown of **lactose** into **lactic acid**. Probiotics are also available in **yogurt** and other **fermented foods**.

■ Xylitol

➤ Recent studies suggest that the artificial sweetener **xylitol** may pose **health risks**.

Xylitol is a **sugar alcohol** commonly used in sugar-free products like **chewing gum**, **diabetes-friendly foods** and **oral-care products**. Although

xylitol has sugar-like properties, it is a unique compound combining traits of both **sugar molecules** and **alcohol molecules**.

■ Weight Loss Drugs

➤ Research reveals that **weight loss drugs** designed to combat **obesity** may also benefit the treatment of various other diseases.

These drugs mimic the action of **glucagon-like peptide 1 (GLP-1)**, a hormone that regulates **insulin production** and reduces **glucagon**

production, leading to suppressed appetite and slower digestion, thereby aiding in **weight loss**.

COMPUTING & ELECTRONICS

■ Supercomputers

➤ Three **Param Rudra Supercomputing Systems** and new **High-Performance Computing (HPC) systems**, **Arka** and **Arunika** were launched.

Arka and **Arunika**, aim at improving accuracy in weather and climate predictions, such as for tropical cyclones and heavy precipitation. These

advancements are part of India's **National Supercomputing Mission (NSM)**, which aims to make India a global leader in supercomputing. The mission envisions installing supercomputers with a cumulative capacity of 45 PetaFlops and connecting them through the **National Supercomputing Grid**. India's supercomputing history includes the **PARAM 8000**, its first

supercomputer and AIRAWAT, its largest and fastest AI supercomputer, ranked 75th in the **Top 500 Global Supercomputing List of 2023**. The world's fastest supercomputer, **Frontier** (USA), is capable of over one quintillion operations per second.

■ India Semiconductor Mission

➤ The Union Cabinet recently approved the establishment of the **fifth semiconductor unit in Sanand, Gujarat, under the India Semiconductor Mission (ISM)**.

The ISM is a specialized division within the **Digital India Corporation** under the Ministry of

Electronics and Information Technology (MeitY). It serves as the nodal agency for implementing the schemes approved under the **Semicon India Programme**.

Semiconductors are materials with properties that lie between those of conductors and insulators. They can either be made from a single element (like **silicon**) or a combination of elements (like **gallium nitride**, a compound semiconductor). These materials are crucial in various electronic components, such as **diodes, transistors, integrated circuits** and telecommunication systems.

OTHER CONCEPTS IN NEWS

Kavach

➤ RailTel Corporation of India has secured a **₹2.88 billion (\$33.2 million)** tender to install the **Kavach** train protection system across **71 railway stations** in India. **Kavach** is an **indigenously developed Automatic Train Protection (ATP)** system designed to enhance railway safety by automatically applying brakes if a train **overshoots a red signal** and preventing **head-on collisions** between equipped locomotives. It enables **SoS communication, centralized live monitoring and hooter activation** at level crossings, especially in **low-visibility conditions** like fog. Utilizing **Traffic Collision Avoidance System (TCAS)** with **RFID-based communication**, it alerts loco-pilots about **signals and speeds**, significantly improving railway safety and operational efficiency.

GNSS-based Electronic Toll Collection (ETC) System

➤ India is transitioning to a **GNSS-based Electronic Toll Collection (ETC)** system to replace the **FASTag** system. **GNSS-Based Electronic Toll Collection (ETC)** uses **satellite-based imaging** to track vehicle movement and charge tolls based on **distance travelled** instead of fixed toll booths. It relies on **GNSS-enabled On-Board Units (OBU)** in vehicles and **Automatic Number Plate Recognition (ANPR)** cameras on highways for toll calculation. **Geo-fencing** establishes virtual zones that trigger automatic toll deductions.

Nano Fertilisers

➤ IFFCO received **FCO 1985 approval** for **Nano Zinc** and

Nano Copper liquids. **Nano Fertilisers** are nutrient-rich nanomaterials that enable **controlled release** and **slow diffusion** into the soil, enhancing plant absorption. **Nano Zinc** supports **enzyme functions and growth**, while **Nano Copper** aids **chlorophyll synthesis and seed production**. Previously, IFFCO's **nano-liquid urea and DAP** were approved. Government efforts include the **Nano Mission (2007)** under **DST & IFFCO's Nano Fertilizer Plant in Phulpur, Prayagraj**.

Lithium

➤ Lithium has gained significant attention due to the discovery of **1,600 tonnes** of lithium resources in **Mandya district**. Often referred to as "**white gold**", lithium is a soft, silvery-white alkali metal with the lowest density among metals. It reacts vigorously

with water and doesn't naturally occur as a pure metal. Instead, lithium is found combined in small amounts in **igneous rocks** and **mineral springs**. Important minerals containing lithium include **Spodumene, Petalite, Lepidolite** and **Amblygonite**. The extraction of lithium involves the electrolysis of molten **lithium chloride** and **potassium chloride** to produce the metal, which is critical for the production of batteries used in electronic

devices, electric vehicles and renewable energy storage systems.

Critical minerals

➤ Critical minerals have gained attention due to their pivotal role in modern technologies. Critical minerals are minerals that are essential for modern technology and economic development. India has identified 30 critical minerals. These are **Antimony, Beryllium, Bismuth, Cobalt, Copper,**

Gallium, Germanium, Graphite, Hafnium, Indium, Lithium, Molybdenum, Niobium, Nickel, PGE, Phosphorous, Potash, REE, Rhenium, Silicon, Strontium, Tantalum, Tellurium, Tin, Titanium, Tungsten, Vanadium, Zirconium, Selenium and Cadmium. India is a member of the **Mineral Security Partnership (MSP)**, aimed at strengthening global mineral supply chains.

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