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SCIENCE & TECHNOLOGY

Classroom Study Material 2024

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SCIENCE AND TECHNOLOGY

Table of Contents

A Note for Students

Dear Students,

Understanding current affairs can add depth to your perception of intricate issues and help you form nuanced perspectives, especially in the context of the Mains examination.

In light of this, Mains 365 Science and Technology documents attempt to simplify your mains preparation.

Science and Technology Mains 365 Key Features

Concise and Objective:
Brief, objective presentations of each topic, incorporating relevant examples and figures to ensure clarity and precision in your answers.

Enhanced Infographics:
Designed for effective understanding of Science and Technology phenomena, these infographics will make complex concepts easier to grasp.

Topic at a Glance:
This feature summarizes static topics and recurring important themes, providing a quick review.

Sectoral Applications:
The document delves into the sectoral applications of various technologies like AI, biotechnology, nanotechnology, and more.

Weekly Focus:
QR code-linked list of relevant weekly focus documents, keeping you updated with the latest developments and trends in Science and Technology.

Appendix and Previous Years Questions (PYQs):
Includes an appendix of important scientists and their contributions, and a segregated list of previous years' questions from 2013 to 2023, organized topic-wise.

We sincerely hope the Mains 365 Science and Technology documents will guide you effectively in your preparation and aid you in scoring better in your Mains examination. Remember,

, "Learn everything you can, anytime you can, from anyone you can. There will always come a time when you will be grateful you did."

All the Best! Team VisionIAS

1. IT, COMPUTERS, ROBOTICS

1.1. FOURTH INDUSTRIAL REVOLUTION

FOURTH INDUSTRIAL REVOLUTION (4IR) AT A GLANCE

- Refers to **digital transformation of the manufacturing industry by new technologies such as AI, AM/3D Printing, augmented/virtual reality, and the Internet of Things (IoT).**
- Term was coined by **Klaus Schwab, founder of the WEF.**
- Also, refers to concept of **smart factories** (fully connected cyber-physical systems)

Significance/Applications

- **Better digital infrastructure** and **massive Productivity boom due to** digital communication, digital energy (e.g. smart power grids), and digital health.
- **In healthcare,** used for monitoring, recording, visualisation and **sharing of symptoms using wearable devices,** etc.
- **India can develop** itself as a **global manufacturing hub.**
- Makes **supply chains more efficient, reduction in factory waste** and increased productivity.

Initiatives

- **Centre for the Fourth Industrial Revolution (India)** is collaboration between the WEF and the Government of Maharashtra, coordinated by the NITI Aayog.
- **Urban transformation,** India Hub for Urban Transformation in partnership with Smart City Mission.
- **Education 4.0** in partnership with **WEF and UNICEF**
- **FIRST Cancer Care on the lines of FIRST Healthcare (Fourth Industrial Revolution for Sustainable Transformation of Healthcare)** has been developed in Meghalaya.
- **Smart Advanced Manufacturing and Rapid Transformation Hub (SAMARTH) - Udyog Bharat 4.0,** an initiative of Ministry of Heavy Industry.

Constraints/Challenges/Concerns

- **Environmental Impacts** due to increased digital environment footprint.
- **Cyber security challenges** include privacy issue, etc.
- **Fear of corporate takeover** as it may be difficult to regulate big tech companies.
- **Other: Lack of skilled workforce,** etc.

Way Forward

- Enhancing **regulatory framework** while also protecting the rights and privacy of individuals.
- **Developing ethical guidelines** to ensure that technologies are used for the benefit of society.
- **Promoting digital literacy,** particularly among those who may not have access to technology.
- **Emphasizing on cyber security** to protect data and intellectual property.
- **Investing in up skilling and reskilling,** government and the industries should focus on bridging this gap.

1.2. ARTIFICIAL INTELLIGENCE TECHNOLOGY

ARTIFICIAL INTELLIGENCE (AI) AT A GLANCE

- Enables computers to **simulate human intelligence and problem-solving capabilities.** It includes learning, reasoning, problem-solving, and language understanding.
- **Potential of AI:** AI is expected to raise India's annual growth rate by 1.3 percentage points by 2035 and can add $1 trillion to India's economy by 2035 **(NITI Aayog).**

Initiatives

- **India AI Mission**
- **National Strategy on Artificial Intelligence (NSAI),** by NITI Aayog
- **Centre of Excellence** for Artificial Intelligence by NIC
- **New Delhi Declaration of Global Partnership on Artificial Intelligence (GPAI)** to mitigate risks arising from AI.
- **Future Skills PRIME'** for Reskilling/Up-skilling of IT Manpower for Employability in 10 new/emerging technologies.
- **National Artificial Intelligence Portal,** one-stop digital platform for sharing of resources related to AI in India.
- **Other:** Responsible AI for Youth 2022, 'YUVAi: Youth for Unnati and Vikas with AI'

Constraints/Challenges/Concerns

- **Lack of Transparency:** Internal workings of AI Based model are not known by users (considered as black boxes)
- **Data Privacy and Security:** Fear of Data Breaches and Privacy Violations
- **Ethical Issues:** Biased AI models can make decisions that unfairly target or exclude certain groups, etc.
- **Regulation and Governance:** Lack of clear regulations and guidelines for applications.
- **Infringing Intellectual property rights:** Many artists have claimed that their artworks were recreated by AI.

Way Forward

- **International Cooperation:** To establish basic global standards.
- **Proportionate Governance:**
  - Policymakers and regulators need to be in a position to deploy dynamic capabilities to sense, plan, and reconfigure competencies in response to AI innovation.
- **Private sector accountability:** Increased transparency by private actors in developing frontier AI capabilities, appropriate evaluation metrics, etc.
- **Adopting Asilomar AI Principles:** By countries in development and deployment.

1.2.1. INDIAAI MISSION

Why in the news?

The Union cabinet has approved over Rs 10,300 crore for **IndiaAI Mission** to strengthen Artificial Intelligence (AI) Innovation Ecosystem.

About IndiaAI Mission

- **Aim**:
  - Establish an ecosystem for AI innovation through **public-private partnerships.**
  - Deploying over **10,000 Graphics processing units (GPUs)** for advanced AI computing infrastructure.
  - Driving **responsible, inclusive growth of India's AI ecosystem** through democratization, data quality improvement, and indigenous AI capabilities development.

- **Nodal Ministry:** Ministry of Electronics and Information Technology (MeitY).
- **Funding:** Over **5 years** through a public-private partnership model.
- **Implementing agency:** 'IndiaAI' Independent Business Division under Digital India Corporation.
- **Components:** Compute Capacity, Innovation Centre, Datasets Platform etc.

Pillars of IndiaAI and Related Schemes		
AI in Governance	**AI Computr & Systems**	**Data for AI**
• **BHASHINI - [BHASHa INterface for India]** an AI-based language translation tool for Indian languages. • **India Stack and AI**	• **AIRAWAT:** India's AI supercomputer installed at C-DAC, Pune. • **National Supercomputing Mission** • **MeitY Quantum Computing Applications Lab**	• **Data Management Office**: Helps in standardisation of data management. • **India Datasets Program and India Data Platform:** Provides access to non-personal datasets for start-ups and researchers.
AI, intellectual property (IP) & Innovation	**Skilling in AI**	**AI Ethics & Governance**
• **Centre of Excellence for Artificial Intelligence** • **MeitY Start-up Hub** • Proposed **National Centre on AI (NCAI)**	• **Future Skills Prime:** Joint initiative by Nasscom & MeitY for AI certification programs. • **Responsible AI for Youth:** Program for government making school students AI ready.	• **RAISE:** Responsible AI for Social Empowerment, by MeitY • **Digital Sansad app** is an AI-powered platform to transcribe house proceedings at the new Parliament.

Regulation of AI

Today, AI is being used in different spheres thus there is need to regulate it.

Challenges associated in regulating AI

- **Innovation Gatekeeping:** Decisions about the development of AI are overwhelmingly in the hands of the big tech companies.
- **Technological Advancement**: Frontier AI systems may amplify risks such as disinformation through the use of algorithms.
- **Technological humanization**: Creating consensus among different countries over ways to regulated AI.
  - Determining liability in cases where **AI's Algorithmic Bias** can cause harm is complex.

Key Initiative taken to Regulate AI

- **UN General Assembly (UNGA):** Adopted a landmark resolution on the promotion of **"safe, secure and trustworthy"** artificial intelligence (AI) systems.
- **European Union:** EU's AI Act is **world's first comprehensive AI law**.
  - It **classifies AI systems** into four tiers of risk and different tiers are subject to different regulations.
- **Other**:
  - **Bletchley Declaration for AI:** It was signed by 29 countries including United States, China, Japan, United Kingdom, France, and **India**, and the European Union.
    - ✓ **Objective:** To address the **risks and responsibilities involved in AI comprehensively**
  - **Hiroshima AI Process (HAP) by G7 to regulate AI:** It aims to promote safe, secure, and trustworthy AI.

1.2.2. AI AND AGRICULTURE

AI AND AGRICULTURE AT A GLANCE

- The application of AI in agriculture has been widely considered as one of the most viable solutions to **address food inadequacy** and to adapt to the **need of a growing population.**

Significance/Applications

Intelligent crop planning

Helps in improving the overall harvest quality and accuracy – known as precision agriculture. **E.g SENSAGRI, Sensor-based Smart Agriculture**

Smart Farming

Helps in nutrition management, promotion of one health, mechanization of farms, soil analysis, pest and weather predictions. **E.g. AgroStar Startup**

Farmgate-to-fork

Market-based intelligence, traceability and quality of logistics, supply chain optimization, emergence of fintech, and demand and price production improves efficiency. **E.g. Stellapps**

Data-driven agriculture

Data driven AI can enhance agricultural productivity and help in creation of a national market through analysis. **E.g. BharatAgri App**

Key Initiatives

- **National Strategy for Artificial Intelligence** of NITI Aayog emphases on implementing AI in agriculture.
- **AI for Agriculture Innovation (AI4AI) initiative**, launched by the World Economic Forum.
  - Under it, **'Saagu-Baagu' initiative** was launched to promote innovation in agriculture in Telangana.
- **Kisan-eMitra,** an AI Chatbot for the Pradhan Mantri Kisan Samman Nidhi (PM-KISAN) Scheme
- Microsoft in collaboration with **International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)**, developed an AI Sowing App.
- **NITI Aayog and IBM** have partnered to develop a crop yield prediction model using AI to provide real time advisory to farmers

Constraints/Challenges/ Concerns

- **Lack of datasets** needed to train AI models.
- **Initial investment** required for AI-driven machinery, sensors, and software can be prohibitively **expensive.**
- **Marginalisation and the digital divide** might prevent smallholders from using advanced technologies.

Way Forward

- Require a lot of **data to train machines** and make accurate predictions.
- Improving **technological infrastructure** in rural areas.
- **Bridging** the gap between farmers and AI engineers to make efficient AI Models for fields.
- **Providing financial support and subsidies** to Research Institute to develop region specific AI models and Application.

1.2.3. AI AND HEALTH CARE

AI AND HEALTH CARE AT A GLANCE

- The emergence of AI in healthcare has been ground-breaking, reshaping the way we **diagnose, treat and monitor patients.**

Significance/Applications

Diagnosis and Treatment Planning

Analyses imaging (such as X-rays), helps in identifying diseases. **E.g. S.A.R.A.H. Smart AI** Resource Assistant, developed by WHO

Clinical research and discovery

Examines data on drug interactions and side effects. **E.g. ProteinSGM**, a Generative AI model from the University of Toronto is used for protein designing.

Robotic Surgery

AI integrated Robot surgeries will minimize surgery-related complications.

Workforce optimization

Enables operational and cost efficiencies. **E.g. Virtual Assistants and Chatbots**

Initiatives

- **AI based Health Care Start-ups,** E.g., a non-profit AI based healthcare start-up, Wadhwani AI is developing various interventions related to the TB patient care.
- **International Centre for Transformational Artificial Intelligence (ICTAI)**, to be set up by Maharashtra government and it will focus on rural healthcare.
- Indian Council of Medical Research released **Ethical Guidelines for Application of Artificial Intelligence in Biomedical Research and Healthcare.**
- **iOncology.ai.,** designed for the early detection of breast and ovarian cancer, Launched by **All India Institute of Medical Sciences (AIIMS) Delhi**

Constraints/Challenges/Concerns

- **Biasness:** Biased result can be produced from AI models are not trained by data which represent wider section of the society.
- **Accountability:** Who will take responsibility of any mistake committed by AI based system?
- **Other:** Equitable use (in the initial phase will be unaffordable for a lot of people), fear of job loss, etc.

Way Forward

- Developing governance frameworks and **technical standards** for AI.
- Promoting cooperation on **knowledge** and **data sharing** to ensure **AI solutions** reach all communities.
- **Promoting AI models** which are **trained using diversified set** of data.

1.2.4. AI AND DEFENCE

AI AND DEFENCE AT A GLANCE

- The adoption of technology based on AI will revolutionise the Indian Military. It also places India firmly in the huge defence product market.

Significance/Applications

Border Security, Detects border intrusions, target classification, and enhance the accuracy of defence operations.	**AI-based technologies** can be used for training, ISR (Intelligence, Surveillance and Reconnaissance), logistics, UAV, advanced military weaponry, etc.	**Warfare systems** Uses AI to make operations less reliant on human input. E.g. **Vista,** AI-controlled F-16 **(Fourth generation fighter jet** of USA)	**Autonomous decision-making** reduces the chance of human error.	**Assist humans** to take precise and appropriate warfare decisions.	**Military robots** having AI can undertake operations, saving human lives.

Initiatives

- **NITI Aayog and the Ministry of Defence** partnered to build a roadmap for integrating AI within the defence forces in 2018.
- **Defence AI Council (DAIC) and Defence AI Project Agency (DAIPA)**
- **Defence India Startup Challenge (DISC),** under the Innovations for Defence Excellence (iDEX) programme
- **Department of Defence Production** has earmarked Rs 100 crore per year for AI projects for Armed Forces.
- IAF has established the **Unit for Digitization Automation, AI an App Networking (UDAAN)**

Constraints/Challenges/Concerns

- Relies on **vast amounts of data** that can become vulnerability in warfare.
- Proliferation of AI technology, especially in military contexts, raises concerns **about its spread to non-state actors and rogue nations.**
- **Ethical and legal concerns** such as the potential for autonomous weapon systems to make decision related with life-or-death.

Way Forward

- **Partnership with the Industry:** Tech companies are spending billions of dollars on AI, and many of the applications developed can be utilized in the military.
- **Managing the Human-Machine Interface:** Finding the right balance and establishing trust is a crucial area that needs greater debate and clarity within the military.
- **Establishing Data Section:** For improving accessibility of data to AI applications

1.2.5. DEEPFAKES

Why in the news?

Recently, the Centre issued an advisory to **social media intermediaries** to identify **misinformation and deepfakes.**

Key Provisions of the Advisory

- **Identify deepfakes**: Ensure that **Due diligence** is exercised and reasonable efforts are made to **identify misinformation and deep fakes**.
- **Quick action**: within the **timeframes stipulated under the IT Rules 2021**.
  - **Remove any such content** when reported **within 36 hours** of such reporting.

About Deepfakes

- Refers to **a video/image** that has been edited using **an algorithm to replace a person** in the original video/image **with someone else,** in a way that **makes the video look authentic.**
  - It uses **deep learning** to make images of fake events.
- **Deepfake imagery** could be an **imitation of a face, body, sound, speech, environment,** or any other personal information**.**

How does Deepfake work?

- Uses technologies of **deep learning, AI and photoshopping** to create images of events.
- In it, **GANs (Generative Adversarial Networks)** (a class of Machine Learning) are interplayed to create the videos.
  - **GANs** consist of generators and discriminators.
    - ✓ **Generators** take the initial data set to create new images.
    - ✓ Then, the **discriminator evaluates** the content for realism and does further refinement.
- Also employs **a variational auto-encoder**, a type of **artificial neural network** (algorithm works like human brain) that is normally used for facial recognition.
  - **Auto-encoders** detect facial features, suppressing visual noise and "non-face" elements in the process. They enable a **versatile "face swap" model** using shared features of person/image etc.

Opportunities with Deepfake technology

- **Entertainment: Voices and likenesses can be used** to achieve desired creative effects.
- **E-commerce**: Retailers could let customers use their likenesses to **virtually try on clothing.**
- **Communication**: **Speech synthesis and facial manipulation** can make it appear that a person is authentically speaking another language.
- **Research and Simulation**: Aids in training professionals in various fields by providing realistic scenarios for practice, **such as medical training.**

Concern associated with Deepfake

- **Privacy Concerns**: **Damaging content** (**breach of personal data**) featuring individuals without their consent, causes potential harm to reputations.
- **Weaponization against Women:** Women form about **90% of the victims of crimes like revenge porn, non-consensual porn**, etc.
- **Ethical challenges**: Balancing the need to **combat the negative impacts** of deepfakes with the protection of free speech and **artistic expression**.
- **Other**: **Crisis of Authenticity** (Misinformation and Disinformation), **Lack of Regulation** (Lack of a clear legal definition), Challenges in Detection, **Erosion of trust** (trustworthiness of media content), etc.

Regulatory measures applicable to deepfakes in India

- **Legal provisions:** There are **no specific legal provisions against deepfake** technology. However, some laws indirectly address deepfake, viz.,
  - **Section 66E of the IT Act of 2000**: An act involving **capturing, publishing, or transmitting** a person's images in mass media, violates their privacy.
  - **Section 66D of the IT Act of 2000**: Provides a provision to **prosecute individuals** who **use communication devices or computer resources** with malicious intent, **to cheat or impersonate someone.**
  - **Indian Copyright Act of 1957:** Provides for penalties for the infringement of copyright.

Way Forward

- **Strengthening legal framework:** Need to **establish and update laws and regulations** specifically addressing the creation, distribution, and malicious use of deepfake and associated content.
- **Responsibility and Accountability of social media platforms**: Create a **uniform standardization** that **all channels can adhere to and is common across borders.**
  - **For example**, **YouTube** has recently announced measures requiring creators to disclose whether the content is created through AI tools.
- **Other**: **International Cooperation** (for shared standards and protocols), **Invest in Research and Development** (for research into deep fake technologies, detection methods) etc.

1.3. QUANTUM TECHNOLOGY

QUANTUM TECHNOLOGY AT A GLANCE

- An emerging field powered by the principles defined by **quantum mechanics,** a subfield of physics that explains the nature and behaviour of matter and energy on the **atomic and subatomic level.**

Significance/Applications

- **Quantum communication:** Uses quantum bits, typically photons of light, for transmitting data along optical cables. Include technologies like- Quantum **key distribution.**
- **Quantum sensing and metrology:** Uses individual particles such as photons to measurements of forces, gravitation, electric fields etc.
- **Quantum computing:** Solve problems that are too complex for classical computing.
- **Quantum simulation:** Specially designed quantum computer, simulate materials or chemical reactions of the physical world.

Initiatives

- **National Quantum Mission**
- National Mission on Quantum Technologies & Applications **(NMQTA).**
- Quantum-Enabled Science and Technology **(QuEST) initiative**
- **QSim -** Quantum Computer Simulator Toolkit
- **Quantum Frontier Mission** of Prime Minister's Science, Technology, and Innovation Advisory Council (PM-STIAC)
- Setting up of dedicated labs and centres at a **military engineering institute** at Mhow, Madhya Pradesh.
- **UN designated 2025** to be international year of Quantum Science and Technology

Constraints/Challenges/Concerns

- **Technological challenges** such as difficulty in achieving and maintaining quantum superposition and entanglement long enough to complete a task.
- **Industry-academia gap** is hindering translation of research into scalable applications.
- Challenges in **upscaling the number of qubits** on a processor chip.
- **Absence of indigenous development** of critical quantum components.
- **Spending on R&D in India** remained about 0.64 % of GDP which is very low.

Way Forward

- Establishing **dedicated centres** for research to translate research into real-world applications.
- Setting priorities to **safeguard national security** such as investing in post-quantum cryptography.
- Promoting **domestic manufacturing facilities** and units for development of quantum components.
- **Revisit and rework National policies** like military doctrines, ethical guidelines etc.
- Facilitating **international cooperation.**

1.3.1. NATIONAL QUANTUM MISSION (NQM)

Why in the News?

The 1st meeting of Mission Governing Board (MGB) of **National Quantum Mission (NQM) discussed implementation strategy and timelines of NQM** as well as the formation of Mission Coordination Cell (MCC).

About Mission Coordination Cell (MCC)

- MCC will be set up as a **coordinating agency for the NQM** and will **work in coordination with the Mission Secretariat,** Department of Science of Technology **(DST).**
- MCC will be **set up in an institution identified by DST**.
- It will **function under** the overall supervision and guidance of **Mission Technology Research Council (MTRC).**
  - MTRC is responsible for providing guidance and oversight to the NQM.

About National Quantum Mission (NQM)

- **Aim: To seed, nurture and scale up scientific** and industrial R&D and create a vibrant & innovative ecosystem in Quantum Technology (QT).
- **Implementing agency:** Department of Science & Technology (DST) under the Ministry of Science & Technology.
- **Mission duration:** 2023 to 2031.
- **Establishing four Thematic Hubs (T-Hubs)**: Quantum Computing, Quantum Communication, Quantum Sensing & Metrology, and Quantum Materials & Devices.
- **Mission objectives:**
  - **Quantum Communication Network**: Establishing a secure and high-bandwidth communication infrastructure spanning 2,000 kilometres.
    - ✓ Also, inter-city **quantum key distribution (QKD)** over 2000 km.
    - ✓ QKD is a **technique of quantum communications** which enables future-proof **security of communication networks** using a **cryptographic protocol** involving components of quantum mechanics.
  - **Quantum Computing Power**: Developing quantum computers with a processing capacity of 1,000 qubits, unlocking immense computational capabilities.
  - **Magnetometer** (used for measuring the strength and the direction of magnetic fields**) and Atomic Clocks**: Advancing the development of highly sensitive magnetometers for precision measurements and reliable atomic clocks.
  - **Quantum Materials Design**: Synthesizing and characterizing novel quantum materials with tailored properties for cutting-edge device fabrication.

Conclusion

National Quantum Mission is a giant stride in the future. To realise its potential, a collaboration between businesses, universities, and government must happen. This will address the financial and human resource gaps and at the same time, aid in the creation of a national quantum research ecosystem.

1.4. BLOCKCHAIN TECHNOLOGY

BLOCKCHAIN TECHNOLOGY AT A GLANCE

- Blockchain is a **shared, immutable ledger** that facilitates the process of recording transactions and tracking assets in a business network.

Significance/Applications

- **E-Governance:** This includes Property Record Management, Digital birth, death and education certificates Management etc. **E.g. Smart Dubai initiative of UAE.**
- **Banking:** Avoiding risk of payment losses involved in banking transactions, reduces cross-borders transaction fees, corporate payments and remittances etc. crypto currency are based on it only.
- **Supply Chain:** Can create a tamper proof record to check real time information about product journey.
- **Healthcare:** By establishing a secure chain of network blockchain can help in handling the patient records, consent forms, billings and public health monitoring.

Initiatives

- **National Strategy on Blockchain,** 2021 (launched by Ministry of Electronics and Information Technology).
- Design and Development of a **Unified Blockchain Framework** for offering National Blockchain Service and Creation of Blockchain Ecosystem' Project.
- Telangana has conceptualized **India's first Blockchain District.**

Constraints/Challenges/Concerns

- **Technological Challenges**
  - ⋆ **Variable requirements for processing power,** network bandwidth, block size, Consensus etc. affect their scalability.
- **Legal & implementation Challenges**
  - ⋆ **Privacy & Regulation:** Decentralized storage on every node creates privacy challenges.
  - ⋆ **Localization hurdles:** As data redundancies are stored across all nodes on a blockchain network.

Way Forward

- **Recommendation in the National Strategy on Blockchain**
  - ⋆ A **National Level Blockchain Framework (NLBF)** for scaling deployments for developed applications, creating shared infrastructure, etc.
  - ⋆ Integration of important **National Level Services** to Blockchain such as eSign, e-Pramaan, etc.
  - ⋆ Focus on research in the domains of standards & interoperability, **scalability & performance, consensus mechanisms, security & privacy etc.**
  - ⋆ Capacity building by **conducting short term courses or bootcamps.**

1.4.1. WEB 3.0

WEB 3.0 AT A GLANCE

- Web 3.0 provides a version of the web where users have a **financial stake and more control over** the web communities they belong to.
- **India's Potential:** In 2022, India held 11% of the global Web 3.0 developer pool, ranked 3rd worldwide. (Bharat Web3 Association)

Key features of Web 3.0

- **Decentralized** data networks for storing data within a peer-to-peer interconnection using blockchain.
- **Permissionless** will allow everyone to participate on the platform without authorization.
- **Semantic Web** i.e., search and analysis by understanding the meaning of words rather than by keywords or numbers.
- **Ubiquitous** as Web 3.0 could be accessed from anywhere with anything.

Significance/Applications

- In finance, it promoted use of **cryptocurrencies and decentralized finance (DeFi).**
- In **Healthcare,** it will ensure secure and transparent health records.
- **Governance models** will become more inclusive and efficient. E.g. Decentralised Autonomous Organisations (DAO)
- **Removing platform dependence** and control by making digital activity platform transferable.

Constraints/Challenges/Concerns

- **Scalability issue** as Blockchain technology can handle **limited transactions per second.**
- Difficult to **regulate** due to **decentralized structure.** It could lead to a rise in issues like cybercrimes, hate speech, and misinformation.
- **Limited Accessibility** and slow adoption due to higher usage costs and other entry barriers like technical know-how.
- **Potential environmental implications** like high energy consumption, excessive mining etc.
- Limited **Global collaboration** due to rising Techno-geopolitics.

Way Forward

- **Dedicated and integrated program** which provides financial support and enables national-level coordination.
- Creating a **technological** and infrastructural base with reliable electricity connection, internet connectivity etc.
- Creating **conducive conditions** to encourage and support innovation via promoting Ease of Doing Business, incentives etc.
- **Recognize Web3** as a **separate vertical under Startup India.**
- Development of India-centric solutions on the lines of Aadhaar, Jan Dhan, UPI, CoWin etc.

1.5. INTERNET OF THINGS (IOT)

INTERNET OF THINGS (IOT) AT A GLANCE

- Refers to a **network of physical devices,** vehicles, appliances, and other physical objects that are embedded with sensors, software, and network connectivity, allowing them to collect and share data.
- IoT devices are also known as **smart objects.**
- Industrial IoT (IIoT) refers to **smart devices used in manufacturing, retail, health,** and other enterprises

Significance/Applications

- **Healthcare:** Monitor patients remotely and collect real-time data on their vital signs, such as heart rate, blood pressure etc.
- **Manufacturing:** Monitor machine performance, detect equipment failures and optimize production processes.
- **Agriculture:** Monitor livestock health, track equipment and manage supply chains.
- **Transportation:** Sensors can be used to monitor the fuel efficiency of connected cars, reducing fuel costs and improving sustainability.

Initiatives

- **Draft Policy on IoT** by MeitY
- **Centre of Excellence in Intelligent IoT** Sensors has been established.
- **MeitY in collaboration with NASSCOM** has initiated a programme titled FutureSkills PRIME.

Constraints/Challenges/Concerns

- **Security and privacy risks:** Vulnerable to hackers and other cyberthreats
- **Data overload:** IoT devices generate vast amounts of data, which can overwhelm businesses that are not prepared to handle it.
- **Cost and complexity:** Implementing an IoT system can be costly and complex in the initial stage, requiring significant investments in hardware, software, and infrastructure.
- **Regulatory and legal challenges:** Businesses need to comply with various data protection, privacy and cybersecurity regulations, which can vary from country to country.

Way Forward

- **Monitor and maintain devices:** IoT devices need to be monitored and maintained regularly to ensure that they are performing optimally and are not vulnerable to security threats.
- **Manage data effectively:** Businesses should have a clear data management strategy in place, including data storage, analysis, and visualization.
- **Regulation:** A framework for regulating IoT ecosystem needs to be created.

1.6. ROBOTIC TECHNOLOGY

ROBOTIC TECHNOLOGY AT A GLANCE

- **Robotic technology** includes **design, construction, operation, and use of robots,** that operate by sensing their environment, carrying out computations for decision-making, etc.
  - ★ **Classification** of robots: **Industrial, Service and Medical Robots**
- **Status:** In terms of annual industrial installations, India ranks 10th globally as per the World Robotics Report, 2022 **(Draft National Strategy for Robotics (NSR)).**

Significance/Applications

Manufacturing
Logistics and **Warehousing automation,** Process Optimization etc.

Healthcare
Surgical Robots, telemedicine area, Rehabilitation and physical therapy etc.

Agriculture
Precision farming, Crop and Soil Health Monitoring, Crop scouting, spot Spraying, etc.

National Security
Combat robots, Remotely operated vehicle, Explosive Ordnance Disposal, Mine Detection etc.

Initiatives

- **Draft National Strategy for Robotics (NSR),** released by MeitY.
- **Research & Development Centres**
  - ★ **ARTPARK–** Technology Innovation Hub under National Mission on Interdisciplinary Cyber Physical Systems (NM-ICPS)
  - ★ **Center for Advanced Manufacturing** for Robotics and Autonomous Systems (CAMRAS)
- **Capacity Building Initiative**
  - ★ **FutureSkills Prime:** Creating a revolutionary skilling ecosystem
- **Make-in-India Robots**
  - ★ **Manav:** India's first 3D-printed humanoid robot.
  - ★ **Daksha:** Remotely Operated Vehicle (ROV) developed by the DRDO
  - ★ **Vyommitra:** A spacefaring humanoid robot being developed by the ISRO

Constraints/Challenges/Concerns

- Difficult to replicate **human-like sensory perception,** from touch and vision to hearing and smell.
- **Limited Governance Mechanisms** (Absence of separate robotics legislation or legislation for allied technologies)
- Lack of **reliable & continuous** access to **foundational infrastructure**
- **Other:** High Costs (required customized solutions that are tailored to specific needs and environments), etc.

Way Forward

- Setting up and managing the **Robotics Innovation Unit (RIU)** network in the form of Partner Incubators etc.
- **Collaborations** with major demand units may be facilitated to **jointly develop and undertake demonstrations,** provide test platforms.
- Undertake ambitious and ground-breaking exploratory research through mission mode **moonshot projects.**

1.6.1. ROBOTICS AND HEALTH CARE

ROBOTICS AND HEALTH CARE AT A GLANCE

- In the recent time, robotics is playing key role in revolutionizing the way medical services are delivered and experienced. It has laid the foundation of precision medicine along with the AI, nanotechnology etc.

Significance/Applications

Cleaning & Disinfecting Robots

Disinfecting robots utilise ultraviolet-C (UV-C) light or hydrogen peroxide vapour (HPV) for cleaning identified areas.

Safety & Monitoring Robots

Telepresence systems use computer vision technology to monitor the patient's vitals and voice recognition to communicate with the patient.

Surgical Robots

Surgery can be performed through smaller cuts as compared to conventional open surgery.

Initiatives

- **Draft National Strategy for Robotics (NSR)** emphasizes on domestic manufacturing of robots.
- India got its **first urologic robotic installation** at the AIMS, New Delhi, in 2006.
- **National Health Policy, 2017** promotes integration of advanced technologies.

Constraints/Challenges/Concerns

- **Reliability and accuracy:** Any errors or malfunctions can lead to adverse events, including injury or harm to patients.
- **Integration with healthcare systems:** Integration challenges can include security concerns, compatibility issues with legacy systems, etc.
- **Regulatory Mechanism:** There is no specific policy/mechanism to ensure accountability of any accident or fault by surgical robots.

Way Forward

- **Establishing guidelines** and requirements for the security, privacy, and liability etc.
- Medical research oriented **Robotic Centers of Excellence** shall be established.
- Invest in the necessary **technological infrastructure,** such as high-speed internet and advanced medical facilities, etc.

1.7. BRAIN-COMPUTER INTERFACE (BCI)

Why in the News?

Neuralink, an Elon Musk company has successfully installed a wireless brain-computer interface (BCI) implant in a human patient.

More about News

- Neuralink also announced that their first product will be named **Telepathy**.
  - Telepathy will facilitate BCI.
    - ✓ Ultra-fine threads in it will help in **transmitting signals from brain**.

- Users will able **to control a computer or phone** just by thinking with the help of it.
- Aim is to restore functions which are lost when the communication pathways between brain and body break down.

About Brain–Computer Interface (BCI)

- A system that **determines functional intent** - the desire to change, move, control, or interact with something in our environment - **directly from brain activity**.
  - BCIs allow controlling an application or a device using only our mind.
  - **Using a BCI skips over the need to have voluntary control of your muscles** to interact with devices around you.
- **Three main parts:**
  - **A device** to detect and record signals coming from the brain.
  - **A computer to process and analyze** the recorded brain activity.
  - **An application/device to control**.
- **Another important** part is **feedback**.
- **Types of BCIs:**
  - **Non-Invasive:** E.g. Electroencephalography (EEG), Functional Magnetic Resonance Imaging (fMRI) etc.
  - **Semi-invasive:** E.g. Electrocorticography (ECoG)
  - **Invasive:** Chips/Sensors are placed directly into the cortex. E.g. Neuralink's Implant.

Applications of BCI

- **Helping people with physical disabilities and ageing:** Enables precise control of prosthetic limbs, giving amputees natural motor skills.
- **Treatment for diseases:** Parkinson's disease, epilepsy and spinal cord injuries etc. can be treated.
- **Facilitate brain research**: Some researchers have used a BCI to detect the emotions of patients in a vegetative or minimally conscious state.
- **Improving human performance:** Used as a neurofeedback training tool to improve cognitive performance.

Concerns related to BCI

- **Technical and user challenges:** Each person generates unique brain signals, which are difficult to measure clearly.
  - Also, Translation of brain signals to speech by a BCI could cause harm if it is not accurate.
- **Data Privacy and Security:** Vulnerable to cyberattacks
- **Ethical issues:** BCIs may raise questions about what constitutes consent and about potential unfair advantages conferred by certain human enhancements.
- **Medical issues:** BCI's may unintentionally influence other brain functions, or cause any unwanted side effects such as seizures, headaches, etc.

Conclusion

BCI will play significant role in in dealing with many health related issues which are not being tackled at present time. However, it needs to be implemented after assessing it side-effects.

1.8. 3D PRINTING TECHNOLOGY

3D PRINTING TECHNOLOGY AT A GLANCE

- 3D Printing Technology or Additive manufacturing (AM) is the technology that constructs a three-dimensional object from a digital 3D model by **adding material layer by layer.**

Significance/Applications

Aerospace & Defence	**Automotive**	**Electronics**	**Healthcare**	**Consumer Goods**
Landing gears, Thrust reverser doors, Small surveillance drones, high-value components etc. **E.g. World's first single-piece 3D printed rocket engine of Rocket Agnibaan SOrTeD.**	Engine components, gear boxes, air inlet, etc.	Wearable devices, soft robots, Data processing technologies, **RFID (Radio Frequency Identification) devices, etc.**	Surgical Models (Organs), Surgical Instruments (medical) etc.	Jewellery, shoes, clothing, cosmetics products, toys, figurines, furniture, office accessories, musical instruments, etc. **(E.g. confectionery items)**

Initiatives

- **National Strategy for Additive Manufacturing, 2022 by MeitY.**
- **National Institute of Electronics & Information Technology,** Aurangabad, has established **a 3D printing lab.**
- In 2023, **National Centre for Additive Manufacturing,** set up by MeitY in collaboration with the **Telangana.**

Key Advantages

- **Rapid Prototyping:** Expedited prototyping, serves as a **catalyst** in the **product development cycle.**
- **Design Flexibility: Intricate** designs, which would have been nearly impossible or prohibitively expensive with conventional manufacturing methods, are now feasible.
- **Sustainability:** Reduces material waste by **only consuming what's necessary for the print.** Also, uses sustainable materials. E.g. **Polylactic Acid (PLA).**
- **On-demand Production:** Companies can move from mass production to mass customization.

Constraints/Challenges/Concerns

- **Expensive:** Initial investment in equipment is substantial.
- **Limited Materials:** Selection of plastics and metals is not exhaustive.
- **Restricted Build Size:** Print chambers have small sizes, larger parts need to be joined after printing.
- **Limitations in design:** Layers can delaminate under stress due to the layer-by-layer production process.

Way Forward

- 3D printing can be promoted on large scale by ensuring smooth **coordination between different stakeholders** such as government, corporates, research institutes etc. Following ways can be adopted-
  - ★ **Promoting linkage** between **research institute** and enterprises.
  - ★ **Adopting governance mechanism** to regulate standards and other related aspects etc.

1.9. METAVERSE

METAVERSE AT A GLANCE

- A **3-D-enabled virtual reality space** that provides **digital experiences as an alternative** to or a **replica of the real world.**
  - Allows people to have lifelike experiences online.

Significance/Applications

- **Education:** With the help of tools like Google Arts & Cultures, students can take a virtual 3D tour of some of the world's most well-known museums.
- **Real Estate:** Helps in creating a virtual world and adding buildings, plants and other natural elements.
- **Healthcare:** Help in easier monitoring of patient data such as body temperature, heart rate, etc. E.g. Microsoft Hololens help surgeons in various surgical procedures.
- **Military:** Tactical Augmented Reality (TAR) could easily display the precise location of a soldier alongside the positions of allies and hostiles.

Constraints/Challenges/Concerns

- Higher equipment costs and the continuing **digital divide.**
- Threats of **data breaches and misuse of personal data.**
- Prolonged **exposure** to virtual environments can lead to addiction, **mental health harm,** mental fatigue, **sleep disruption** and more

Way Forward

- **Telecom Regulatory Authority of India (TRAI)** has recommended following measures:
  - **Securing networks, building confidence** through open standards and interoperability
  - Establishing mechanisms for **registering Intellectual Property Rights** in the metaverse.
  - Ensuring **metaverse accessibility to all.**

1.10. CRITICAL TECH SECTORS

Why in the news?

The Ministry of Electronics and Information Technology (MeitY) recently unveiled **draft road maps for Critical Tech Sectors**.

About Draft Roadmaps

- Draft Roadmaps are prepared by **Centre for Development of Advanced Computing (C-DAC),** giving emphasis on **indigenisation of software and hardware in the critical sectors**.
- Aim to solve **a series of issues by different time spans between now and 2047**, with **specific domestic research goals** outlined.
- **Also, aim to synergize efforts** of stakeholders to align with **NITI Aayog's strategy for R & D.**

About C-DAC

- **Genesis**: Set up in 1988 to build Super-computers in context of denial of import of Supercomputers by USA. Premier R&D organization for carrying out R&D in IT, Electronics and associated areas.
- **Ministry**: MeitY
- **Key Initiatives**:
  - Supercomputer PARAM 8000
  - eGovernance – SARITA initiative

What are Critical Technology Sectors?

- **Critical Technologies are those technologies identified by government as 'Critical'** for a nation's future economic growth, national security, and technological advancement.
- **Includes** cutting-edge research, innovation, and strategic importance.
- **Important** for **state's critical infrastructure.**
- **Examples:** AI, Quantum computing, IoT, and Blockchain

Significance of Critical Tech Sectors

- **Global Partnership**: Promotes **India's technological leadership;** cooperation with partners to advance, etc**.**
- **Indigenisation**: Deter foreign hostile forces from **economic espionage, strengthen the protection of key technologies**.
- **Economic growth**: Drives **innovation and competitiveness** across key industries and creates job opportunities.
- **Other**: Promotes cryptographic techniques for **protecting sensitive data, etc.,** ensuring the resilience of IoT ecosystems, etc.

Critical technology collaborations with other countries

- **U.S.-India initiative on Critical and Emerging Technology (iCET)**
- **India and Australia** signed the **Framework Arrangement on Cyber and Cyber – Enabled Critical Technology Cooperation**, 2020.
- **India and EU** have also signed intent of cooperation in the area of **High-Performance Computing** in 2022.
- In 2023, **India and Japan** have also entered into a **Memorandum of Cooperation (MoC)** on **semiconductor supply chain** partnership.

Challenges in developing critical tech sectors

- India faces brain drain in **AI algorithms and hardware accelerators** as many opt post graduate training in USA and Europe.
- **Lack of R & D Funding**
- Despite producing a large number of STEM graduates, there's a **gap between the skills taught** and **those required by industries.**
- **Other: Global Competition** (from other **countries like China, USA**, etc.) Environmental Concerns (creation of electronic waste etc.) etc.

Way Forward: Key Highlights of the Roadmaps

Critical tech sector	Roadmaps
Quantum Technologies	Focus on **developing superconducting materials**
Cryptography	Focus on **quantum-resistant cryptography**, **novel non-linearity schemes**, **etc.**
Mobile Security	Deploy self-defending security and quantum-backed security for mobile systems
IoT security	Develop an **IoT sandbox**, IoT network security orchestration, and automation
Cyber Forensics	Create '**Dark Web Forensics**' and **forensics tools for sectors like deepfakes**, UPI apps, and tools **for reconstructing events from CCTV footage**.

1.11. ETHICS OF EMERGING TECHNOLOGIES

Why in the News?

In recent time, emerging Technologies such as AI, 3D printing etc. are promoted on large scale, these technologies also possess several ethical concern.

Key Ethical Concerns

- **Human vs Machines**, i.e. Autonomous machines replacing humans.
- **Invasion** of **citizen's privacy** and reducing freedom of choice. E.g. Digital health data can be stolen.
- **Environmental consequences** as it can threaten ecological balance. E.g. Bitcoin mining's energy consumption rose 34-fold between 2015 and 2020 **(Digital Economy Report 2024)**
- **Discrimination** risk at individual, companies and communities level.
- **Distortion** of reality through deep fakes, misinformation etc. E.g. Spreading narratives in elections, religious hatred etc.

Roadmap for an Ethical Technology Ecosystem

- Developing Certain Universal Principles for global governance and accountability. E.g. **Asilomar AI Principles**
- Framing domestic Laws and regulations to secure data, etc.
- Appointing **Ethical Officers** by tech companies to address rising ethical concern related with technologies.

2. BIOTECHNOLOGY, NANOTECHNOLOGY AND ISSUES RELATING TO INTELLECTUAL PROPERTY RIGHTS

2.1. BIOTECHNOLOGY

BIOTECHNOLOGY AT A GLANCE

- Area of Biology that **uses living processes, organism or systems to manufacture products** intended to improve quality of human life.
- **Types of Biotechnology:** Blue (Marine and Aquatic application), Green (Agriculture Processes), Red (Medical) and White (Industrial)
- **Market Size:** India is ranked **12th globally (India Bio-economy Report 2023)**

Significance/Applications

- **Bioremediation:** To break environmental pollutants **E.g. Oilivorous-S and Oilzapper Health/Medicine:**
- **Gene therapy:** Treatment of Hemophilia A
- **Gene editing tech.:** CRISPR-cas9, GM mosquitoes
- **Recombinant DNA technology:** Artificial Insulin Production
- **Bioenergy:** Use of bioethanol and biodiesels. **E.g. Fourth-generation biofuels (FGB)**

Initiatives

- **Biotechnology Industry Research Assistance (BIRAC),** a PSU of DBT
- **Biological Research Regulatory Approval Portal (BioRRAP):** For Regulatory approval of biological research
- **National Biopharma Mission (NBM):** In line with Make-in India & AatmaNirbhar Bharat"
- **Atal Jai Anusandhan Biotech Mission by DBT**

Constraints/Challenges/ Concerns

- **Low R&D:** 0.67 per cent of India's GDP. **(UNESCO)**
- **Intellectual Property Right regime:**
  - Strict standards under Patents act 2005 and Compulsary licensing
- **Ethical Issues:** E.g. Bio piracy, Designer Babies, Human clinical trials.
- **Environmental Issues:** Unintended consequences on environment and genetic variability.
- **Less Lucrative** as number and quality of jobs offered is less.

Way Forward

- **Increase in investment** towards R&D
- **Building capacities** for both human resource and infrastructure to cater to the current needs
- **Collaboration between government and industry** for improving IP regime.
- **Balance between basic and translational research** needs to be maintained for ensuring robust pipeline of new knowledge.
- **Strategic Road Map** for industry-based R&D

2.1.1. BIOTECHNOLOGY AND AGRICULTURE

BIOTECHNOLOGY AND AGRICULTURE AT A GLANCE

- Biotechnology has a potential to transform the agriculture sector to deal with crisis which are looming over the sector such as **climate change , reduced yield etc.**

Significance/Applications

- **Increased crop productivity:** by introducing such qualities as **disease resistance** and **increased drought tolerance** to the crops. **E.g. DMH 11 Mustard**
- **Enhanced crop protection:** by making both insect pest control and weed management safer and easier. **E.g. GM Cotton**
- **Environmental benefits:** As reduced pesticide dependence, have less pesticide residues on foods, reduces pesticide leaching into groundwater etc. **e.g. BT brinjal**
- **Nutritional benefits:** For example, **golden rice** has potential to significantly improve vitamin A uptake in poverty-stricken areas.

Constraints/Challenges/ Concerns

- **Health-related issues:** risk of introducing allergens and toxins into otherwise safe foods, rise in Antibiotic resistance etc.
- **Environmental and ecological issues:** transgenic crops might cross-pollinate with related weeds, possibly resulting in super weeds that become more difficult to control.
- **Ethical concerns:** Concerns regarding inequitable benefits, corporate dominance.

Way Forward

- Biotechnology can be used for the betterment of society through development of crops with improved nutritional quality, resistance to pests and diseases, and **reduced cost of production.** However, there is a need to ensure that they pose **no environmental and health risks.**

2.1.2. GENETICALLY MODIFIED ORGANISM

GENETICALLY MODIFIED ORGANISM AT A GLANCE

- A genetically modified organism **(GMO)** is any **living organism** whose **genetic material** has been **modified** to include certain desirable traits.

Significance

- **Genetic Biodiversity:** By resurrecting Extinct species
- **Industrial Use:** Biofuels **(use of GM algae)**, Bioplastics **(Genetically engineered microbes)**, etc.
- **Medical:** Production of Pharmaceuticals **(Insulin)**, Xenotransplantation **(GM Pig kidney)**, Gene therapy, etc.
- **Agriculture:** Pest Resistance **(Bt Cotton)**, Herbicide Tolerance & Enhanced Nutritional Content **(e.g. Golden Rice)**, Cloned animal **(e.g. Dolly Sheep)** etc.
- **Environmental:** Bioremediation **(Oilzapper)**, Genetically engineered microbes to fight pollution.
- **Disease/Paste Control:** Use of Gene drive technology for malaria outbreak.

Regulation

- **Environment Protection Act 1986 (EPA):** Govern the handling of GMOs and products.
- **Genetic Engineering Appraisal Committee:** Responsible for approving commercial cultivation of GM crops.
- **Biological Diversity Act, 2002:** To ensure benefits arising from utilization of these resources are shared fairly with local communities.
- **Codex Alimentarius Commission (Codex):** Responsible for developing international food code.
- **Cartagena Protocol on Biosafety:** Deals with the trans boundary movement of living modified organisms.

Constraints/Challenges /Concern

- **Environmental Impact:** Can have unintended and irreversible effects on the environment E.g. Reduced Biodiversity.
- **Health Concerns:** Introduction of new toxins into food supply, development of antibiotic resistance
- **Ethical Concerns:** Concern about inequitable access and benefits of GMOs
- **Economic and Socio-cultural Concerns:** Issues related to Intellectual Property and Seed Sovereignty, Concerns about impact on **small-scale farmers** and **traditional farming practices.**
- **Regulatory and Governance Issues.**

Way Forward

- **Conduct field demonstration** studies with respect to the effect of GM Crops
- **Following Bioethics, environmental ethics & Research ethics** while developing GMOs
- **Increased Research** and **Improved Safety**
- **Risk assessments** to determine the possible consequences of their use.
- **Create more awareness on** issues of GMOs to facilitate uptake of public concerns on GMOs.
- **Clear and mandatory labelling of GMO products** to make informed choices.

2.1.2.1. GM CROPS & FOOD SECURITY

Why in the News?

A new "gene revolution" is being promoted as a solution to global hunger caused by extreme weather damaging food systems.

More about the News

- **First Gene Revolution:** Beginning in the 1970s, first wave of genetic modification involved inserting genes from one organism into another, creating transgenic crops.
  - These crops aimed **to improve yield, resistance to pests,** and **tolerance to herbicides**.
- **New "gene revolution":** Utilizes more precise techniques like **CRISPR-Cas9 for gene editing**, allowing for targeted changes within the plant's own genome without introducing foreign DNA.

GM Crops in India

- **Bt-Cotton:** Only approved GM crop (2002) for commercial cultivation. In 2018-19, Bt-cotton was 95% of the total cotton planted in India.
- **Bt-Brinjal**: In 2009, Bt-brinjal was cleared by GEAC for commercial cultivation, but it was put on a 10-year moratorium following public backlash.
  - Recently, GEAC has allowed field trials of new varieties of indigenously developed Bt-brinjal in eight states during 2020-23. Trial requires a no objection certificate (NOC) from concerned states.
- **GM Mustard:** In October 2022, GEAC approved the environmental release of GM mustard **(Dhara Mustard Hybrid/DMH-11, developed in 2002)** and its parental crops **(Indian and east European lines).**
  - Later, **release of the GM Mustard** was put on hold after Supreme Court.

Benefits of GM technology (For Food Security)

- **Increasing Yields**: **DMH-11** has shown approximately **28%** more yield than the national check and **37 %** more than the zonal checks and its use has been approved by the **GEAC.**
- **Climate Resilience**: E.g., drought-tolerant rice **E.g. *Sahbhagi Dhan* in India.**
- **Nutritional Enhancement**: E.g., Golden rice developed by **International rice research institute** is an effective source of vitamin A
- **Sustainability & Climate Change**: Improved crop varieties can reduce the **need for chemical inputs like fertilizers and pesticides**.
  - Scientists are developing a **suite of genetically engineered crops** that will more efficiently remove and store carbon dioxide from the atmosphere.

Challenges and Criticisms

- **Environmental Concerns**: GMOs often involve **"large-scale monocultures"** of limited crop varieties that also require great amounts of artificial fertilizers, pesticides and irrigation.
  - Food systems account for **over one-third of global greenhouse gas emissions.**
- **Health and Safety**: GM crops produce toxin meant to protect plants against pests but it posed safety risks due to "enhanced toxicity." E.g. **GM cowpea approved for cultivation in Nigeria.**
- **Ethical and Social Issues**: Concerns about corporate monopoly over food systems and marginalization of smallholder farmers.
- **Regulatory and Legal Challenges**: Different countries have varying regulations on GM crops, impacting their development and distribution.
- **Other Challenges:** Changes in the structure of genetic diversity, Intensification of farming, increased pressure on biodiversity & development of herbicide resistance in weed species.

Conclusion

In a recent SC judgment, Apex court recommended that union government should evolve a national policy on GM crops in consultation with all stakeholders, including states, farmers groups, etc.

2.1.3. BIOTECHNOLOGY AND BIOPHARMACEUTICALS

BIOTECHNOLOGY AND BIOPHARMACEUTICAL AT A GLANCE.

- Biopharmaceuticals are **complex medicines made from living cells or organisms,** often produced using cutting-edge biotechnological methods.

Significance/Applications

- **Prevention and early detection:** Vaccines and improvements in wellness could help prevent disease. **E.g. ELISA, Biosensors**
- **Personalization medicine:** Effectively match patients with customized drug cocktails, or design therapies. **E.g. Pharmacogenomics**
- **Curative therapies:** could eliminate the demand for some medicines. **E.g. Gene Therapy**
- **Precision intervention:** Pharmaceutical products, combined with their ability to **Present fewer side effects** because of their specificity, unlike conventional drugs that affect multiple systems.

Constraints/Challenges/ Concerns

- **Capital intensive:** Large-scale biotech-manufacturing facilities require additional $200 million to $500 million or more to build. **(McKinsey analysts)**
- **Novel therapeutics:** Adapting to new and previously unfamiliar technologies, including **mRNA.**
- **Others:** Long process durations, **low yields, expensive raw materials,** need for a team of highly skilled experts to operate them etc.

Way Forward

- Growing awareness among patients about **biopharma's health benefits** and efficacies drives the demand for bio-pharma products worldwide. As learnt from the pandemic, **de-risking supply chains,** and manufacturing operations while **expanding capacity in sensitive APIs** and intermediates is critical.

2.1.4. GENE EDITING

GENE EDITING AT A GLANCE

- It is a way of making **specific changes to the DNA of a cell or organism**. This allows genetic material to be added, removed, or altered at particular locations in the genome.
- It is a **three-stage complex mechanism of unwinding, cleaving and rewinding of DNA** to bring desirable changes in the genome of any living beings.

How it Works?

- It uses a **type of enzyme called an engineered nuclease**' which cuts the genome in a specific place.
- After cutting the DNA in a specific place, **cell will naturally repair the cut.**
- This **repair process can be manipulated** to make changes (or 'edits') to the DNA in that location in the genome.
- **Various techniques of gene editing:** CRISPR-Cas9, ZFNs (zinc-finger nucleases),TALENS (Transcription activator-like effector nucleases), Bridge Recombinase Mechanism etc.

Significance/Applications

- **For Research:** Can be used to change **DNA in cells or organisms** to understand their biology and how they work.
- **Treatment of diseases:** It has been used to modify human blood cells that are then put back into the body to treat conditions **including leukemia and AIDS.**
- **Biotechnology:** In agriculture, to genetically modify crops to improve their yields and resistance to disease and drought, as well as to genetically modify cattle etc.
- **Therapeutic Cloning:** Process whereby embryonic cells are cloned to obtain biological organs for transplantation

Constraints/Challenges/ Concerns

- **Ethical Dilemma:** Including eugenics, helping fittest to survive, possible rise of designer babies, issue of informed Consent, etc.
- **Safety concerns:** What if we manage to wipe out particular disease only to introduce a brand new and even more dangerous one.
- **Potential loss to diversity:** Green Revolution in India led to extinction of certain crop varieties.
- **Health risks:** Could cause allergic reactions/ cancer, damage to organs/tissues.

Way Forward

- **Altruistic Science:** Research must be designed to increase human health and wellbeing.
- **Consensus-based application:** Genome editing for reproductive purposes should be stopped until a social consensus is reached.
- **Last Resort to treatment:** Human germline editing should be permitted only when there is no reasonable alternative for disease prevention.
- **Robust policy framework:** Ensuring accountability and self-regulation

2.1.4.1. CRISPR

Why in the News?

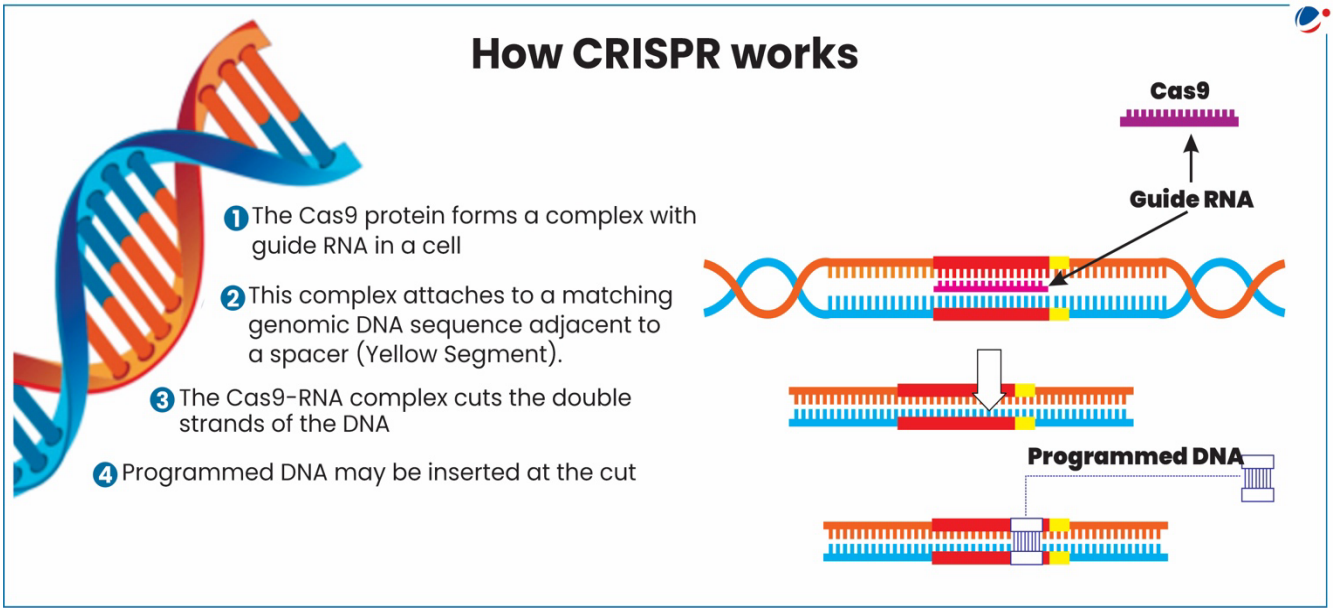
Recently Scientists developed a **new exosome-based CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats)/Cas9 gene-editing Platform**

More on the News

- Exosomes are **naturally occurring vesicles** that have potential to be manipulated to become promising **drug delivery vehicles for gene editing.**
  - Vesicles are small cellular containers, performing a variety of functions **e.g. transporting materials needed to survive and recycle waste materials.**
- It significantly **enhances delivery of CRISPR/Cas9 genome** editing components to specific cells.
- It will also **facilitate development of precision medicine** and will improve cancer treatment.

About CRISPR-Cas9

- **CRISPR-Cas9** is used to **modify gene function**, to change genetic code or edit DNA at particular locations.
  - Earlier, **Nobel Prize for Chemistry, 2020** was awarded to Emmanuelle Charpentier and Jennifer A Doudna for development of **CRISPR-cas9 technique**.
- **How CRISPR-Cas9 works?**
  - It works as a **cut and paste mechanism on DNA Strands**. Genetic codes that need to be changed are identified.
  - **Cas9 protein** is used as a **pair of molecular scissors to cut off a part from strand.**
  - **Strand when broken has self-repairing tendency.** This way a damaged DNA strands can be removed and help human body to restore to healthy state.
- **Applications of CRISPR:** Edit genes in human embryo; **Change genetic codes of crops** to improve crop resilience; creating new therapies for **Cancer treatment & sickle cell diseases** etc.



2.1.4.2. CAR-T CELL THERAPY

Why in the news?

Recently, Cancer remission was achieved after **commercial use of NexCAR19, India's first indigenous CAR-T cell therapy.**

More in News

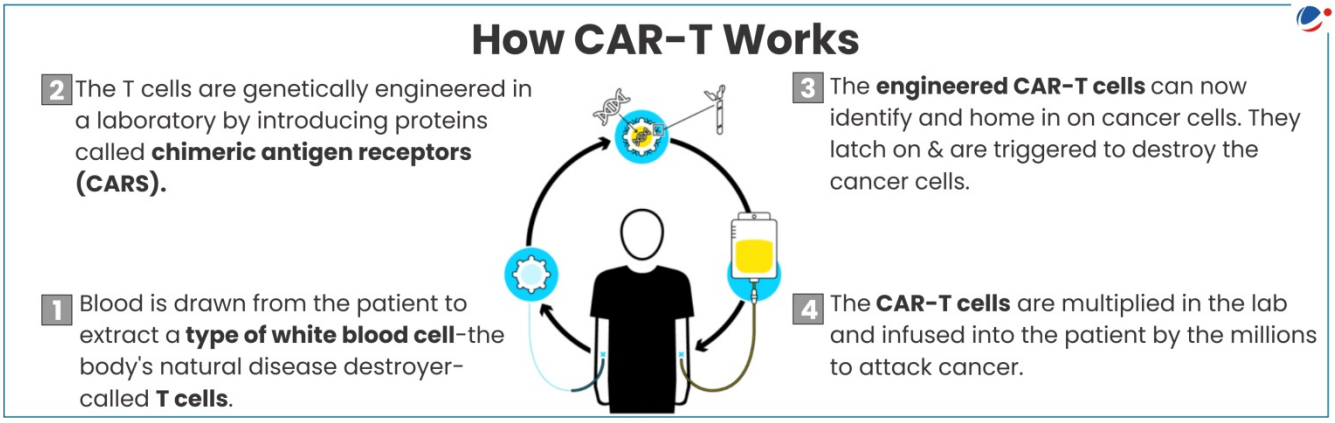
- The **therapy has been** developed indigenously in India by **ImmunoACT,** which is a company incubated at IIT Bombay.
- **India** is now one of the **first developing countries** to have its indigenous CAR-T and gene therapy platform.

About NexCAR19 (Actalycabtagene autoleucel)

- The therapy is designed to target cancer cells that carry the **CD19 protein**.
  - CD-19 is a biomarker (or flag) for **B lymphocytes (or B-cells)** and can be utilised as a target for leukaemia immunotherapies.
    - ✓ A **Biomarker** is a measurable and assessable indicator, often a molecule or characteristic, that provides information about a biological process, condition, or response to a treatment.
- This therapy is for people with **B-cell lymphomas** (blood cancer) who **don't respond** to standard treatments like **chemotherapy**, leading to relapse or recurrence of the cancer.

About CAR-T cell therapy

- CAR-T cell therapy is a type of cellular immunotherapy treatment that uses T cells that are genetically altered in a lab to enable them to locate and destroy cancer cells more effectively.



CAR-T Therapy vs. Chemotherapy		
Aspect	**CAR-T Therapy**	**Chemotherapy**
Mechanism of Action	Genetically modifies patient's T cells to target cancer	Uses drugs to kill rapidly dividing cells, including cancer
Precision	Highly precise, targeting specific cancer cells	Non-specific, affecting both cancer and healthy cells
Treatment Duration	Typically, a single infusion or a few treatments	Multiple cycles, often over an extended period
Personalization	Individualized treatment based on patient's own cells	Standardized treatments, less personalized approach

Challenges in adoption

- **Cytokine Release Syndrome (CRS):** CAR T-cells leads to the release of **abundant cytokines into the bloodstream**, triggering an intensified immune system response.
- **Neurological Toxicity** leading to confusion, seizures, or other neurological issues.
- **Patient Eligibility:** factors such as age, overall health, and the presence of certain pre-existing conditions can impact eligibility
- **Other issues:** high cost, Limited Applicability (Only successful in certain blood cancers), etc.

Conclusion

There is need for **enhanced safety profiles** for minimizing severe side effects such as **cytokine release syndrome** and **increased accessibility** by intregating it in healthcare system**.**

2.1.4.3. GENE THERAPY

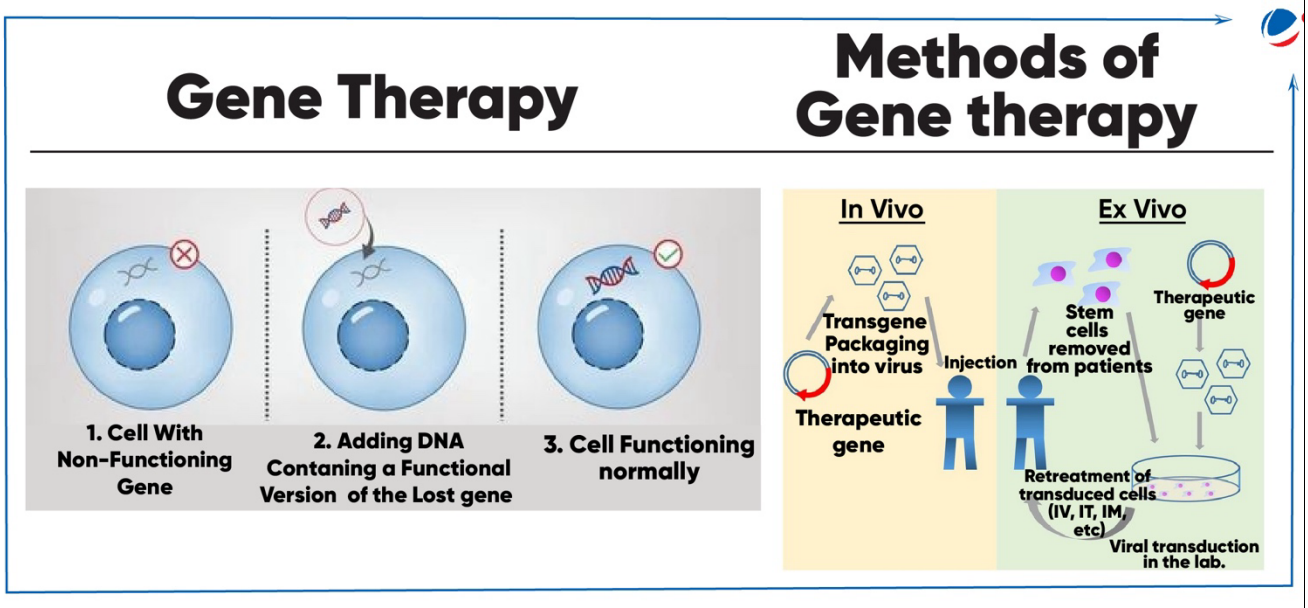
Why in the news?

India has conducted the first human clinical trial of gene therapy for **Haemophilia A (FVIII deficiency)** at Christian Medical College (CMC) Vellore (Tamil Nadu).

About Gene Therapy

- **Definition:** A technique that **uses a gene(s) to treat, prevent, or cure a disease** or medical disorder.
  - In most gene therapy, a **normal gene is inserted into the genome** to supplement an abnormal disease-causing gene and **restore target cell to a normal state.**
- **Types**
  - **Germline gene therapy**: **Germline Cell** (egg or sperm) are **modified** by the introduction of **functional genes**, which are **integrated into the genome**.
  - **Somatic cell gene therapy:** Therapeutic gene are **transferred to a patient's somatic cells (**cells other than germline cells). Any modification and any effects are **restricted only to that patient** and are **not inherited** by future generation.
- **Application:** Both **inherited genetic diseases** (e.g., haemophilia and sickle cell disease) and **acquired disorders** (e.g., leukaemia) could be **treated** with gene therapy.
- **Key Gene Therapy Products**
  - **Plasmid DNA:** Circular DNA molecules can be **genetically engineered** to carry **therapeutic genes** into human cells.
  - **Viral Vectors:** Gene therapy products derived from viruses can be used as **vectors (vehicles) to carry therapeutic genes**.
  - **Other:** Patient-derived cellular gene therapy products, Bacterial vectors, Human gene editing technology etc.

Gene Therapy Process and Methods



NOTE: National Guidelines for GTP Development and Clinical Trials (2019) issued by Department of Biotechnology (DBT) and ICMR broadly **specifies the ethical, scientific, regulatory procedures** for conducting clinical trial on gene therapy products (GTP) in India.

2.1.5. GENOME SEQUENCING

GENOME SEQUENCING AT A GLANCE

- **Genome sequencing** means determining the exact order of base pairs in a strand of DNA in an individual.
- **Human genome** contains approximately 3.2 billion nucleotides and 23,500 genes.

Significance/Applications

- **Enable treatments for genetic diseases:** Useful in **Prenatal screening** (identify genetic disorders in foetuses), etc.
  - Development of **Predictive diagnostics** and **personalized healthcare**
- **Facilitate Advanced Analytics and Artificial Intelligence integration:** To enhance understanding of genetic causative factors and develop disease treatments.
- **Agriculture & Food System:** Selecting desirable traits in plants and animals, Food safety monitoring.

Initiatives

- **IndiGen programme:** Whole genome sequencing of diverse ethnic groups from India, funded by CSIR.
- **Global Alliance for Genomics and Health (GA4GH):** Sets standards to expand genomic data use.
- **GenomeIndia Project:** Inspired by **Human Genome Project (1990)** and launched by DBT. To collect **10,000** genetic samples from citizens across India and create a **Reference Genome.**

Constraints/Challenges/ Concerns

- **Lack of Aggregated summary data,** thus of no usage for public health decision-making.
- Privacy and **genomic data Protection** (sensitive information such as genetic composition, medical and family history)
- **Absence** of **legal policy & regulatory framework**
- **Other issues:** Financial constraints , Limited skilled personnel

Way Forward

- Establish centralized sequencing facilities
- **Develop advanced training programs** for researchers at both experimental and computational levels
- Improved access of up-to-date genomic data and **open access publication models.**
- **Follow best practices** to curb data misuse and ensure ethical technology use, E.g. Genetic Information Non-discrimination Act in the U.S.A.

2.1.6. STEM CELL

STEM CELL AT A GLANCE

- **Stem** cells are **special human cells that are able to develop into many different cell types** such as muscle cells, blood cells, and brain cells.

Significance/Applications

- **Biomedicine Applications:** Including developmental biology, disease modeling, tissue engineering, drug Development, toxicity testing, etc.
- **Regenerative Medicine:** E.g. Stem Cell Therapy (SCT)
- **Neurological Disorders:** E.g. Potential treatments for Parkinson's disease, Alzheimer's disease, and spinal cord injuries.

Constraints/Challenges /Concern

- **Safety of the patient:** Immune rejection of donor cells by host immune system post-transplantation is main issue.
- **Ethical concerns:** Use of embryos for human embryonic stem cell lines may lead to commoditization of human cells and tissues.
- **Limited technology:** Therapies using these avenues are largely new and much more research and testing is needed.
- **Other Concerns:** Possible risk of genomic changes etc.

Way Forward

- **Better regulation for basic, clinical research** and product development based on categories of research and level of manipulation.
- **Informed consent** for trials.
- **Appropriate measures** should be taken to ensure that the stem cell derived product is safe for human application.
- **Addressing ethical dilemma** by **developing guidelines** (like India's **National Guidelines for Stem Cell Research**) for various stakeholders.

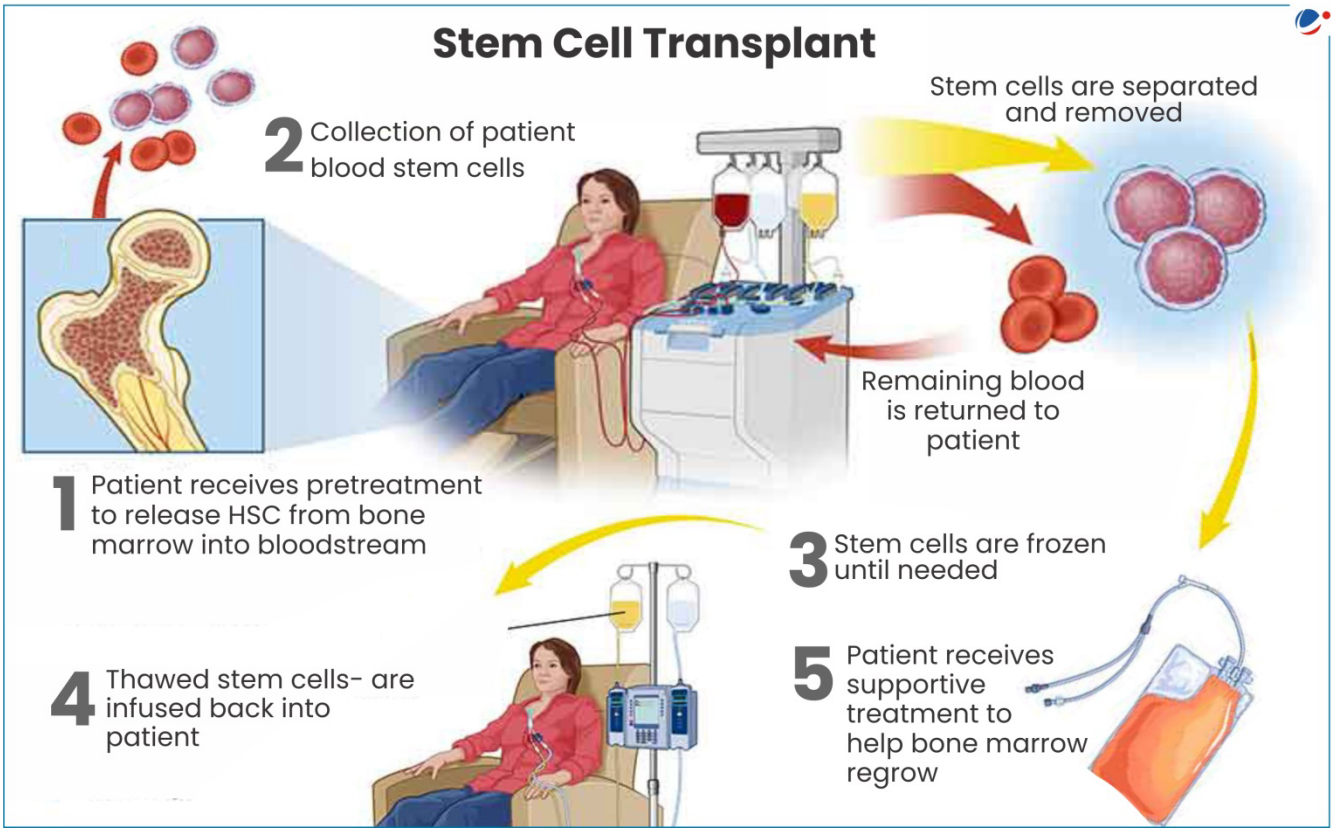
2.1.6.1. STEM CELL THERAPY (SCT)

Why in the news?

Delhi High Court permitted Stem Cell Therapy for treatment of Autism Spectrum Disorder (ASD).

About Stem Cell Therapy (SCT)

- A form of **regenerative medicine** designed to **repair damaged cells** within the body by **reducing inflammation** and **modulating the immune system**.
  - **Regenerative medicine** focuses on developing and applying new treatments to **heal tissues** and **organs** and **restore function** lost due to **aging, disease, damage or defects**.



- **Process involved in SCT:**
  - **It includes Harvesting** (process of collecting stem cells of a donor), **Conditioning** (prepare body for transplant), **Transplanting stem cells and Recovery.**
  - As per **'New Drugs and Clinical Trial Rules 2019'** stem-cell derived products are to be used as **"new drugs"** which **means that any doctor** who uses **SCT** needs to **take permission from government.**

Related Development

Model of Human Embryo

- Scientists Created a Model of Human Embryo without Eggs or Sperm
- Scientists used **mix of stem cells** to **assemble them into an embryo-like structure**, mimicking **molecular** characteristics of an early **embryo stage**.
- **Process of creating an embryo model**
  - **Stem cells were reprogrammed** to become any type of tissue in body.
  - Chemicals were **then used to coax** stem cells into becoming cells **found in earliest stages of human embryo.**
- **Implantation** of this model embryo **is not allowed** and will be **used for research only.**
- **Significance**
  - Assist in the study of the **earliest moments of human lives which is presently difficult to study after the embryo gets implanted in the uterus.**
  - Better understanding of **genetic, epigenetic, and environmental effects** on a developing embryo.
  - **Other:** test effect of **drugs on pregnancies,** improve success rates of in vitro fertilization, and assist in study of **transplant tissues and organs,** etc.

2.2. NANOTECHNOLOGY

NANOTECHNOLOGY AT A GLANCE

- Refers to **the design, characterization, production and application of structures,** devices and systems by controlling **shape and size at the nanoscale.**
- **Nanoscale** refers to dimensions between approximately **1 and 100 nanometers.**
- **Status of India:** Since 2016, secured the **third position** in the global ranking through its contribution to Nanoscience and technology publications **(Department of Science and Technology).**

Significance/Applications

Energy	Agriculture	Water Management	Healthcare	Food Processing
Carbon nanotubes (have much lower resistance), Nanostructured solar cells etc.	Nano-fertilisers, nano-sensors for monitoring, etc.	Nano-membranes for water purification, Magnetic nanoparticles etc.	Nano-capsules for slow and sustained drug release systems, facilitating precision medicine.	Nano-composites for plastic film coatings used in food packaging, antimicrobial nano-emulsions etc.

Initiatives

- **Nano Science and Technology Initiative (NSTI)**, 2002
- **Mission on Nano Science and Technology (Nano Mission)**, 2007
- **Nano-electronics Innovation Council** set up by MeitY
- **Indian Nanoelectronics Users Programme-Idea to Innovation (INUP-i2i) initiated** by MeitY for undertaking research and skill development.
- **Nano Science and Technology (INST)**, first Nano-Science Institute at Mohali, Punjab.

Constraints/Challenges/Concerns

- **Impact on Health:** Nano-sized spherical solid materials will easily enter the lungs and reach the alveoli.
- **Environmental Concern:** Nanoparticles can form new form of non-biodegradable pollutants.
- **Lack of Skill Work Force:** Number of students following undergraduate and graduate degrees in the area is low.
- **Ethical Concern:** For instance, nano-based products may be used in warfare, invade people's privacy etc.
- **Other:** High costs for acquisitions of IPR, lower participation of private sector in R & D, etc.

Way Forward

- Promoting **Academy and Industry Linkage,** this will facilitate funds for Academies and products developed by them can be easily commercialized.
- **Coordination with various** international/ inter-governmental **organizations** to develop standards, safe lab practices and risk governance.
- **Increasing funding of Nano Mission** and establishing more dedicated institutes.

2.2.1. NANOTECHNOLOGY AND AGRICULTURE

NANOTECHNOLOGY AND AGRICULTURE AT A GLANCE

- **Nanotechnology** offers promising applications in agriculture, potentially revolutionizing crop production and management.

Significance/Applications

- **Nanofertilizers:** Enhance nutrient uptake by **90-100% utilization** efficiency, improving crop yields. E.g. Di-ammonium Phosphate (DAP)
- **Nanopesticides:** Delivers active ingredients to pests in a targeted manner. E.g., **Nano Silver**
- **Nanobiosensors:** Monitors soil conditions, crop health, and environmental factors with high precision and **provide real-time data to farmers.**
- **Nanomaterials for Soil Improvement:**
  - **Nanoparticles of clay:** To improve soil structure, water retention, and nutrient-holding capacity.
  - **Nanomagnets:** For removal of soil contaminants.
- **Crop Protection:** Applying **silica nanoparticles** to leaves shield plants from high temperatures and intense UV radiation.
- **Nanotechnology in Crop Breeding:** Aid in the development of genetically modified crops **by enabling precise manipulation of plant genes at the nanoscale.**

Initiatives

- **Guidelines for evaluating nano-agri inputs and products:** Released **by the Department of Biotechnology.**
- **National Agricultural Innovation Project (NAIP):** Several projects have been initiated to explore the applications of nanotechnology in agriculture.
- **Skill development training programme on nanotechnology:** By Indian Council for Agriculture Research (ICAR)
- **Nano Fertilizer Plant (NFP):** Established by IFFCO at Phulpur, Prayagraj.

Constraints/Challenges/ Concerns

- **Nanophytotoxicity:** Impacts growth and development of plant.
- **Hazardous to humans:** Accumulation of NPs in vital organs by consuming nano based food.
- **Deleterious to soil microbiota:** Exposure of non target soil microflora to NPs causes disturbances in their metabolism and stability
- **Effect on underground waters:** NPs accumulated in soil interacts with groundwaters making them unusable

Way Forward

- **Proper Risk Assessment** can be conducted as suggested in the guidelines by the Department of Biotechnology (DBT), and FCO order 2021.
- **Develop regulatory frameworks** to ensure the safe and responsible development and use of nanomaterials in agriculture.
- **Other:** Facilitating nano products to farmers through cooperatives, etc.

2.2.2. NANOTECHNOLOGY AND HEALTH CARE

NANOTECHNOLOGY AND HEALTH CARE AT A GLANCE

- Nanotechnology along with other emerging technologies like AI is paving way for the **precision medicine** in the Health care.

Significance/Applications

- **Clinical investigation,** e.g., **Gold nanoparticle** is used for the detection of targeted sequences of nucleic acids, as potential treatments for cancer and other diseases.
  - Recently in a study it has been found that **Hybrid Nanoparticles/ nanohybrids** made of gold and copper sulphide can be used to **cure cancer.**
- **Better imaging tools** for earlier diagnosis, more individualized treatment options, and better therapeutic success.
- **Drug delivery**, nanotech materials can contain hydrophobic and hydrophilic drugs, protect drugs from chemical and enzymatic degradation etc.
- **Gene sequencing technologies** through design and engineering of advanced solid-state **nanopore** materials.

Constraints/Challenges/Concerns

- Creates **'free radicals'** which can harm body cells. E.g. cobalt and chromium nanoparticles cross skin barrier and damage fibroblasts.
- **Triggers an acute inflammatory reaction** when enters in circulation system, as these particles are recognized and identified by the immune system of the body as "invader" particles.
- **Other:** high cost, controlling their activity in sensitive environments, environmental impacts, etc.

Way Forward

- **Nanomedicines and nanoformulations** targeting various diseases must be meticulously designed in order to achieve the safest and most efficacious therapeutic regimen.
- **Clinical trials** should be adequately conducted before using the products.
- A **dedicated authority need** to establish to govern the development and other mechanism of the nanotech in health care.

2.2.3. NANOTECHNOLOGY AND ENVIRONMENT

NANOTECHNOLOGY AND ENVIRONMENT AT A GLANCE

- The **Organisation for Economic Co-operation and Development (OECD)** suggests that nanotechnology offers environmental benefits in the following principle areas: **cleaner production, pollution reduction, and other environmental benefits.**

Significance/Applications

- **Sustainable Production:** Green chemistry; synthesis and processing of nanoscale materials will reduce consumption of raw materials and natural resources.
- **Pollutant sensing:** Detects contaminations such as mercury ions in lake water.
- **Water treatment: Graphene filters** can help in cleaning water.
- **Reduction in energy Consumption: Carbon nanotubes** can be used in super-capacitors, batteries, solar cells (also Carbon nanoflorets) etc.
- **Antimicrobial: Carbon dots (CD)** in contact with the bacteria cell under visible or natural light could efficiently generate reactive oxygen species.

Constraints/Challenges/Concerns

- Nanomaterials themselves constitute a new generation of **toxic chemicals.**
- Manufacture of nanomaterials has an unexpectedly **large ecological footprint.**
  - Nanomaterials fabrication **require large amounts of water.**

Way Forward

- **International Cooperation** to develop efficient applications.
- Ensuring adequate funding for the R & D by utilizing the funding mechanism of **Green Environment Facility** etc.
- Developing **cost-effective material** will pave for large scale demand.

2.2.4. NANOTECHNOLOGY AND DEFENCE

NANOTECHNOLOGY AND DEFENCE AT A GLANCE

- Defence sector has not been untouched by the impacts of the nanotechnology. In the different spheres of defence ranging from **armory to first aid, application or products** made from nanotechnology can be seen.

Significance/Applications

- **Nano-Sensors:** Detect chemical and biological weapons. Nano-devices may also be applied to detect or even decrease radio-activity.
- **Body Armour:** Silicon dioxide nanoparticles in a liquid polymer which hardens on ballistic impact (Shear Thickening Fluid).
- **Health Aid:** Nanomedicines and bandages for wound healing
- **Advanced weapon/equipments:** Provides the army with stronger and lighter ware.
  - E.g. Nanotechnology is being applied to aluminium to change phases and microstructure in order to make it perform like titanium – but without the weight.
- **Other:** Silver-packed foods as antibacterial and antiviral, Adaptive camouflage, etc.

Constraints/Challenges/Concerns

- Use of nano weapons/equipment may lead to the so-called **nanowars**, a new age of destruction.
- Widespread availability of these devices would inevitably lead to their use for **criminal activity** and **terrorist attacks.**
- Medical applications developed to improve soliders' endurance and performance, would also need **careful regulation.**

Way Forward

- Setting up **global standards** and **regulatory** mechanism
- **Treaty like START** can be signed to share development related to nanotechnology with other countries.
- Taking proper safeguard to **prevent reach of non-state actors** to the advanced **nano-weapons**.

2.2.5. GRAPHENE

Why in News?

MeitY Secretary launched **India's first graphene centre - India Innovation Centre for Graphene (IICG) in Kerala.**

About India Innovation Centre for Graphene (IICG)

- A joint venture of the **Digital University of Kerala, Centre for Materials for Electronics Technology (C-MET)** and **Tata Steel Limited, funded by MeitY.**
- **Aim**: To foster Research and development, product innovation and capacity building in the area of Graphene and two-dimensional materials (2DM).

About Graphene

- **Derived from graphite**, the material found in pencil lead.

- A **one-atom-thick layer of carbon atoms** arranged in a hexagonal lattice like a honeycomb.
- A **two-dimensional form** (allotrope) of carbon.
- Prepared by heating either **Intercalated Graphite, Coal tar or Shellac or a mixture of these three** in inert atmosphere.
- Recently, researchers in Georgia have created the **world's first functional semiconductor** made from graphene.
- Hailed as the **Wonder Material** of the 21st century
- **Properties:**
  - **Strongest material:** 200 times stronger than steel, yet six times lighter.
  - **High Thermal Conductivity:** up to 5000 W/m/K at room temperature
  - **High Electrical conductivity:** Exhibits incredibly high electrical conductivity surpassing even copper.
  - **High Surface Area:** Exceptionally high surface area due to its two-dimensional structure.
  - **Impermeable:** to gases, even those as light as hydrogen or helium,
  - **Transparent**: it only absorbs 2% of light. Even more transparent than glass and plastic.
  - **Other**: Flexible, Large surface area, Chemical Stability, Biocompatibility, etc.

Applications of Graphene

- **Electronics:** Graphene-based transistors, circuits, and conductive elements for faster and more efficient electronic devices.
- **Energy Storage**: Graphene-based batteries and supercapacitors with high energy density and rapid charging capabilities.
- **Conductive Films:** Transparent conductive films for applications in touchscreens, flexible displays, and solar cells.
- **Materials Reinforcement**: Reinforcement of composites and materials to enhance mechanical strength and reduce weight in aerospace and automotive industries.
- **Thermal Management:** Heat sinks and thermal interface materials for efficient heat dissipation in electronic devices.
- **Sensors:** High-sensitivity sensors for detecting gases, chemicals, and biological molecules.
- **Other:** Biomedical Devices, Coatings and Films (such as anti-corrosion coatings), lightweight Materials etc.

Related Developments

Graphene-Aurora Program

- **MeitY** launched the 'Graphene-Aurora program'.
- **Aim:** To bridge the gap between graphene research and commercialization

Giant Magnetoresistance(GMR)

- Recently, **Nobel laureate Andre Geim** discovered that **Graphene** displays an anomalous **GMR** at room temperature.
- GMR is the result of **electrical resistance of a conductor** (sandwiched between two materials) being **affected by magnetic fields in adjacent materials**.
  - **When** materials are **magnetised in same direction**, electrical **resistance in the conductor is low**.
  - **When** directions are **opposite** to each other, **resistance increases**.
- **Application of GMR:** Hard disk drives and magnetoresistive RAM in computers, biosensors, automotive sensors, micro-electromechanical systems, and medical imagers.

2.3. INTELLECTUAL PROPERTY RIGHTS

2.3.1. TRADITIONAL KNOWLEDGE IN INDIA

TRADITIONAL KNOWLEDGE AND GENETIC RESOURCES (GRS) IN INDIA AT A GLANCE

- **Traditional knowledge (TK)** is a knowledge system held by indigenous communities, often **relating to their natural environment** like Agriculture, medicinal knowledge, etc.
- **Genetic Resources (GRs):** Resources that are contained in medicinal plants, agricultural crops, and animal breeds.
  - While **GRs** themselves **cannot be** directly **protected as intellectual property,** inventions developed using them can be protected through a patent.

Measures by Government to Protect India's TK and GRs

- **Traditional Knowledge Digital Library (TKDL):** Digital repository to prevent bio-piracy and wrongful patents.
- **India's Patent Act, 1970: Adopted the PDR mechanism** for the disclosure of involved GRs and TK in the claimed patent.
- **Biological Diversity Act, 2002 (in line with Convention of Biodiversity):** Fair and equitable sharing of the benefits arising out of the use of biological resources and knowledge
- **Forest Rights Act 2006:** Provides for Community rights over forest resources and traditional practices.
- **Ministry of AYUSH:** Dedicated ministry for traditional medicine.
- **UNESCO's recognition:** Yoga, etc. recognized as Intangible Cultural Heritage.
- **Other:** The Protection of Plant Varieties and Farmer's Rights Act, 2001, Geographical Indications Act 1999 etc.

Constraints/Challenges/Concerns

- **Biopiracy:** Exploitation, patenting, and commercialization by foreign entities without benefit-sharing or recognition of indigenous communities.
- **Impact on Farmers:** Farmers who developed staple food crops through generations have **no effective rights over patented varieties** by multinational companies.
- **Lack of Documentation:** Enhances risk of **loss or erosion in transmission of traditional knowledge** to younger generations.
- **Inadequate Global Legal Framework:** to prevent misappropriation, ensure benefit-sharing, and recognize indigenous community rights.

Way Forward

- **Establishing agricultural research programmes and centres for ex situ and in situ conservation** of plant varieties and plant genetic resources.
- **Setting up or promoting herbal gardens** of traditional medicinal plants.
- **Ensuring adequate income to the community** experts on traditional knowledge.
- **Incorporating TK as part of the curriculum for schools,** universities and research centres.
- **Enhancing traditional medicine and healing arts in state-run hospitals.**
- Recognizing leaders, experts and innovations in TK in various fields **by providing incentives.**

2.3.2. TREATY ON INTELLECTUAL PROPERTY, GENETIC RESOURCES AND ASSOCIATED TRADITIONAL KNOWLEDGE

Why in the News?

World Intellectual Property Organization (WIPO) adopted the **Treaty on Intellectual Property, Genetic Resources and Associated Traditional Knowledge**.

About the treaty

- Adopted by **consensus** among more than 150 countries (including India).
- This is the **first WIPO Treaty** to-
  - Address the interface between **intellectual property (IP), genetic resources (GRs) and traditional knowledge (TK).**
  - **Include provisions specifically for Indigenous Peoples** as well as local communities.
- **Members:** Any **member states** of WIPO **may become party** to this treaty.
- With regard to **Genetic Resources and Associated Traditional Knowledge**, the treaty aims to-
  - **Enhance the efficacy, transparency** and **quality of the patent system**.
  - **Prevent patents from being granted erroneously** for inventions that are not novel.
- Treaty acknowledged **the United Nations Declaration on the Rights of Indigenous Peoples** (UNDRIP) and its commitments.

Key provisions of the Treaty

- **Mandatory Patent Disclosure Requirements (PDRs)**
  - **Patent applicants must disclose the country of origin or source of genetic resources** when the claimed invention is based on these resources.
  - **Applicants must also disclose the Indigenous Peoples or local community** who provided the traditional knowledge if the patent is based on such knowledge.
- **Mandatory legal, administrative, and/or policy Framework at national level**: To remedy failure to provide PDRs.
- **Establishment of information systems:** Such as databases of GRs and associated TK, in consultation with Indigenous Peoples and local communities, and other stakeholders.
- **Assembly:** Made up of one delegate for representation of each Contracting Party.

Significance of the Treaty

- **Increase transparency in the patent system:** Current IPR regimes such as **the TRIPS Agreement** do not adequately protect TK in the public domain.
- **Recognition and Inclusion**: Formal recognition of the connection between local communities and their GRs and TK within the global IP system.
- **Prevention of Misappropriation**: Mandatory disclosure obligations offer **added protection to GRs** and **associated TK in countries without existing disclosure laws.**
- **Curbing Biopiracy**: Prevents companies exploiting the biodiverse South by patenting their TK.
  - For Instance**, the US patent on turmeric for wound healing and Neem oil to prevent fungus were revoked** after India proved its long-standing traditional use.

3. AWARENESS IN THE FIELD OF SPACE

3.1. INDIA'S RACE TO SPACE

Why in the news?

With the successful launch of Mars, Moon and solar missions, the Indian Space Research Organisation (ISRO) is reinforcing India's status as a rising power in space exploration.

Background of Space Race

- **Space race**: An outgrowth of the mid-20th-century Cold War, was a **period of competition between the Soviet Union and the United States** over who could conquer space exploration first.

Emerging trends of the Indian space sector

- **Growing commercialization:** ISRO has been actively promoting Non-Governmental Entities (NGE) to carry out independent space activities E.g. Agnikul Cosmos and Skyroot
- **Increasing international collaborations:** ISRO has signed several agreements, including the Artemis Accords, a joint lunar mission with Japan's space agency etc.
  - **381 Foreign satellites** have been launched in 34 countries by India between1999-2022.
- **Focus on challenging exploration missions:** India was the first Asian country to reach the Martian orbit with the Mangalyaan Mission (Mars Orbiter Mission) and now became the first country to soft land on the lunar's south pole.
- **Development of new technologies:** such as reusable launch vehicles and Inflatable Aerodynamic Decelerator (IAD).
- **Expansion of satellite-based services:** ISRO provides satellite-based services in areas such as remote sensing, satellite-based navigation, and satellite-based meteorology, and is looking to expand these services in the future.

Implication of India's enhanced role in space exploration

- **Geopolitical significance:** India's rising capabilities to engage, innovate, and support a commercial space will allow it to become one of the world's leading producers of space technology.
- **India as a space start-up hub:** India has become home to almost 190 registered space-tech start-ups
- **Leading nation for satellite launches:** With a success rate of almost 95%, India has the required provisions, evolving infrastructure, and young talented minds
- **Outer Space use for national security:** China's anti-Satellite (ASAT) capability has provided the impetus for India to develop and test its own ASAT capability.

Conclusion

Overall, the Indian space sector is poised for growth in the coming years, with a focus on cost-effectiveness, self-reliance, and international collaborations.

3.1.1. INDIAN SPACE POLICY – 2023

Why in news?

Recently, Indian Space Policy-2023 was approved by the Government.

About Indian Space Policy – 2023

- The Policy has been notified as an overarching framework to implement the vision for unlocking India's potential in Space sector through enhanced private participation.
- **Vision of Space Policy 2023:** To augment space capabilities; Develop a flourishing commercial presence in space; use space as a driver of technology development; etc.

Strategy outlined in the policy

Stakeholder	Role
Government	• Encouraging advanced **Research & Development.** • Safe, Stable and **predictable regulatory framework**.

Non-Governmental Entities (NGEs)	• Offer national and international **space-based communication services.**
	• Establish and **operate**
	  ○ **Ground facilities for space object** operations, e.g. Satellite Control Centres (SCCs).
	  ○ Remote sensing satellite systems.

Department of Space (DOS)	• **Nodal department** for implementation of the Indian Space Policy-2023. • Ensure **availability of continuous & improved earth observation capability**.

Indian Space Research Organization	• **Role under policy**
	  ○ Focus **primarily on research and development**
	  ○ **Share technologies, products, processes** and best practices with NGEs

IN-SPACe-	• Act as the **single window agency** for the authorisation of space activities by govt entities and NGEs. • Work with industry to **establish India as a preferred service** provider at global level.
New Space India Limited (NSIL)	• Responsible for **commercializing space technologies and platforms** created through public expenditure.

Significance of Space Policy 2023

- **Delineates specific roles for major stakeholders**, including ISRO, IN-SPACe, NSIL, and DoS.
- Collaborate globally in **addressing global challenges- climate change, disaster management etc.**
- Sets stage for India's expanded **participation in global space arena.**
- **Facilitating technology transfers,** for a vibrant space economy.
- Emphasis on **fostering innovation through public-private partnerships.**

Conclusion

Indian Space Policy 2023 **sets the stage for a bold and ambitious future** for India's space sector, opening the door to innovation, collaboration, and international cooperation.

3.1.2. PRIVATE SECTOR IN SPACE

PRIVATE SECTOR IN SPACE AT A GLANCE

- In 2023, size of India's space economy is estimated at **$8 billion (around 2-3% of global space economy)**, which has potential of USD 100 billion by 2040. **(Arthur D Little Report)**
- Recently, Tamil Nadu based Startup Agnikul launched world's first rocket with **fully 3D-printed engine** and India's first **semi-cryogenic engine-powered rocket.**
- Space Start-ups have increased to **nearly 200 in 2024 from 1 in 2022. (Economic survey 2023-2024)**

Significance

- **Reduces burden over ISRO:** Allows ISRO to **concentrate on cutting-edge research and development,** exploration mission and human spaceflight program.
- **Enable shift from supply driven model to demand driven model:** Almost every sector now wants satellite data and space technology.
- **Rapidly rising space industry:** Indian space sector is projected to increase at a- 48% CAGR over the next five years to reach US$ 50 billion.
- **Other Benefits:** Promote Make in India, increased cost competitiveness, innovation etc.

Initiative

- **Indian Space Policy** 2023
- **Indian National Space Promotion and Authorization Centre (IN-SPACe),** an independent nodal agency under Department of Space.
- **New Space India Limited** to promote private sector participation.
- Budget 2024–25 announced **Rs 1,000 crore venture capital fund.**

Constraints/Challenges /Concern

- **Multiplicity of regulations:** Approvals needed from Department of Space, ISRO, Antrix etc.
- **Increase in space debris:** 26,000 are pieces of debris that are larger than 10 cm in size. **(Space Environment Report 2024 by European space agency).**
- **Security and strategic concern:** Private sector in this arena can compromise security by possible leak of confidential information.
- **Issue of liability of private entities:** Multilateral treaties of international law are outdated.

Way Forward

- **Regulatory clarity:** To remove barriers for private firms and better synergies with ISRO.
- **Promoting satellite manufacturing:** Indian Space Association (ISpA) seeks a PLI scheme for satellite manufacturing.
- **Handhold private sector:** ISRO can act as an enabler by technology transfer, collaborations, and sharing of infrastructure.
- **Other:**
  - **Intellectual Property (IP) protections**
  - **Government extending the support** to start-ups with critical items

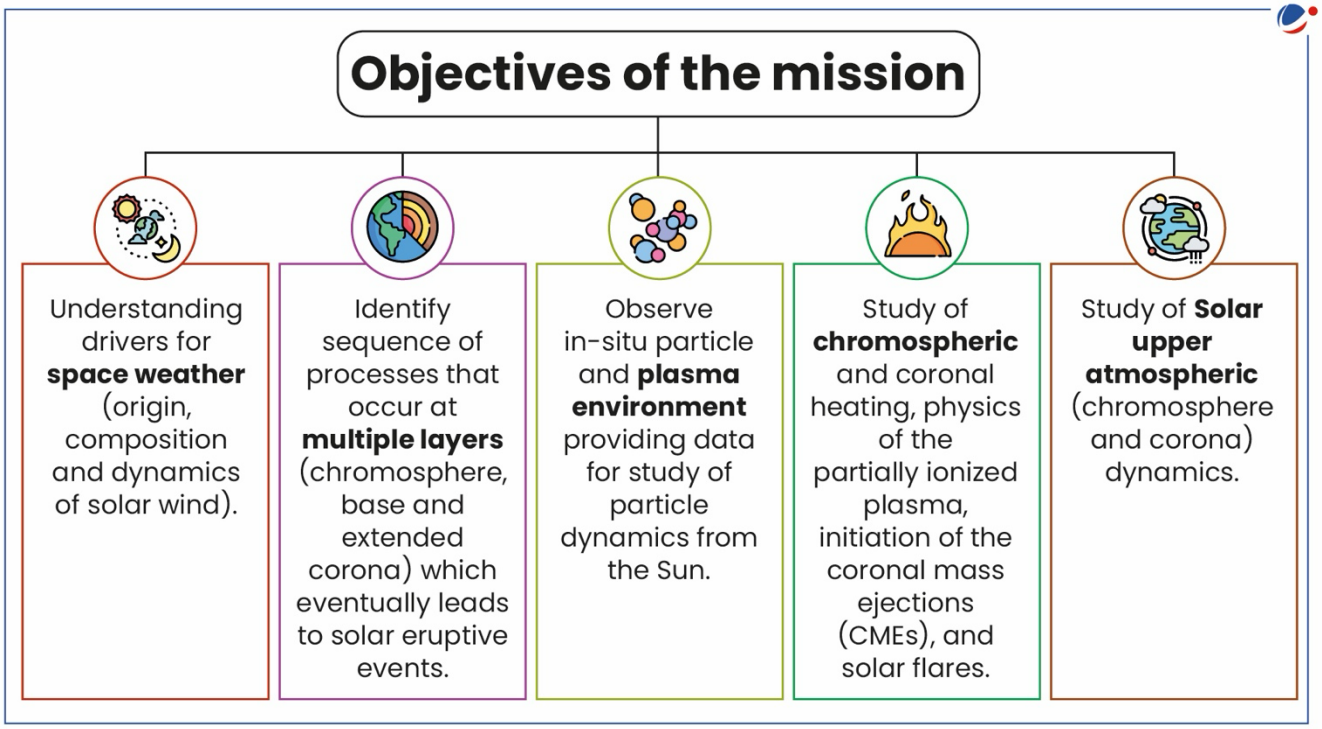
3.2. ADITYA-L1

Why in the News?

India's first solar observatory Aditya-L1 has been successfully placed in a halo orbit around Lagrangian point (L1) of the Sun-Earth system, about 1.5 million km from Earth.

About Aditya – L1

- **Launch vehicle: PSLV C57** (25th mission using **PSLV XL configuration**)
- **Aditya – L1 carries 7 payloads** (5 by ISRO and 2 by Indian Academic institutes)
- Out of 7, four of will carry out remote sensing of the Sun and three will do in-situ observation.
  - **Remote sensing payloads**
    - ✓ Visible Emission Line Coronograph (VELC)
    - ✓ Solar Ultraviolet Imaging Telescope (SUIT)
    - ✓ Solar Low Energy X-ray Spectrometer (SoLEXS)
    - ✓ High Energy L1 Orbiting X-ray Spectrometer (HEL1OS)
  - **In-situ payloads**
    - ✓ Aditya Solar wind Particle Experiment (ASPEX)
    - ✓ Plasma Analyser Package For Aditya (PAPA)
    - ✓ Advanced Tri-axial High Resolution Digital Magnetometers

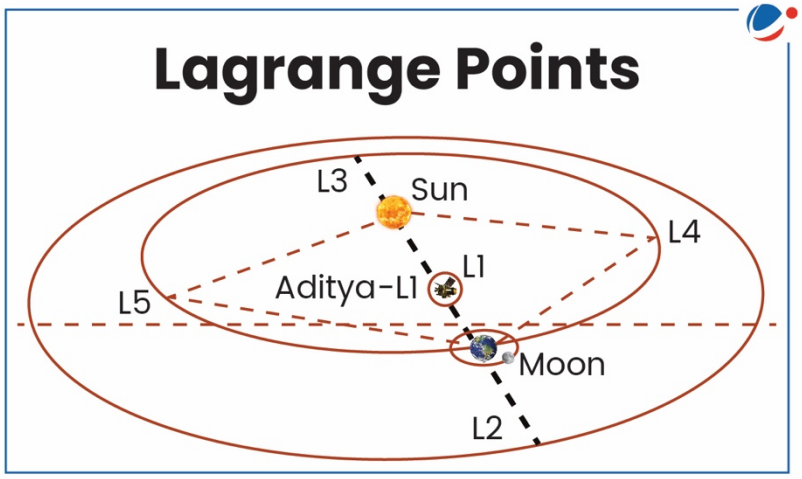


- **Uniqueness of the mission**
  - It will provide for the first time **spatially resolved solar disk** in the **near UV band.**
  - **CME and solar flares will be measured close** to the solar disk (from a 1.05 solar radius). It will provide **information in the acceleration regime of CME** which is not observed consistently.
    - ✓ For this, it will use on-board intelligence system, it will also **detect solar flare.**
  - **Directional and energy anisotropy of solar wind** using multi-direction observations.

About Lagrangian points

- It is a spot in space where the force of gravity of the nearest celestial entities cancels each other out, helping an object remain in equilibrium.

- For two body gravitational systems, there are **total of five Lagrange points** denoted as L1, L2, L3, L4 and L5.
- Of these **five Lagrange points**, three **(L1, L2, L3) are unstable** and two **(L4, L5) are stable**.



- **Significance**: Can be used by spacecraft to remain at these positions with **reduced fuel consumption.**
  - **Placing satellite around L1** gives advantage of **continuous observation of the Sun without any occultation/ eclipses.**
- **Other key information**:
  - NASA-ESA's joint **Solar and Heliospheric Observatory Satellite (SOHO) mission** is **placed near L1 point** while NASA's **James Webb Space Telescope is placed around L2 point**.

Conclusion

The mission embodies the nation's commitment to advancing scientific knowledge and securing its place on the global space exploration stage.

Other Missions to study Sun

- **Parker Solar Probe (NASA):** Launched in 2021, this spacecraft became the first to fly through the Sun's outer atmosphere, the corona.
- **Solar Orbiter (NASA/ESA):** Launched in 2020, this mission aims to take the closest-ever images of the Sun and study the solar wind.
- **Interface Region Imaging Spectrograph (NASA):** This mission aims to understand how the Sun's atmosphere is energized, leading to solar eruptions.
- **Solar and Heliospheric Observatory (NASA/ESA/JAXA):** Launched in 1995, this observatory monitors the effects of space weather on Earth.

3.2.1. SOLAR STORMS

Why in the news?

Recently, Earth witnessed G5 level of solar storm, the strongest in two decades and possibly one of the strongest displays of auroras in past 500 years.

What are Solar Storms?

- **Solar storms** happen when a large magnetic eruption on the Sun's surface, often accompanied by solar flares and coronal mass ejections (CMEs), accelerates charged particles to incredibly high speeds.
- Depending on the intensity, they are classified from G1 (Minor) to G5 (extreme).
- These are a result of Sun entering a **peak of Sun's activity cycle**.

Implications of solar storms

- **Damage to space infrastructure:** Highly energetic particles can penetrate the materials of spacecraft and potentially damage them.
- **Damage to ground assets:** such as power grids and can also interfere in radio communications.
- **Dangers to satellites:** Intense space weather causes changes in Earth's atmosphere and making it difficult for satellite to stay on track.

- **Auroras:** An aurora (northern or southern light) is caused when charged particles from the Sun, mainly electrons and protons, interact with the upper atmosphere.

About Sun's activity cycle

- Sun follows **a cycle of 11 years called sun's activity cycle** during which **solar activities fluctuate between solar maxima** (highest number of sunspots) or **solar minima** (lowest number of sunspots).
  - Sunspots are **small and dark**, yet cooler areas formed on the solar surface with strong magnetic forces.
- **Sunspots vary** as the **amount of magnetic flux** that **rises up to Sun's surface varies** with time in a cycle called the solar cycle, also called **sunspot cycle**, usually lasting for **11 years**.

3.3. CHANDRAYAAN-3

Why in the news?

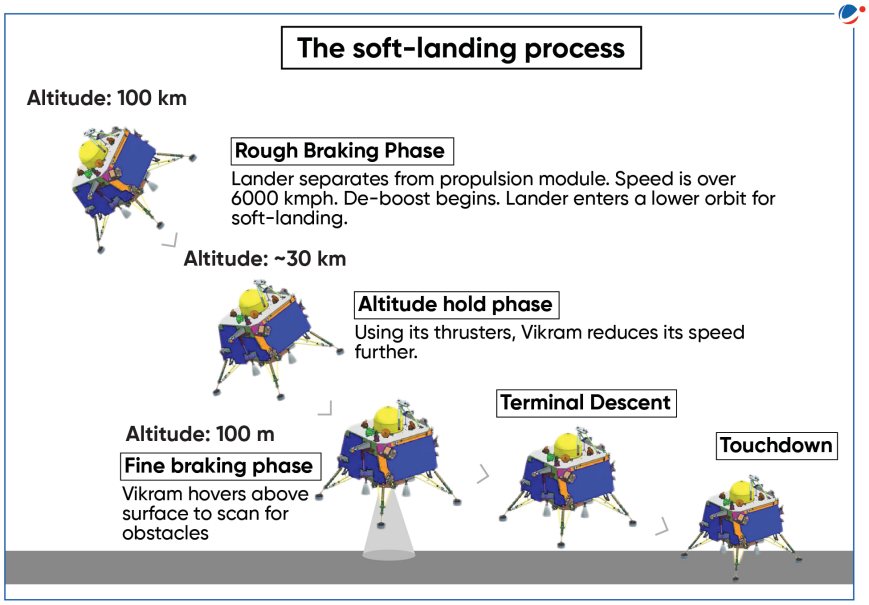
Chandrayaan-3 lander accomplished a 'soft landing' on the Moon's south pole.

More about the News

- The **spot where the Chandrayaan-3 Vikram lander made a soft landing** would be named **Shiv Shakti Point.**

About Chandrayaan-3 Mission

- **Chandrayaan-3 objectives**:
  - **Accomplished:**
    - ✓ **Demonstration of a Safe and Soft Landing** on the Lunar Surface
    - ✓ **Demonstration of Rover roving** on the moon.
  - Conducted **in-situ scientific experiments.**
- **Indigenous Payloads:**
  - **Lander module (LM)**
  - **Propulsion module (PM),** consist of **Lander** Vikram)
  - **Rover** (Pragyaan)



- **Chandrayaan-3** also **successfully underwent a 'hop experiment':** On command, it fired the engines, elevated itself by about 40 cm as expected and landed safely.
  - The success of this 'kick-start' experiment raises hopes for future missions such as sample return missions or human missions.

Chandrayaan-3 Payloads

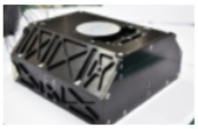
Lander Payloads

RAMBHA-LP

Langmuir Probe To measure the near surface plasma (ions and electrons) density and its changes with time

ChaSTE

Chandra's Surface Thermo-physical Experiment
To carry out the measurements of thermal properties of lunar surface near polar region.



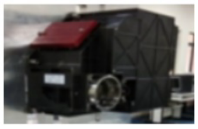
ILSA

Instrument for Lunar Seismic Activity To measure seismicity around the landing site and delineating the structure of the lunar crust and mantle

Rover Payloads

APXS

Alpha Particle X-Ray Spectrometer
To determine the elemental composition (Mg, Al, Si, K. Ca, Ti, Fe) of lunar soil and rocks around the lunar landing site.



LIBS

Laser Induced Breakdown Spectroscope
To derive the chemical composition and infer mineralogical composition to further enhance our understanding of lunar surface.

Propulsion Module Payload

SHAPE

Spectro-polarimetry of Habitable Planet Earth
An experimental payload to study the spectro-polarimetric signatures of the habitable planet Earth in the near-infrared (NIR) wavelength range (1-1.7 μm).

Key findings made by Chandrayaan-3

- **Temperature Profile of Moon's Surface: temperature was believed to be** around 20 degrees centigrade to 30 degrees centigrade on the surface, **but it is 70 degrees centigrade.**
- **Elements on the moon:** Probe confirmed' the **presence of sulphur** nea south pole.
  - **Other elements** like Aluminum (Al), Calcium (Ca), Iron (Fe), Chromium (Cr), etc. were also detected.
- **Thin plasma:** findings include that there is thin plasma on the surface of the moon.
- **Natural seismic activity:** Recording from Instrument for Lunar Seismic Activity (ILSA) payload indicates a possibility of a quake on the moon,
- **Crater:** Chandrayaan-3 Rover identified a 4-meter diameter crater on the moon's surface.

Implications of Findings

- The lumpy lunar soil could indicate the presence of a volatile substance like water ice and could prove **critical for missions envisaging lunar habitation.**
- **Measurements of Lunar Plasma** potentially assist in mitigating the noise that Lunar plasma introduces into radio wave communication.
- **Understand the moon's formation and evolution**, and provide water resources for future human exploration.

Conclusion

Chandrayaan-3 represents not just a mission to the Moon but a **giant leap for India's space program** and its contributions to our understanding of the cosmos.

Why Moon's South Pole is Important?

- The **South pole is speculated to consist of pockets of ice** , which could provide valuable insights on
  - The record of **lunar volcanoes.**
  - Material **that comets and asteroids delivered** to Earth.
  - To **understand the origin of oceans**.

3.4. GAGANYAAN MISSION

Why in the news?

Recently Government revealed names of four astronaut-candidates for first Indian human spaceflight mission, a.k.a. Gaganyaan.

About Mission Gaganyaan

- Envisages a demonstration of human spaceflight capability by **launching a crew of 3 members to an orbit of 400 km for a 3-day mission** and bringing them back safely to earth, by landing in Indian sea waters.
- LVM3 (Geosynchronous Satellite Launch Vehicle Mk III) rocket is **identified as the launch vehicle for the Gaganyaan mission**.
  - It consists of solid stage, liquid stage and cryogenic stage.

Significance of the Gaganyaan Mission

- **To develop future technological capability:** Mission will further boost technology in the field of crew safety, spacecraft design, effect of Microgravity, and life support systems.
- **Space station:** Indian Space station will be an extension of the Gaganyaan Programme.
- **Economic benefits:** mission will provide stimulus to the space economy and will increase employment in this sector.
- **International collaboration:** The French and Russian governments are already supporting the training of astronauts and the development of technology for Mission.

Status of the Gaganyaan programme

- The **design of all systems and sub-systems for Gaganyaan has been completed.**
- Human-rated **L110-G VIKAS engine** has been successfully tested.
- An **Astronaut training facility has been commissioned in Bengaluru.**
- ISRO is indigenously developing **Environmental Control And Life Support System (ECLSS)**.
- Gaganyaan's **first Flight Test Vehicle Abort Mission-1 (TV-D1)** was successfully executed.

Challenges associated with the Mission

- **Development of Indigenous technology:** because human space flight is a relatively new field.
- **Human health and safety:** Smooth working of the Life support system, radiation exposure, effect of microgravity, etc. are possible challenges to the crew's health and life safety.
- **Training of astronauts:** India lacks major critical training facilities, which is why it is taking help from Russia and France.
- **Budget constraints:** Delays or budget overruns can impact the overall success of the mission.

Conclusion

Gaganyaan mission holds the potential to inspire generations, **strengthen international collaborations**, and contribute to the broader goals of **advancing humanity's presence in space**.

3.5. INTERNATIONAL SPACE STATIONS

Why in the news?

One of the four astronauts undergoing training for the Gaganyaan mission will travel to the International Space Station (ISS) as part of a collaborative effort with NASA

About the International Space Station (ISS)

- It is a **habitable artificial satellite**, in low Earth orbit (at an altitude of between 370–460 km).
- **Key partners for ISS**:
  - European countries **(represented by European Space Agency)**
  - United States **(National Aeronautics and Space Administration)**
  - Japan **(Japan Aerospace Exploration Agency)**
  - Canada **(Canadian Space Agency)** and
  - Russia **(Roscosmos)**

Significance of ISS

- **Research and Science:** Provides opportunities to conduct meaningful studies on topics such as **DNA sequencing, robotics, and satellites in microgravity environment**.
- **International Cooperation**: Global collaboration in **developing space facilities**; communications networks, **and scientific research**.
- **Low Earth Orbit Economy:** ISS is **used by small businesses and entrepreneurs** to test their technology in space.
- **Long duration Spaceflight and human habitation:** Serves as **a testing ground to study how to keep astronauts safe and healthy on long-duration missions**.

About Bharatiya Antariksha Station: India's own Space Station

- India should aim to set up **'Bharatiya Antariksha Station' (Indian Space Station) by 2035.**
- ISRO is planning to carry out the **first tests of the proposed Bharatiya Space Station next year** and talks are on with the industry to **manufacture, test and launch its first module by 2028.**
- **Benefits:** Advancing scientific knowledge, enhancing the nation's prestige, promoting global co-operation & peace etc.
- **Challenges regarding Indian space station:**
  - **Station building is costly endeavor**: India's R&D expenditure-GDP ratio is low (0.7%).
  - **Need of expertise in human spaceflight:** India will have to train a team of astronauts and ensure their safety and well-being in space.
  - **Upgrade needed in ISRO's technological infrastructure:** For components like **life support, radiation protection, structural integrity and orbital maintenance etc.**

3.6. OTHER ISRO RELATED DEVELOPMENTS

3.6.1. X-RAY POLARIMETER SATELLITE (XPOSAT)

Why in news?

ISRO successfully launched the **X-ray Polarimeter Satellite (XPoSat)** by Polar Satellite Launch Vehicle (PSLV) -C58.

About XPoSat (X-ray Polarimeter Satellite)

- XPoSat is the **first dedicated satellite from ISRO** to carry out research and **measure X-ray emission** from celestial sources
  - It is the **second satellite** in the world to **study X-ray polarization**, first being NASA's **Imaging X-ray Polarimetry Explorer (IXPE).**

- **XPoSat payloads:** POLIX (Polarimeter Instrument in X-rays) and XSPECT (X-ray Spectroscopy and Timing)

Significance of the Mission

- **Understanding the nature of radiations:** better understanding of the emission processes from astronomical sources.
- **Advanced data collection:** X-ray polarimetry in medium energy band is being done for the first time.
- **Chemical Composition of celestial bodies:** reveals the physics and elemental composition of celestial bodies and can provide insights into interaction of matter with magnetic fields.
- **Better understanding** of the Universe.

AstroSat

- India's space telescope AstroSat has for the **first-time measured X-ray polarization** from the Cygnus X-1 black hole.
- **About AstroSat**
  - Launched by ISRO in 2015 using PSLV-C30 in Low Earth Orbit.
  - **First dedicated Indian astronomy mission** with a multi-wavelength space observatory.
  - **Objectives:**
    - ✓ To understand high energy processes in binary star systems containing neutron stars and black holes.
    - ✓ Estimate magnetic fields of neutron stars.
    - ✓ Study star birth regions and high energy processes in star systems lying beyond our galaxy, etc.

3.6.2. REUSABLE LANDING VEHICLE (RLV) LEX

Why in the News?

ISRO has achieved a third consecutive success in the final test of RLV Landing EXperiment (LEX), following the success of RLV LEX-01 and LEX-02 missions.

More about the News

- **RLV LEX-03** mission **simulated high-speed landing conditions for a vehicle returning from space**.
- Test was conducted with a **winged vehicle, named 'Pushpak'** which autonomously approached the runway and **performed a precise horizontal landing**.

About RLV LEX

- RLV LEX is part of **RLV-Technology Demonstration Programme**.
  - Under it, a series of TD missions including **HEX-01 mission (2016), three LEX missions** have been conducted and **RLV Orbital Re-entry Experiment (ORE)** has been planned.

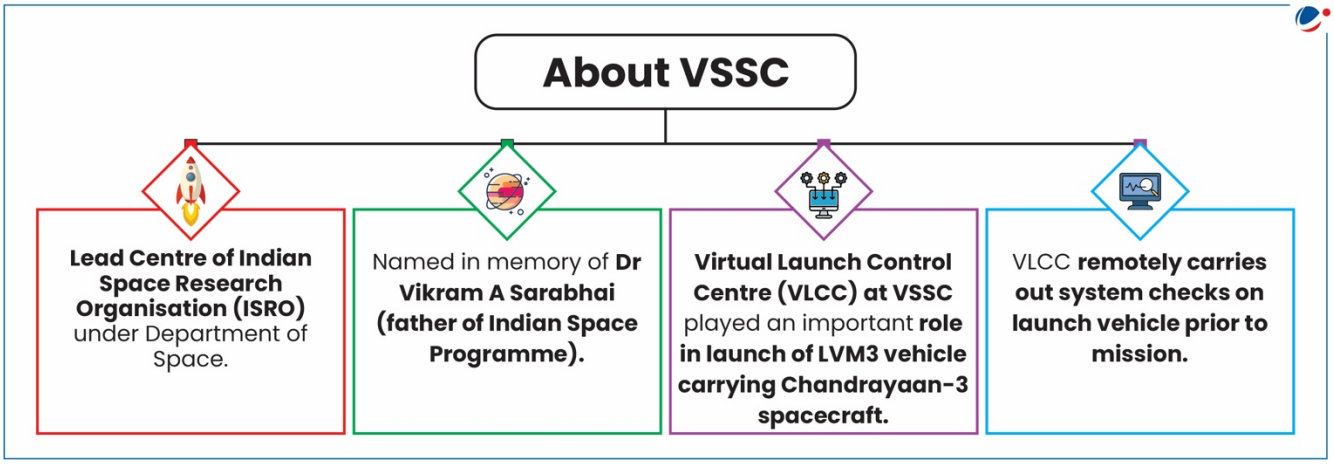
About RLV-TD Programme

- **RLV-TD Programme** aims at **developing essential technologies** for a **fully RLV** to enable low-cost access to space.
  - **RLV** is essentially a space plane which can travel to low earth orbits to deliver payloads and return to earth for use again.
  - **NASA is using RLV** for long time.
- **Advantages**: RLV is considered a low-cost, reliable, and on-demand mode of accessing space.
- **Challenges**: Selection of materials like special alloys, composites, and insulation materials and the crafting of its parts is very complex and demands highly skilled manpower.

3.6.3. VIKRAM SARABHAI SPACE CENTRE (VSSC)

Why in the News?

Recently, Prime Minister's visited **Vikram Sarabhai Space Centre (VSSC) in Thiruvananthapuram.**



About Three Projects

- **SLV Integration Facility (PIF) at Satish Dhawan Space Centre, Sriharikota** to **boost frequency of Polar Satellite Launch Vehicle (PSLV) launches** from 6 to 15 per year.
  - It also caters to **launches of Small Satellite Launch Vehicle (SSLV)** and other small launch vehicles designed by private space companies.
- **Semi-cryogenics Integrated Engine and Stage Test** facility at ISRO Propulsion Complex at Mahendragiri.
  - Facility is equipped with **liquid Oxygen and kerosene supply systems** to test engines up to 200 tons of thrust.
- **Trisonic Wind Tunnel at VSSC** for aerodynamic testing for characterisation of rockets and aircraft.

Semi-cryogenic engine (SCE)-200

- ISRO successfully conducted the first Pre-Burner Ignition trial for semi-cryogenic engine (SCE)-200.
- **About Semi-Cryogenic Engine (SCE)**
  - SCE utilizes **liquid oxygen (LOX)** as an oxidiser and **refined kerosene** as fuel.
  - SCE will **improve the payload capacity of the Launch Vehicle Mark-3 (LVM3)** and future launch vehicles.
- **Advantages of SCE**
  - **Easy storage and handling:** Refined kerosene is **lighter, needs less space** and can be **stored at a normal temperature.**
  - **More thrust:** They can **carry huge weight** to a higher altitude.
  - **Other benefits:** They are **eco-friendlier and more cost-effective** compared to cryogenic engines.

3.6.4. DEVELOPMENTAL ROLE OF ISRO

Developmental Role of ISRO

Food security and Agriculture	▶ To carry out crop production forecasts for major crops and to improve crop condition and productivity by using remote sensing satellites data **E.g. Resourcesat-2 Sattelite** ▶ ISRO has developed methodologies for **FASAL Project** (used for crop production forecasting) & **CHAMAN Project** (for horticulture crops)
Rural Development	▶ ISRO has launched **Village Resource Centers (VRCs)** to provide space-based services directly to rural areas like Telemedicine, Tele-education, Panchayat planning etc. ▶ Various programmes are carried out by ISRO addressing rural developmental viz. monitoring of Integrated Watershed Management Programme **(IWMP)**, GIS implementation of MGNREGA **(GeoMGNREGA)** etc.
Urban Development	▶ High resolution satellite data provides accurate information on current land use practices in a city or town for better urban Planning **e.g. Use of geospatial data in AMRUT scheme.**
Water Management	▶ **Satellite with ARGOS and ALTIKA (SARAL)** launched to monitor ocean continental water surface.
Resource Management	▶ **E.g. TRISHNA (Thermal infraRed Imaging Satellite for High-resolution Natural resource Assessment)**
Railways	▶ ISRO's regional navigation satellite system -**Navigation with Indian Constellation (NavIC) and Bhuvan (a web-based utility to explore a set of map-based content)** have been integrated into Railways' systems.
Weather Forecasting	▶ Given impetus provided by **INSAT & earth observation satellites, IMD** has improved its monsoon forecast and daily weather.
Disaster Management	▶ Using geoportals like **Bhuvan** to address various aspects of natural disasters, using space-based inputs. ▶ Development of **Flood Early Warning System (FLEWS) in Assam**
Education	▶ **EDUSAT** provided connectivity to schools, colleges and higher levels of education and also supported non-formal education.
Navigation	▶ **NaviC** is an independent regional navigation satellite system developed and maintained by India.
Infrastructure development	▶ **GSAT-N2 (GSAT-20)** will enhance India's Broadband Infrastructure

3.7. NASA RELATED DEVELOPMENTS

3.7.1. DEEP SPACE OPTICAL COMMUNICATIONS (DSOC)

Why in the news?

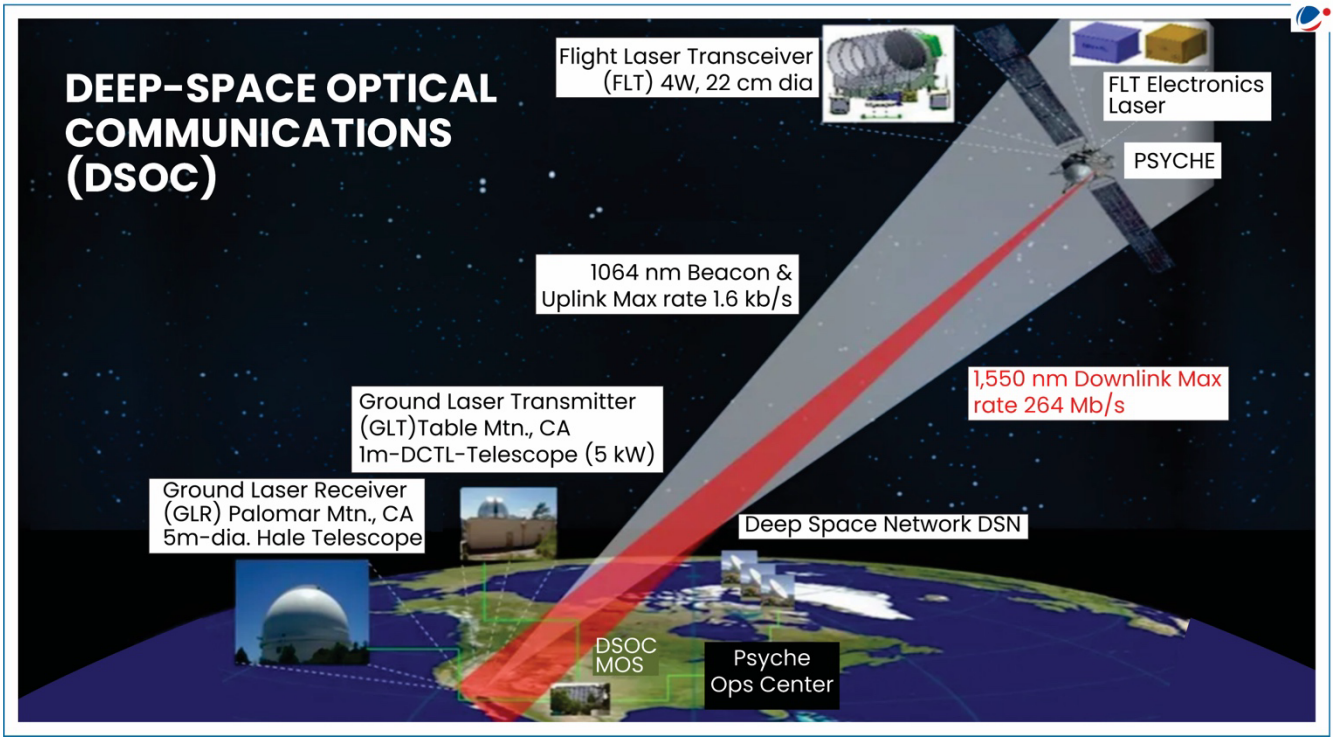
NASA successfully experiment's Deep Space Optical Communications (DSOC)

More about the News

- DSOC system was launched with Psyche spacecraft and is configured to send high-bandwidth test data to Earth.
  - **Psyche Mission (2023)** was launched to study a **metal-rich asteroid** that is Psyche Asteroid.
- The experiment aims to demonstrate data transmission rates 10 to 100 times greater than the state-of-the-art radio frequency systems used by spacecraft today.

About DSOC:

- A system that consists of a **flight laser transceiver**, a **ground laser transmitter**, and a **ground laser receiver.**
- It is the NASA's **first demonstration** of **optical communications** beyond the **Earth-Moon system**.
  - In **optical communications,** light is used to carry the signal, instead of electrical current.
- **Significance of DSOC:**
  - Uses **near-infrared light packs** which facilitates higher rate of data transmission.
  - High-definition imagery transmission.
  - Enables **human exploration of deep space** like **sending humans to Mars**.
    - ✓ **Deep space** starts just past the Moon's and includes the solar system and beyond.



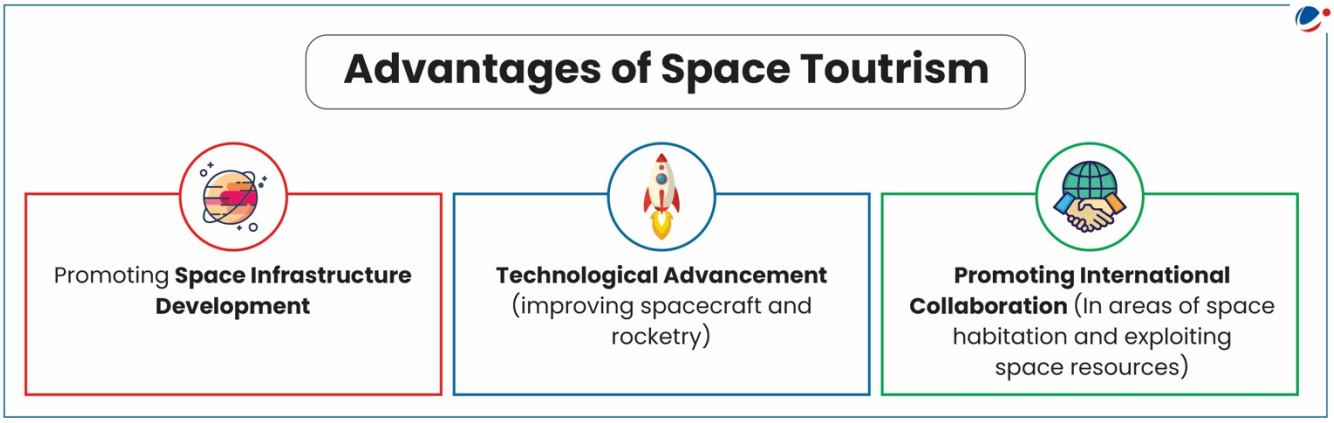
3.8. SPACE TOURISM

Why in the news?

Space startup Blue Origin has announced that Gopi Thotakura will be part of its New Shepard's 25th Mission (NS-25 mission).

What is Space Tourism?

- Space tourism is the commercial practice of sending **private individuals to space for recreational, adventure, or leisure purposes**.
  - The global space tourism market size is estimated at USD 851.4 million in 2023.
- **Types**:
  - **Suborbital**: In it, passengers are taken between 50 and 70 miles above Earth (crossing the **Kármán line** and back).
  - **Orbital**: In it, passengers are taken significantly above the Kármán line.
  - **Other**: Lunar Space Tourism, Interplanetary Tourism etc.



Challenges associated with Space Tourism

- **High Costs**: Require infrastructure for **specialized training** and **health checks** for the passengers.
- **Limited Market Demand**: Potential market for space tourism is comprised mainly of wealthy individuals
- **Rights and obligations:** Whether the passengers should be granted a status similar to that of astronauts
- **Safety Concern**: Due to the involvement of complex technological set-up and mechanism
- **Lack of Regulation**: Currently, there is **no specific treaty** to deal with issues related to space tourism.
- **Space Debris**: There is an inherent fear that space debris will increase due to potential collision of rockets with satellites. It can aggravate the **Kessler syndrome**.

Conclusion

To encourage Space Tourism, several steps would have to be taken from developing a global standard (like the Outer Space Treaty (1967)) to ironing out passenger challenges such as safety and application of rights.

3.9. SPACE HABITATION

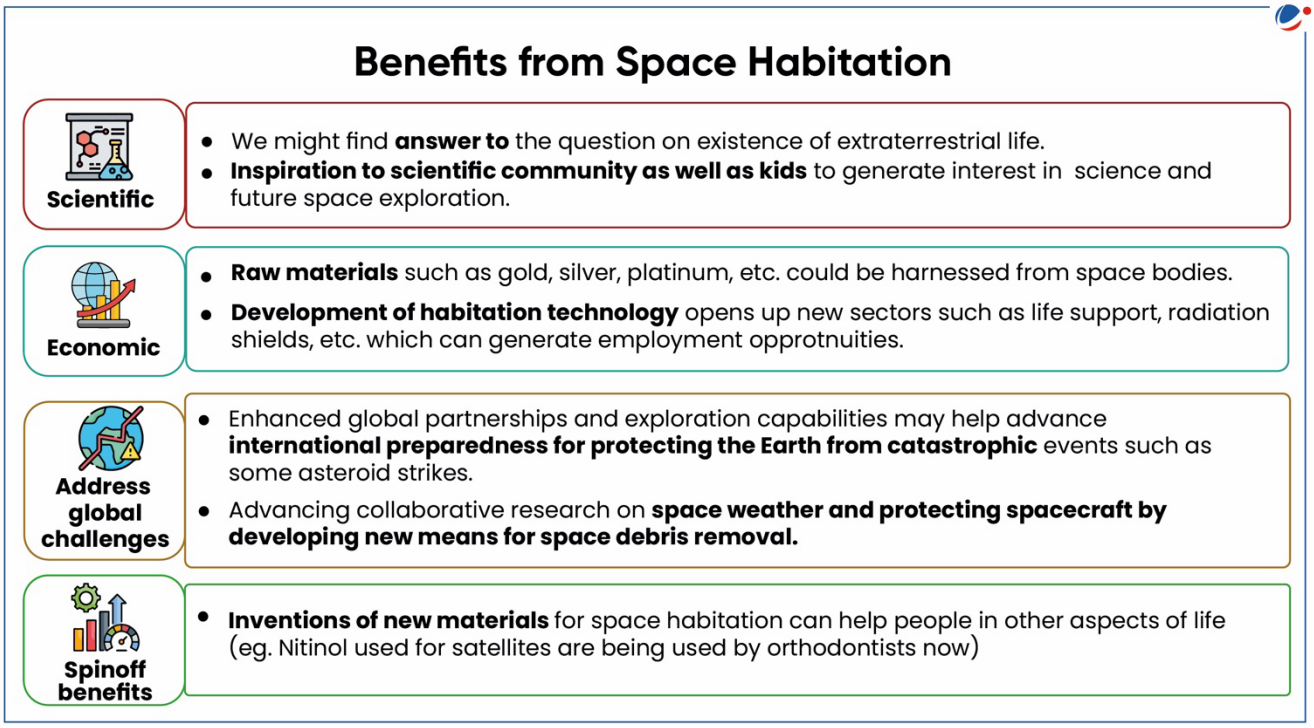
Why in the News?

NASA's plans to **create homes and habitable colonies on moon by 2040** have opened up the debate about habitation of the moon as well as other heavenly bodies.

About space habitation

- Space habitation refers to **setting up of habitation for humans beyond earth** such as on Moon, Mars etc.
- It could be done in **two ways.**
  - **Habitation of the celestial bodies** such as mars
  - **Building space habitats in form of capsule** modules which can be located anywhere in the solar system. **For example International space station**
- **Stanford Torus and O'Neill Cylinder have been proposed as** self-sustaining habitats in space which can support agriculture and various activities in a **microgravity environment**.

- **Stanford Torus** proposed by NASA envisions a **toroidal (doughnut-shaped) space station** with a central hub and a rotating outer ring.
  - ✓ The **rotation would create artificial gravity** on the inner surface of the ring, allowing for human habitation.
- **O'Neill Cylinder** consists of a pair of **large cylinders rotating in opposite directions** to create **artificial gravity** on their inner surfaces.



Issues associated with space habitations

- **Enormous Costs**: Development of essential technology and infrastructure for space exploration incurs significant costs.
- **Execution:** Managing oxygen, food, medical supplies, power sources, communications, and transportation to and from Earth poses technical and operational challenges.
- **Health Implications:** Cosmic radiation, lack of a breathable atmosphere, reduced gravity, isolation, and psychological stress pose health risks to inhabitants.
- **Environmental Modification**: Altering other planets' environments may harm their landscapes and contribute to space debris, with a possibility of triggering the **Kessler syndrome.**
- **Other Issues:** Lack of Legal Regulation and ethical concerns (such as Damage to the value of alien planets, afforded by limited people, etc.), etc.

Conclusion

For space habitation, humans should adhere to the trusteeship principle, taking responsibility for the well-being of non-human animals and the environment of Earth and alien planets.

3.10. OUTER SPACE GOVERNANCE

Why in the News?

Armenia has joined as the 43rd signatory nation to NASA's Artemis Accords for lunar exploration.

About Artemis Accords

- **Established:** In 2020 by **NASA**, in coordination with the US Department of State, together with **seven other founding member nations**.

- Grounded in the **Outer Space Treaty of 1967** and other agreements.
- **Objective:** It sets common **non-binding principles** to govern civil exploration and use of outer space, the moon, Mars, comets, and asteroids, for peaceful purposes.
- **India is also a signatory** to this Accord.
- This Accord will help in improving **outer space governance.**

Existing Outer Space Governance Framework

- **In 1958, the United Nations General Assembly (UNGA) established the Committee on the Peaceful Uses of Outer Space (UN COPUOS)** to govern the exploration and use of space for the benefit of all humanity.
- **Key International Space Treaties:**
  - **Outer Space Treaty 1967:** Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies.
  - **Rescue Agreement 1968:** Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space**.**
  - **Liability Convention 1972:** Convention on International Liability for Damage Caused by Space Objects.
  - **Registration Convention 1976:** Convention on Registration of Objects Launched into Outer Space.
  - **Moon Agreement 1979:** Agreement Governing the Activities of States on the Moon and Other Celestial Bodies.
- India is a **signatory to all five of these treaties but has ratified only four.** India has **not ratified the Moon agreement.**

Need for Reform in Outer Space Governance

- **Space debris:** According to ESA estimates, there are **130 million space debris objects** from greater than 1 mm to 1 cm.
- **Resource activities**: There is not an agreed international framework on space resource exploration, exploitation, and utilization **E.g. Space mining**
- **Space traffic coordination:** At present, national and regional entities coordinate space traffic with different sets of standards.
  - This relative **lack of coordination widens gap** for countries with less space capacity.
- **Prevention of conflict in outer space:** Additional normative frameworks are needed to prevent **weaponization of outer space.**

Conclusion

United Nations in its policy brief document titled 'For All Humanity – the Future of Outer Space Governance' recommended measures to improve outer space governance such as develop norms and principles for space debris removal, enacting new treaty to ensure peace, security, and the prevention of an arms race, etc.

3.11. SPACE DEBRIS

Why in the news?

Indian Space Research Organization (ISRO) released **Indian Space Situational Assessment Report (ISSAR) for 2023** compiled by ISRO System for Safe and Sustainable Space Operations Management (IS4OM).

More about the News

- **Space Situational Awareness (SSA)** is knowledge, characterization, and practice of **tracking space objects** and their operational environment.
- **Reports highlights that:**
  - Since beginning of Indian space era, **127 Indian satellites** (Including from private operators) have been launched till December 2023.

- There have been **five major on-orbit break-up events** in 2023, resulting in a net addition of **69 fragmented objects** to space debris population.
- **Increasing trend in Collision avoidance manoeuvers** per year is observed, which can be correlated with the growing congestion in outer space.

About Space Debris (Space Junk)

- Defined as all **non-functional, artificial objects, including fragments and elements** thereof, in Earth orbit or re-entering into Earth's atmosphere.
  - Maximum debris concentrations can be noted at altitudes of 800-1000 km, and near 1400 km (mainly in Lower Earth Orbits (LEO))
- Majority of debris objects **originate from on-orbit break-ups as** well as on-orbit collisions.

Concerns/Risks Associated with Space Debris

- Space debris objects can cause harm to operational spacecrafts and satellites **resulting into Kessler Syndrome.**
- Current and future space-based explorations and operations **pose a safety risk to astronauts.**
- Large space debris objects that re-enter the atmosphere in an uncontrolled way can **create risk to the population** on the ground.

Initiatives for mitigating Space Debris	
Indian initiatives	**Global initiatives and international partnerships**
• **Debris Free Space Missions (DFSM) 2030:** To achieve debris-free space missions by all Indian space actors, by 2030. • **ISRO System for Safe and Sustainable Operations Management (IS4OM):** Operational since 2022 to safeguard ISRO's space assets • **Space Situational Awareness Control Centre (SSACC):** assimilates tracking data of inactive satellites • **Project Network for Space Object Tracking and Analysis (NETRA) by** ISRO	• **Inter-Agency Debris Coordination Committee (IADC):** Established in 1993, international governmental forum for worldwide coordination related to man-made and natural debris in space. • **UN Space Debris Mitigation Guidelines:** Prepared by UN-COPUOS and endorsed by UN General Assembly in 2007. • **Zero Debris Charter:** Signed by **12 countries** ○ It contains high-level guiding principles and jointly defined targets to become **debris neutral by 2030**.

Way Forward

- **Minimize debris generation** through regulatory action or international agreements
- Ensure the **safe disposal of space objects** through atmospheric reentry or re-orbiting to a safe altitude.
- **Satellite health monitoring must be improved**, and robust passivation techniques implemented to prevent satellites breaking up from within.
- Innovative ways need to be explored for **Active Debris Removal (ADR)**.

3.12. LIGO-INDIA PROJECT

Why in the news?

Union Cabinet has approved the **Laser Interferometer Gravitational-Wave Observatory, or LIGO, project**.

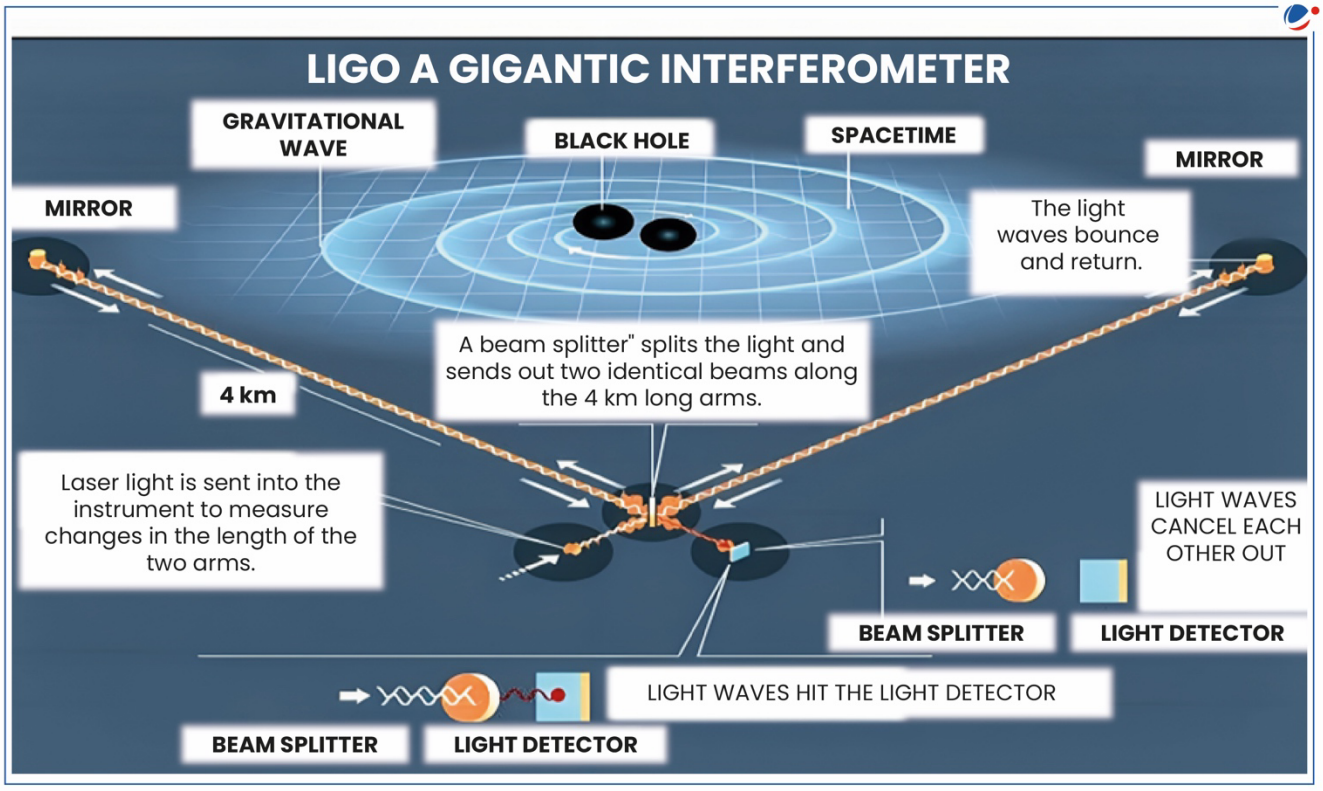
About LIGO - India

- A planned **advanced gravitational-wave observatory** to be located in India as part of the worldwide network.
- The project was given "in principle" approval in 2016 to be **completed by 2030**.
- **Location:** Hingoli district in Maharashtra.
- **Funding:** Department of Atomic Energy (DAE) and the Department of Science and Technology (DST).

- It is a **collaborative project** between a consortium of Indian research institutions and the LIGO Laboratory in USA.

What is LIGO and how it works?

- LIGO currently consists o**f two interferometers**, each with **two 4 km long arms** arranged in th**e shape of an "L"**. These instruments act as **'antennae' to detect gravitational waves.**
- It comprises stable **high-power lasers, precisely figured mirrors,** etc.



What are gravitational waves?

- Gravitational waves are **'ripples' in space-time** caused by some of the most violent and energetic processes traveling at the speed of light in the Universe.
- Some examples of events that could cause a gravitational wave are:
  - When a star explodes asymmetrically (called a supernova).
  - When two big stars orbit each other.
  - When two black holes orbit each other and merge.
  - Black hole-neutron star merger

Significance of LIGO

- LIGO provided direct evidence for the existence of gravitational waves, a major prediction of **Albert Einstein's General Theory of Relativity**.
- Understanding **Astrophysical phenomenon** such as black holes, neutron stars, supernovae, even the Big Bang.
- Promoted development of advanced technologies such as **Interferometric displacement sensor.**

3.13. SATELLITE COMMUNICATION TECHNOLOGY

Why in the News?

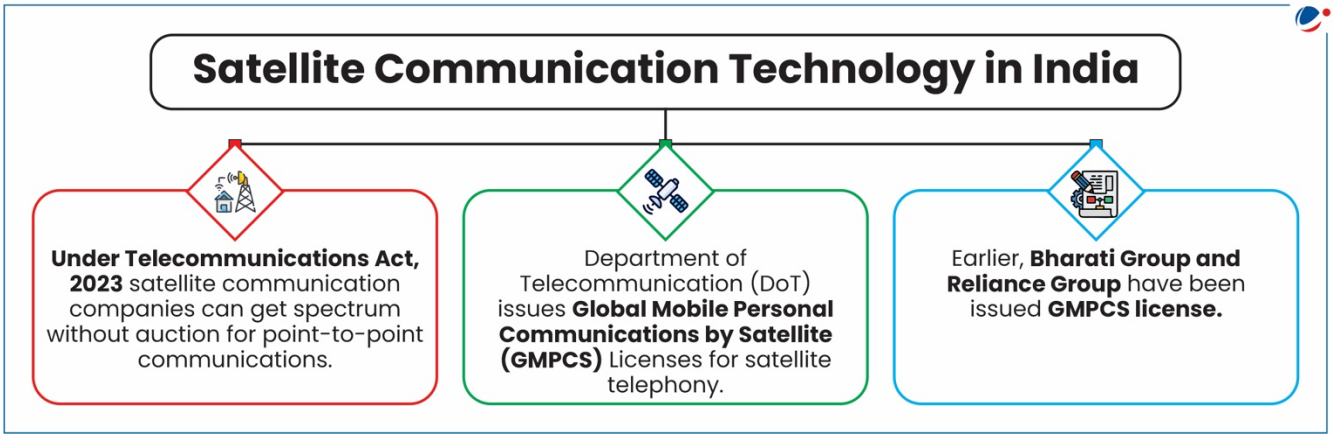
Chinese scientists have developed world's **first satellite series (Tiantong-1)** capable of **enabling smartphone calls without the need for ground-based infrastructure**.

More about the News

- **Tiantong-1 series** of satellites consist of **three satellites placed in geosynchronous orbit** at an altitude of ~36000 km.
  - **Geosynchronous orbit** is a low inclination orbit having a period of 23 hours 56 minutes and 4 seconds.

About Satellite Communication Technology (SCT)

- Satellite communication is the transfer of information using artificial satellites that have been launched into Earth's orbit, transmitting and relaying information from one place to another on a global scale.
- **Significance:**
  - Seamless and ubiquitous access to communication services in remote, rural areas.
  - During natural disasters or other emergencies it will play key role when terrestrial networks may be damaged or disrupted.
  - Enables secure and reliable communication, navigation, surveillance, and intelligence gathering.
- **Concerns:**
  - Space debris and orbital congestion, regulatory and governance challenges due to issues of international coordination and liability, cyber threats such as jamming, spoofing, etc.



4. HEALTH

4.1. ANTIMICROBIAL RESISTANCE

Why in the news?

The First **Multicentric Point Prevalence Survey of Antibiotic Use** was released recently by the **National Centre for Disease Control** under the Union Health Ministry.

Key Findings

- **Empirical prescriptions:** 94% of patients surveyed were given antibiotics before medical diagnosis.
- **High prevalence of antibiotic usage: At 71.9%** of patient surveyed.
- **Classification of prescriptions based on AWaRe groups:** 57% from watch groups, 38% from access group and 2% from reserve group.
  - High use of **watch group antibiotics** raises concern as these antibiotics have a **higher potential to develop antibiotic resistance.**
- **Only 8 out of 20 institutes** surveyed have an antibiotic policy in place.

WHO Access, Watch, Reserve (AWaRe) classification of Antibiotics

- **Access group Antibiotics**: Offer the best therapeutic value with less potential for resistance.
- **Watch group Antibiotics:** Higher resistance potential and need to monitor usage to avoid overuse.
- **Reserve group Antibiotics:** Last-resort antibiotics to treat severe infections caused by multidrug-resistant pathogens.

About Antimicrobial resistance (AMR)

- AMR occurs when **microbes** (bacteria, fungi, parasites and viruses) evolve so that **antimicrobial drugs** against them are **no longer effective**.
  - As a result of this drug resistance, **infections spread and become harder to treat.**
  - Microorganisms that develop antimicrobial resistance are referred to as **"superbugs".**
  - It is among **top 10 public health threat (WHO).**
  - It is closely linked to **triple planetary crisis** of **climate change**; **biodiversity loss**; and **pollution and waste**.
- **Reasons behind increasing incidence of Antimicrobial resistance**
  - **Overuse and misuse of antimicrobials** among humans and in poultry and farm animals.
  - **Poor infection prevention** and **control practices** in healthcare settings
  - **Effluents discharge from hospitals, industries,** and **urban settlements**
    - ✓ Over 75% of administered antibiotics are excreted unmetabolized in urine and faeces and enter into sewage systems and water bodies.
  - **Confusion over treatment guidelines.** E.g., the optimal duration of antibiotic therapy for common infections like pneumonia was not established for decades.

Implications of the Spread of Antimicrobial Resistance

- **Healthcare Impact:** Increased mortality and morbidity, and prolonged illness.(1.27 million deaths in 2019 by bacterial AMR)
- **Increased Healthcare Costs:** Longer hospital stays, additional diagnostic tests, and expensive second-line or third-line antibiotics leads to increased expenditure.
- **Economic impact:** Working hours lost due to prolonged illness and increase in out-of-pocket expenditure.
  - AMR will result in **US$ 1 trillion to 3.4 trillion annual losses to GDP** by 2030. (World Bank)
- **Limited new options for treatment:** There are limited new antibiotics in the research and development pipeline.

Initiatives

National

- **National Program on AMR containment:** Launched during 12th FYP in 2012-17
- **National Action Plan on AMR (NAP – AMR), 2017:** Focuses **on One Health approach** and involving various stakeholder ministries/departments.
- **National AMR surveillance network of state medical college labs (NARS-Net):** To generate quality data on AMR for priority bacterial pathogens of public health importance.
- **Drugs and Cosmetics Rules, 1945:** Antibiotics included in Schedule H1 of the rules are required to be sold by retail only under the prescription.
- **Other:** Ban on inappropriate fixed dose combinations (FDCs), Red Line awareness campaign, Operation AMRITH (Antimicrobial Resistance Intervention for Total Health) in Kerala etc.

Global

- **Global Action Plan on AMR (by WHO)**
- WHO released core package interventions on Antimicrobial Resistance (AMR)
- **Global Antimicrobial Resistance and Use Surveillance System (GLASS),** 2015
- **Global Antibiotic Research and Development Partnership (GARDP)**, a non-profit organization created **by WHO**
- **GARDP and WHO developed SECURE,** first dedicated mechanism to **expand access** in LMICs to **essential antibiotics**.
- **Combating Antibiotic Resistant Bacteria (Carb-X)**, a global non-profit **partnership** to **accelerate antibacterial innovation.**

Way Forward

- **Defined Antibiotic Use Policy in medical institutes** to keep the consumption of reserve group antibiotics at low levels.
- **Promote use of alternatives to Antibiotics i**n the animal feed industry.
- **Expansion of existing financing instruments** such as Green Climate Fund, etc. to include AMR.
- Quadripartite organizations (FAO, UNEP, WHO, World Organisation for Animal Health (WOAH)) should urgently **update the 2015 Global Action Plan**.

4.2. FIXED-DOSE COMBINATIONS (FDCS) DRUGS

Why in the news?

Central Drugs Standard Control Organization (CDSCO) has allowed companies to manufacture and market five fixed dose combinations (FDCs) that were banned in 2023.

About Fixed Dose Combinations (FDCs) Drugs

- Refers to **products containing two or more active ingredients** used for a particular indication(s) (as per Drugs & Cosmetics Rule 1945)
- An FDC is a **new drug when it meets two conditions**
  - **Combines two or more drugs already approved** for individual use in a fixed ratio.
  - **Alters the ratio of drugs in an already approved FDC**, along with making changes to its claims

Rationale for Usage of FDCs

- **Enhanced efficacy:** Combining specific drugs in a fixed ratio can achieve better therapeutic outcomes.
- **Cost-effectiveness:** Sometimes more affordable than purchasing individual medications separately.
- **Reduced pill burden:** Taking fewer pills can improve convenience and patient compliance.
- **Improved adherence:** Combining multiple medications into one pill can simplify treatment regimens.

Issues associated with FDCs

- **Lack of individual dose flexibility:** FDCs offer a fixed dose of each component, which may not be suitable for all patients.

- **Unapproved and Banned FDCs**: The easy access to untested and unlicensed FDCs in countries like India creates a potentially hazardous situation for public health.
- **Increased risk of AMR**: Combining medications in FDCs raises the risk of adverse events and AMR.
- **Reduced transparency and affordability concerns:** FDCs may be priced higher than their individual components.
- **Limited choice for patients:** The fixed combination may not always be the most suitable for individual patient needs, limiting treatment options.

Way Forward

- Require robust **scientific evidence** of FDC efficacy and safety to prevent unjustifiable combinations.
- Establish vigilant **post-market monitoring mechanisms** for prompt detection and resolution of FDC-related adverse effects.
- Harmonize export policies with domestic regulations to prohibit the overseas export of domestically banned or restricted FDCs**.**
- CDSCO should enforce stringent guidelines for FDC approval.

Drug regulation in India

- It is based on Drugs and Cosmetics Act (DC Act), 1940 and Drugs and Cosmetics Rules, 1945.
- DC Act 1940 created CDSCO under Ministry of Health and Family Welfare.
- **About CDSCO**
  - Serves as **the National Regulatory Authority** (NRA), headed by Drugs Controller General of India (**DCGI**).
  - **Aim:** Ensure safety, efficacy and quality of the medical product manufactured, imported and distributed in the country.
  - **Responsibilities:**
    - ✓ Approval of new drugs, clinical trials, and medical devices.
    - ✓ Laying down standards for drugs and cosmetics, etc.
  - **CDSCO along with state regulators, is jointly responsible for grant of licenses** of certain specialized categories of critical Drugs.
- **Challenges in effective drug regulation**
  - **Absence of centralised drugs database:** For effective surveillance of Pharma companies.
  - **Multiplicity of regulators:** Nearly 36 regional regulators for drugs.
  - **Less emphasis on Good Manufacturing Practice Standards (GMPS),** only 2,000 of 10,500 manufacturing units in India have compliance to WHO-GMPS.

4.2.1. ACTIVE PHARMACEUTICAL INGREDIENTS (APIS)

Why in the News?

India has started manufacturing 38 Active Pharmaceutical Ingredients (APIs) in past 1.5 years

About API

- APIs are the **active components** in a pharmaceutical drug that produces the **required effect on the body** to treat a condition.
- Despite India being 3rd largest pharmaceutical industry by volume in world, it is **primarily dependent on bulk drug import particularly from China.**
- **Challenges in Manufacturing API**
  - India is still largely **dependent on China for Key Starting Materials (KSMs)**, the basic building blocks for making APIs.
  - **Manufacturing APIs is a complex process** involving a number of reaction and purification steps.
    - ✓ Employing **fermentation processes** for making APIs continues to face challenges in terms of both technologies and costs.
  - **Low-profit margins** making less attractive for locals manufacturers.

- **Initiatives**
  - **Production-linked incentive (PLI) scheme** for promotion of domestic manufacturing of critical KSMs/ Drug Intermediates (DIs) and APIs in India.
  - The Scheme for **Promotion of Bulk Drug Park**.
  - **Scheme for Strengthening of Pharmaceuticals Industry (SPI)** aims to provide infrastructure support for pharma MSMEs in clusters.
  - **Government has allowed 100% FDI in the pharma sector** for greenfield projects under automatic route.

4.2.2. GENERIC DRUGS

Why in the News?

National Medical Commission (NMC) put on hold the Rule Requiring Doctors to Prescribe Only Generic Drugs.

More about the News

- Earlier, provision under **the Registered Medical Practitioner (Professional Conduct) Regulations, 2023** was added which entails **penalizing doctors** for failure to **prescribe generic drugs**.

About Generic Drugs

- A **medicine created** to be the **same as an already marketed** branded drug in dosage form, safety, strength, **route of administration, quality, performance characteristics**, and intended use.
  - There is **no definition of 'generic drugs'** in the **Drugs and Cosmetics Act, 1940,** and **Drugs & Cosmetics Rules, 1945**.
- It can be **marketed after the branded drug's patent expires**, but **compulsory licensing** under the **Indian Patent Act** allows for it **without consent during any urgency**.
- **Significance of GDs for India**
  - Improves accessibility and availability of **critical medicines**.
  - **Reduces healthcare costs** due to its relatively cheaper pricing.
  - India accounts for 20-22% of generic drug exports globally. (Invest India)

Challenges

- **Illegitimate drugs:** In 2018, the CDSCO identified nearly **4.5%** of all generic drugs circulated in the **domestic market to be substandard.**
- **Lack of quality testing facilities:** Drug control procedures suffer from the lack of fund, resources, and manpower.
- **Perception of Patient:** Generally it is believed that the quality of the medicine directly depends on its cost.
- **Ever-greening of Patents:** Big pharmacy companies maintain their monopoly by doing minor reformulations or other iterations of the drug.

Way Forward

- Drugs Controller General of India (DCGI) should work in close coordination with all stakeholder to control illegitimate drugs from market.
- **Providing Compulsory licensing,** under it, government allows someone else to produce a patented product or process without the consent of the patent.
- India needs a **strong regulatory framework**.

4.3. ORGAN AND TISSUE TRANSPLANTATION

Why in the News?

National Organ and Tissue Transplantation Organisation (NOTTO) ordered an inquiry into **'cash-for-kidney racket'** allegations against Indraprastha Medical Corporation Ltd.

About Organ and Tissue Transplantation

- **Organ Transplantation:** Includes kidney, liver, heart, lung, pancreas, and intestine etc.
- **Tissue Transplantation:** Involves corneas (eye), skin, bone, heart valves, and blood vessels etc.
- **Compatibility**: Determined by the degree of **immunological similarity** between the donor and recipient, for **e.g.,** Human Leukocyte Antigens (HLAs), blood group match etc.
- **Legal Framework:** Governed under the **"Transplantation of Human Organs Act 1994".**
  - In 2011, amendment of the Act also brought in donation of **human tissues**, there by calling the Amended Act **as "Transplantation of Human Organs & Tissues Act (THOTA) 2011.**
  - Both **living** and **deceased donor** are allowed to donate organ in India.
    - ✓ Also allowed donation by Brain-**stem Dead** donors.
- **National Organ Transplant Programme**: To organize a system of organ and Tissue procurement & distribution for transplantation.
- **Modified National Organ Transplantation Guidelines, 2023.**
  - Allowed those above **65 years of age to receive an organ for transplantation from deceased donors**.
  - Also, **removed the domicile requirement** to register as an organ recipient.

Challenges in Organ Transplantation in India

- **Low Donation**: India has a **Deceased Organ Donation** rate of **0.52 donors per million** population **(**in **Spain it is 49.61 per million)**.
- **Slow progress**: **Number of donors (including deceased)** only grew from **6,916 in 2014 to about 16,041 in 2022 (**Ministry of Health and Family Welfare (MoHFW)).
- **Supply-demand Mismatch**: Only **8,000 out of 1.5-2 lakh** people obtain a kidney transplant**, 1,800 out of 80,000** receive a liver transplant.
- **Brain stem death declaration:** As **brain death** has been defined **only in connection with organ donation** in the THOTA, 1994 and **not in Registration of Births and Deaths Act, 1969.**
  - This makes doctors reluctant to give certificates due to **litigation fear** and **ethical concerns**.
- **Other:** Organ trafficking**, Lack of male donor participation (**70%-75% of donors are female), etc.

Way forward

- Adopting an **opt-out model of organ donation system**, prevalent in countries like **England**, **Singapore**, etc.
  - Under it, the deceased patient **is presumed to have consented** to organ removal.
- **Emulate Kerala model in other states:** Kerala has become the first State to formulate well-defined **clinical protocols for brain death certification**.
- **Transparency in Organ Allocation:** Creation of **digital registry** on organ transplantation to enhance transparency.
- **Streamline transportation process**: **For e.g.,** In air mode**,** Consistent use of **flight notes** to indicate organs on board, so that air traffic control can ensure priority take-off and landing of aircraft.

4.4. E-CIGARETTES

Why in the News?

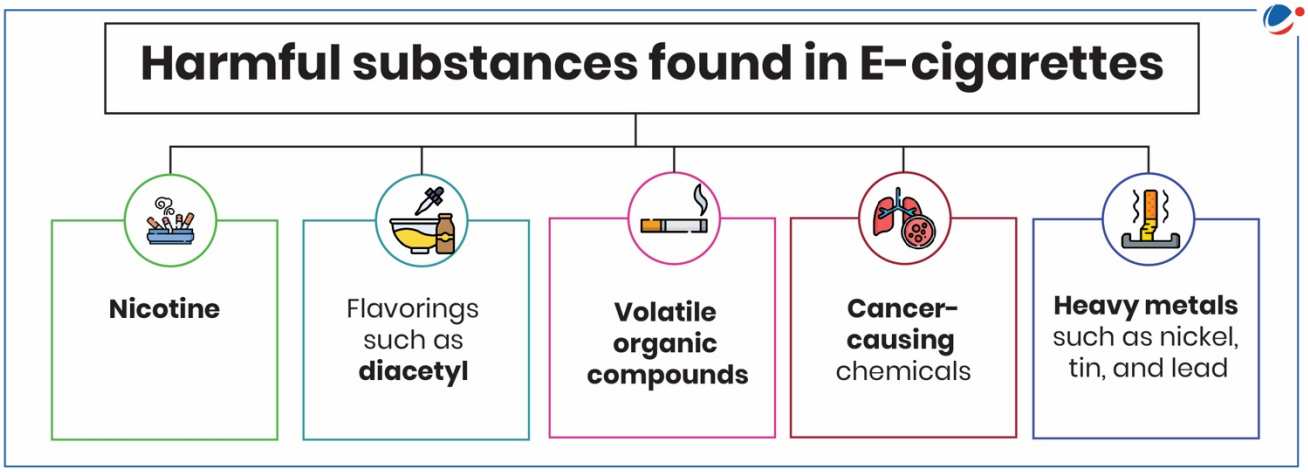
As per **World Health Organization (WHO),** urgent action is needed to protect children and prevent the uptake of **e-cigarettes.**

More about the News

- **Key findings of WHO**
  - **Children 13–15 years old** are using e-cigarettes at rates higher than adults in all WHO regions.

About e-cigarettes

- India has banned **e-cigarettes** under **the Prohibition of Electronic Cigarettes (Production, Manufacture, Import, Export, Transport, Sale, Distribution, Storage and Advertisement) Act, (PECA)** 2019.
- Act defines **electronic cigarette or** e-cigarette as-
  - An electronic device that heats a substance, which **may or may not contain nicotine** and flavors, to create an aerosol for inhalation.
  - Includes all forms of Electronic Nicotine Delivery Systems, Heat Not Burn Products, e-Hookah, etc.
- Also referred as "mods," "vape pens," "vapes," "tank systems," and "electronic nicotine delivery systems (ENDS)."
- **Working**: Aerosol produced by them is inhaled by the user, by heating a liquid that usually contains nicotine, flavorings, and other chemicals.



Issues

- **Health Risks:** Increases the **risk of heart disease and lung disorders.**
  - Nicotine exposure in pregnant women can limit the brain development of the foetus.
- **Enforcement issues:** Easily available in tobacco shops and online.
- **Promote addiction among youth:** due to **attractive flavoring and sleek designs** younger generation is attracted.
- **Less Regulated:** Around 74 countries have no regulations in place.
- **Aggressively marketed:** E-cigarettes target children through social media and influencers.
- **Use as cessation aid:** Presented as devices to help quit smoking, however, the evidence on their use as a cessation aid is inconclusive.

Suggested Measures

- **By WHO:**
  - **Not to be sold as consumer Products:** Governments should **not permit sale of e-cigarettes** as consumer products.

- **Control Access:** Any government pursuing a smoking cessation strategy using e-cigarettes must control the condition of e-cigarette access.

- **Other Measures:**
  - **Strict implementation of the ban by authorities** and taking punitive action against local vendors and online sellers.

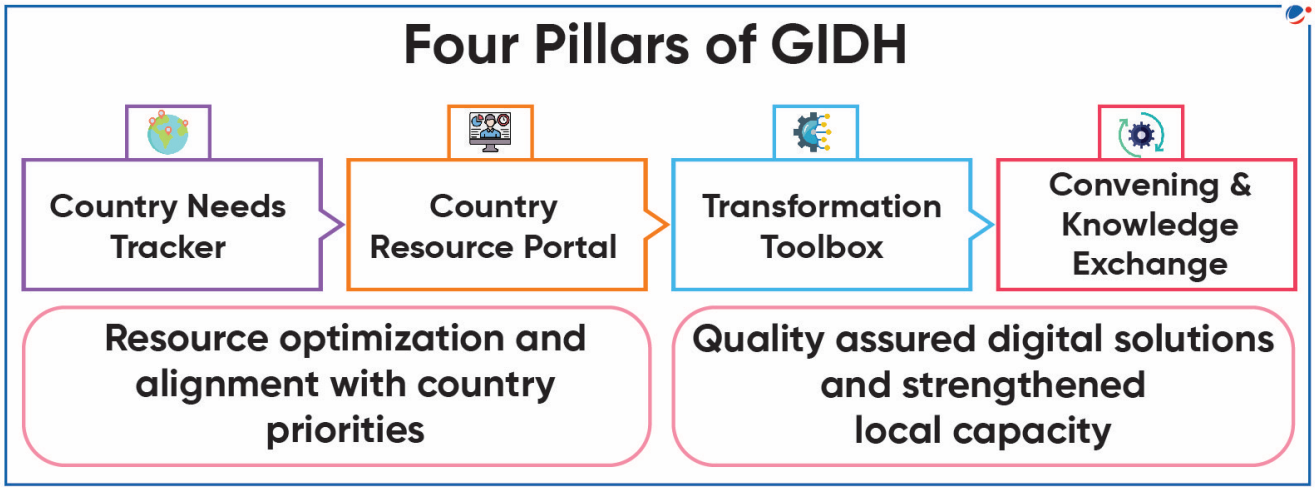
4.5. DIGITAL HEALTH

Why in the news?

World Health Organization (WHO) and Indian government have launched Global Initiative on Digital Health (GIDH).

More about the News

- **GIDH aims to**
  - Support the WHO Global Strategy on **Digital Health 2020–2025**.
  - Supports quality-assured technical assistance to develop and strengthen standards-based and interoperable systems, etc.
  - Democratize digital health.



About Digital Health

- Refers to **use of digital technologies for healthcare purposes**.
- Encompasses a **wide variety of digital health technologies.**
  - It includes dealth information technology, wearable medical devices, telemedicine and telehealth, etc.

Significance

- **Early diagnosis of critical alterations in the disease progression** of a patient.
- **Decreased healthcare costs** for both patients and providers.
- Improved patient health outcomes through personalised **treatment plans.**
  - **Sensitivity of the patient's condition can be prevented by real-time logging** of significant health-related elements like medication use, treatment adherence, etc.
- **Increase quality and reduce the administrative workload** and other tedious tasks.
- **Enhanced accessibility** through initiatives like telemedicine.

Initiatives related to Digital Health

- **Ayushman Bharat Digital Mission (ABDM), Digital Health Incentives Scheme (DHIS)** has been implemented under it.
- **eSanjeevani**, A **National Telemedicine Service** of MoHFW.

- **Telemental Health Assistance and Networking Across States (Tele-MANAS)**: Launched by MoHFW,
- **Nikshay 2.0 portal**, provides a **platform for community support to TB patients**
- **Poshan Didi,** a **chatbot-based for nutrition** counselling service
- **Covid Vaccine Intelligence Network (CoWIN) system**, a digitalised Vaccine Distribution platform.

Concerns

- **Data consent concerns**: Patients are reluctant to share their data due to security reasons.
- **Data Processing:** Vast data generated at hospitals, clinics, etc., pose a significant challenge for organisations to deliver personalised care to patients.
- **Quality Concern**: Patients are concerned about the quality of care that they receive through digital health services. E.g. Tele-medicine
- **Other: Lack of Infrastructure** (such as digital connectivity in rural areas and hilly terrain)**,** Ensuring **accountability or liability** in case of device failure, lack of **Digital Illiteracy** etc.

Way Forward

- **World Bank, in its 'Digital in Health – Unlocking Value for Everyone' report, recommended**
  - **Connect** global and regional collaboration, digital infrastructure and health information gaps, etc**.**
  - **Scale** digital skills and literacy, public-private partnerships for funding, etc.
- **Prioritising Governance:** Establishing digital health governance, instead of focusing exclusively on discrete digital health interventions.
- **Data protection:** Focusing on **ethical and regulatory oversight**, etc.
- **Use of AI:** Technology like AI should be utilised to process the data collected by healthcare professionals.

4.6. TRADITIONAL MEDICINE

TRADITIONAL MEDICINE (TM) AT A GLANCE

- TM is **sum total of the knowledge, skill, and practices based on the theories, beliefs, and experiences indigenous to different cultures,** used in the maintenance of health as well as in the prevention, diagnosis, improvement or treatment of physical and mental illness. (WHO)
- Consists of **Ayurveda, Yoga and Naturopathy, Unani, Siddha, and Homoeopathy (AYUSH)**

Significance/Applications

- **Addresses gaps** in **health services.**
  - Around 80% of the world's population is estimated to use TM. (WHO)
- Countries can **offer specialised resources and services** that may not be available, affordable, or accessible in other parts of the world.
- Around 40% of pharmaceutical products today have a **natural product basis, including aspirin,** etc.
- **Enhancing the accessibility** (Despite 71% of the country being predominantly rural, the proportion of Allopathic doctors in rural areas is only 34%).
- **Effective in managing chronic diseases** such as HIV/AIDS and cancer patients.

Initiatives

- **National Ayush Mission**, Centrally Sponsored Scheme by the **Ministry of AYUSH** (MoA)
- **Gujarat Declaration by WHO** (in the First WHO Traditional Medicine Global Summit)
- **Global Centre for Traditional Medicine (Gujarat)** by MoA and WHO
- **Traditional Knowledge Digital Library (TKDL)**, more than **4 lakh formulations/ practices** have been transcribed.
- **National Ayush Morbidity and Standardized Terminologies Electronic (NAMSTE) portal** and **Ayush Health Information Management System (A-HIMS)**
- WHO's **Module 2** of International Classification of Diseases 11 (ICD-11), **dedicated** supplementary chapter **to Ayurveda, Siddha, and Unani (ASU).**
- **Other: AYUSH Visa** for foreign nationals, **Ayurveda Gyan Naipunya Initiative (AGNI)**, SMART 2.0' (Scope for Mainstreaming Ayurveda Research among Teaching professionals) etc.

Constraints/Challenges/Concerns

- **Infrastructure issue:** Absence of advanced appliances, latest techniques, etc.
- **Quality issues:** Adulteration, misidentification of plants, etc.
- **Irrational use:** Misconception of no side effect is not true.
- **Standardization:** E.g. Ayurveda faces a crisis in standardising with respect to branding and consistency.
- **Procurement of raw materials:** Increase in the use of pesticides affects the quality of raw materials.

Way Forward

- AI can be used to mine **complex data** available on TM and identify practices that show promise for further scientific evaluation.
- Policies based on **ethical** and **equity considerations** can accelerate the safe and effective use in health systems.
- Better **evidence** on the **effectiveness**, safety and quality will help to build trust of people on them.
- Proper **pharmacovigilance** to find the toxicological data and adverse drug reactions of herbal drugs.

4.7. TUBERCULOSIS (TB)

Why in the news?

Union Ministry of Health and Family Welfare released **India TB Report 2024**.

Major Findings of the Report

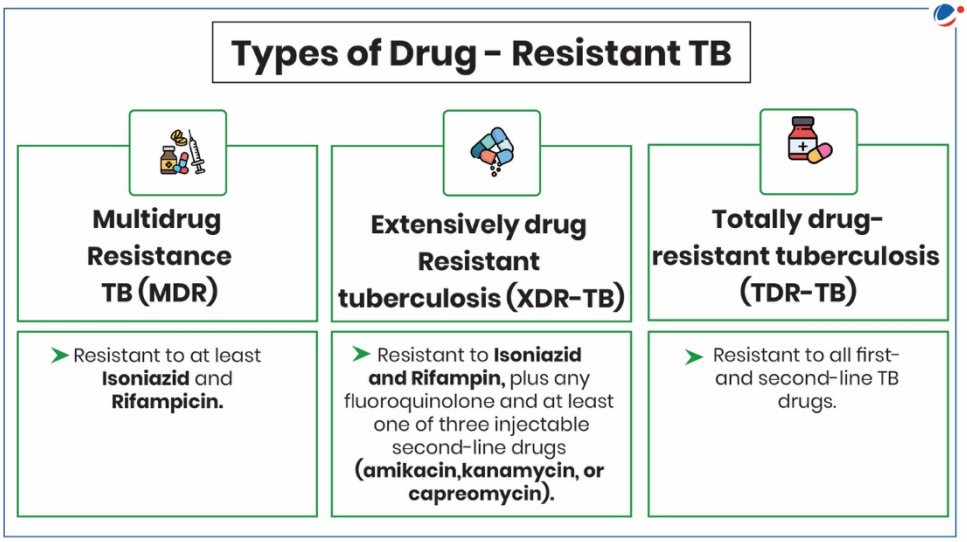
- **Notified TB patients:** 25.52 lakh TB patients in 2023 (increase from 24.22 lakh cases in 2022).
- **Reporting of cases:** ~67% reporting being done by the public sector and ~33%) from private sector.
- **Achievements:**
  - **Target of initiating treatment in 95% of patients** diagnosed with the infection was achieved in 2023.
  - **Reduction in mortality**: 18% in comparison to 2015

About Tuberculosis

- An infectious disease caused by bacillus **Mycobacterium tuberculosis bacteria** which most often **affects lungs** and is known as **pulmonary TB.**
  - **Extrapulmonary TB** affects **other areas of the body. (e.g.** gastrointestinal TB, skeletal TB, liver TB)
- **Transmission:** By air when an infected person coughs, speaks, etc.
- **Common symptoms**: Prolonged cough (sometimes with blood), chest pain, weakness, etc.
- **Treatment**: Medications include **isoniazid, rifampin, ethambutol, pyrazinamide,** etc.
  - **Bacillle Calmette-Guerin (BCG)** vaccine is also available for its prevention.
- **Drug-Resistant TB** doesn't respond to standard drugs.

Challenges

- **Social Stigma and Taboo** leads to delayed diagnosis and social isolation of patients
- Poor **Healthcare Infrastructure**
- **Poverty and Malnutrition** is linked to weak immune system, increases transmission risk
- **Comorbidities (with HIV, diabetes)** increases vulnerability of patients



- **High Treatment Costs** in private hospitals and in cases of Drug Resistant-TB
- **High- dropout rates** due absences robust mechanism of regular follow up etc.

Way Forward

- **Enable Early Detection** by increasing the **use of chest X-ray, strengthening of referral networks** for better screening of patients.
- **Precise Treatment Categorization** such as **resistance status of TB** at the beginning of diagnosis can help in assigning appropriate treatment regimens.
- **Long-term and sustained treatment** should be ensured by regular follow-ups.
- **Nutritional Support to patients** (a 2023 Lancet study found that nutritional support in a 'RATIONS' trial in Jharkhand reduced the risk of death).
- **Dynamic Notification System** for improved notification system to capture real-time TB data.

- **Decentralizing TB service delivery** to the level of **Ayushman Arogya Mandirs**.
  - E.g., TB-WIN platform for registration of the Adult BCG Vaccination beneficiaries.
- **Increase Investment can lead to better outcomes,** for every dollar spent on screening of TB, there is potential benefit of $39. (WHO)

India's Initiatives

- **National Tuberculosis Elimination Programme (NTEP):** Aims to reduce TB burden by 2025.
- **Pradhan Mantri TB Mukt Bharat Abhiyan:** Launched to provide additional patient support, **augment community involvement** and leverage Corporate Social Responsibility (CSR) activities.
- **Nikshay Poshan Yojana:** Launched to provide for **financial incentive of Rs 500**.
- **TB Mukt Panchayat Initiative:** Aims to empower Panchayati Raj Institutions to understand TB issues, take necessary actions.
- **Mission Indradhanush:** BCG vaccine is provided under the mission.
- **BPaL regimen trials,** for treatment of XDR-TB, BPaL is a **six-month**, **all-oral**, **three-drug regimen** (Bedaquiline, Pretomanid and Linezolid) to XDR-TB.
- **Other: Tribal TB Initiative,** National TB Call Centre – Ni-kshay SAMPARK, **etc.**

Global Initiative

- WHO Initiative
  - **#ENDTB Strategy** with goals of-
    - ✓ 95% reduction by 2035 in number of **TB deaths** compared with 2015.
    - ✓ 90% reduction by 2035 in **TB incidence** rate compared with 2015.
    - ✓ Zero TB-affected families facing **catastrophic costs** due to TB by 2035.
  - **TB vaccine accelerator Council:** To facilitate the development, testing, authorization, etc.
- **SDG Goal 3.3** aims to end the tuberculosis by 2030 along with other diseases.

4.8. CERVICAL CANCER

Why in the news?

First ever **Global Cervical Cancer Elimination Forum** took place in Colombia, recently.

About Cervical Cancer

- A disease in which **cells in the body grow out of control**. When cancer starts in the **cervix**, it is called cervical cancer.
- Occurs **most often in women over age 30** and is the **fourth most common cancer** in women globally.
  - **Second** most **common cancer** among **females in India.**
    - ✓ India accounts for about **one-fifth of the global burden of cervical cancer**, with approximately 1.23 lakh new cases diagnosed annually.
    - ✓ Around 67,000 women dying from the disease each year.
- **Cause**: **human papillomavirus (HPV)**

About HPV

- A **common sexually transmitted infection** which can affect the skin, genital area and throat.
- **Persistent infection with high-risk HPV** can cause abnormal cells to develop, which go on to become cancer.
  - There is currently **no treatment for HPV infection**.

HPV vaccination and other prevention steps

- **6 HPV vaccines** are **available globally**. All protect against the high-risk HPV 16 and 18, which cause most cervical cancers.
- **Screening**, every 5-10 years, from the age of 30 (25 years in women living with HIV) can detect cervical disease, which when treated, **also prevents cervical cancer.**
- **Early detection followed** by **prompt quality treatment**.

- **Cervavac** is the first indigenous vaccine against cervical cancer in India, developed and manufactured by Serum Institute of India.

Initiatives for prevention

- **Cervical Cancer Elimination Initiative (by WHO):** Outlined the **'90-70-90' targets for each country by 2030-**
  - **Vaccination**: 90% of girls fully vaccinated with the HPV vaccine by the age of 15;
  - **Screening**: 70% of women screened by the age of 35, and again by the age of 45;
  - **Treatment**: 90% of women with pre-cancer treated and 90% of women with invasive cancer managed.
- **Vaccination to prevent Cervical Cancer:** Proposed in Interim Budget 2024-25. The programme will be for girls in the age group of 9 to 14 years for prevention of cervical cancer.

Challenges in handling Cervical Cancer

- **Raising awareness about the disease** and its prevention and building infrastructure for widespread vaccination.
- **Overcoming cultural barriers** around discussing reproductive health, and ensuring vaccine access remains a critical challenge, particularly in the rural and underserved regions of India.
- **Convincing parents to vaccinate their young daughters** against a sexually transmitted infection, which can be a sensitive topic in many communities.

Conclusion

Multi-pronged approach is required like school-based vaccination programs, public-private partnerships for distribution, and integrating cervical cancer prevention into broader women's health initiatives.

4.9. RARE DISEASES

RARE DISEASES AT A GLANCE

- Rare diseases are also called '**orphan diseases**' and drugs to treat them are called '**orphan drugs.**'
- **80%** of rare diseases are **genetic** and **1.4% of newborn children are affected by them.**

Rare Diseases as a public health issue in India

- **Lack of epidemiological data:** Impedes understanding of the extent of the burden.
- **Marginalisation in policy making:** Interventions generally focus on addressing health problems of a larger number of persons.
- **Unavailability of treatment:** Less than 5% of rare diseases have therapies available to treat them.
- **Other issues: low funds for R & D,** absence of standard definition, etc.

Initiatives

- **National Policy for Rare Diseases (NPRD),** 2021
- **Exemption of all foods and drugs for rare diseases imported** by people for **personal use from customs duty.**
- **Production Linked Incentive (PLI) Scheme for Pharmaceuticals** covers Orphan drugs manufacturers.
- **Ministry of Health and Family Welfare** recently introduced generic drugs for rare diseases such as Tyrosinemia-Type 1, Gauchers Disease, Wilson's Disease, etc.
- **National Registry** by the ICMR for collecting epidemiological data.
- **Digital Portal** for **Crowd funding** for Patients.

Way Forward

- **Define rare diseases:** Standard definition will help the research, local drug development activities, etc.
- **Establishing Centers of Excellence (CoE):** Provides specialized care, research, and support for patients and families.
  - Only 12 CoEs have been identified till date.
- **Improving Diagnosis:** Measures such as newborn screening, genetic testing, etc. can be adopted.
- **Tax benefits:** Crowdfunding amount should be exempted under Section 80G of the Income Tax Act for tax benefits.

4.10. STREAMLINING FOOD REGULATIONS IN INDIA

Why in the News?

Food Safety and Standards Authority of India (FSSAI) endorsed **multiple amendments** geared towards **simplifying food safety regulations**.

Amendments approved by FSSAI

- **Elimination of multiple certifications**: Food businesses would not have to go to different authorities for mandatory certification.
  - **Only FSSAI certification** will be mandatorily required for food products.
  - **Bureau of Indian Standards (BIS) or AGMARK certification will not be required** for food products.
    - ✓ **Presently, Food Safety and Standards (Prohibition and Restriction on Sale) Regulations 2011** have prescribed mandatory certification under BIS Act and AGMARK Scheme.
    - ✓ **BIS certification is mandatory for some food products** e.g infant formula, etc.
    - ✓ **AGMARK is mandatory for blended edible vegetable oils** and fat spreads.

- **First comprehensive manual of methods of analysis** for ensuring regulatory compliance of food products.
- **Expansion of Standards**: Like **standards of Mead (Honey wine)** and **Alcoholic Ready-to-drink (RTD) beverages**, revision of standards of milk fat products, standards for **Haleem** etc.

About Food safety regulations in India

- **Food Safety and Standards Act, 2006:** Overarching regulation on food safety establishing FSSAI as the primary food safety authority.
- **Food Safety and Standards Regulations, 2011:** Contains labelling requirements and standards for packaged food, permitted food additives, microbiological requirements etc.
- **Various FSSAI Food Safety Standards:** Developed by Scientific Committee and Scientific Panels, the principal arms of FSSAI in standard development process.

About FSSAI

- **Genesis**: Established as a statutory body under the Food Safety and Standards Act, 2006.
- **Ministry**: Ministry of Health and Family Welfare.
- **Role**: Laying down science based standards for articles of food and to regulate their manufacture, storage, distribution, sale and import.
- **Key Initiatives**:
  - State Food Safety Index
  - Heart Attack rewind to achieve elimination of Trans fat.

About BIS

- **Genesis**: BIS is the National Standard Body of India established under the BIS Act 2016.
- **Ministry**: Ministry of Consumer Affairs and Food and Public distribution
- **Key Information**:
  - BIS is a member of International Organization for Standardization (ISO) and through the Indian National Committee (INC) is a member of International Electro- technical Commission (IEC).

About AGMARK

- AGMARK is a **certification mark for agricultural produce**, assuring that they conform to a grade standard notified **by Directorate of Marketing & Inspection (DMI**) under **Agricultural Produce (Grading Marking) Act, 1937.**
- **Nature:** Agmark certification scheme **is essentially voluntary,** except few items mandated by FSSAI.
- **Ministry**: Ministry of Agriculture and Farmers' welfare

4.10.1. FOOD FORTIFICATION

Why in the News?

FSSAI operationalised provisions of Draft Food Safety and Standards (Food Product Standards and Food Additives) amendment regulations.

More about the News

- **Draft amendment was notified** by FSSAI **under Food Safety and Standards Act 2006.**
- **Provisions** of draft **related to limits of micronutrients** in vitamin and mineral premix for **manufacturing of fortified rice kernels** (**FRKs**) have been operationalised (refer to the table).
  - This will **strengthen** the **national fortification programme.**

About Fortification

- **Refers** to addition of **key vitamins and minerals** to staple foods such as rice, wheat, oil, milk and salt **to improve their nutritional content.**

- **Rice fortification** refers to **adding FRK-containing FSSAI-prescribed micronutrient**s (Iron, Folic Acid, Vitamin B12) **to normal Rice** (Custom Milled Rice) **in the ratio of 1:100**.
  - ✓ **Coating**, **extrusion** and **dusting** are **key technologies** for rice fortification.
- **Benefits:** Fortification is a cost-effective method for **combating malnutrition.**
- **Key initiatives**
  - **Distribution of fortified rice under**
    - ✓ **Saksham Anganwadi and Poshan 2.0**
    - ✓ **Centrally sponsored pilot scheme** on "Fortification of Rice & its Distribution under Public Distribution System.
  - **'+F' logo** by the FSSAI **to identify fortified foods.**
- **Key issues:** Fortified rice could be **harmful to people suffering from thalassemia and sickle cell anaemia.**

Limits of Micronutrients in Vitamin and Mineral premix for manufacturing of fortified rice kernels (FRKs)

Micronutrient	Composition (per 100g of Vitamin and mineral premix)
Iron	8-20g/100g
Vitamin B9 (folic acid)	45-55mg/100g
Vitamin B12 (Cynocobalamine)	0.45-0.55mg/100g

4.10.2. ULTRA-PROCESSED FOOD

Why in the News?

Food and Agriculture Organisation (FAO) has released **'the State of Food and Agriculture (SOFA) 2023** Report which raises concerns associated with **hidden cost of ultra-processed foods.**

More about the news

- Unhealthy **diets, high in UPF, fats and sugars** drove a **huge hidden cost of over $7 trillion a year** on our health and environment.
- **India's UPF sector grew at** an annual growth rate of **13.37%** in retail sales value from 2011 to 2021 (WHO).

What is Ultra-Processed food (UPF)?

- UPFs are a **category of food products** that have **undergone extensive processing** and contain **significant amounts of additives** (like preservatives, artificial flavours, emulsifiers).
- Often **High in fat, Sugar and Salt (HFSS)** and low in Vitamins, protein, and fibre. E.g., snacks, etc.
- Increased consumptions may lead to various health issues including **hypertension, renal failure, obesity,** etc.

Challenges in Curtailing Ultra-Processed food

- **Lack of nutrition-based tax model**: Higher taxes for products with excess sugar, salt, or fat, lower taxes for healthier options.
- **Lack of data**: Insufficient data for certain subcategories like carbonated drinks by sugar content.
- **Lack of subsidies and fiscal incentives**: Insufficient subsidies for healthy products and consumers. E.g., In South Africa, subsidies on fruits and vegetables are part of private health insurance programmes
- **Lack of implementation**: FSSAI's proposed Indian **Nutrition Rating for Front-of-Pack Labelling (FOPL)** is yet to be implemented.

Initiatives to curtail Ultra-Processed food

- FSSAI has put a **cap on trans-fatty acids** in food products, **at 2% or less** from 2022.
- **Food Safety and Standards (Advertising and Claims) Regulations, 2018** aims to hold food businesses accountable for their claims/advertisements.
- **Food Safety and Standards (Safe Food and Healthy Diets for School Children) Regulations, 2020** bans advertisements of UPF in school canteens or within 50 metres of school campuses
- **FSSAI** launched campaign like '**Eat Right India' movement**, '**Aaj Se Thoda Kam**'

- Aerated beverages in India are taxed at 28% GST and additional 12% compensation cess.
- HFSS foods in India are taxed at a 12% GST rate.
- **ICMR** has released revised dietary guidelines, 2024.

Way Forward

- **Introduction of Nutrition linked taxes** which encourages the consumers to procure healthier food items at a lower price.
- **Provide Fiscal incentives linked to nutrition** as they can drive production, exports and consumption of healthier food options.
- **Mapping global best practices and implementing** it in India. E.g. **Mexico's Junk food tax**
- **Implement better labelling guidelines**. E.g., **Australia and New Zealand** had launched a Health Star Rating system

4.10.3. HEALTH TAX

Why in the news?

Researchers have recommended a health tax of between **20% to 30% in addition** to GST on sugar, sugar-sweetened beverages (SSBs) and foods high in sugar, salt and fat (HFSS).

What is Health Tax?

- **Levied** on **products those have a negative public health impact**, for example tobacco, alcohol and SSBs.
- **WHO recommends taxation** as one of the most cost-effective tools for addressing population levels of obesity and other related non-communicable diseases (NCDs).

Steps taken in India

- **Sin Tax on demerit goods:** Placed on goods and services that are seen to be socially detrimental. E.g., **Tobacco, gambling ventures, and other things**.
  - Presently, the **aerated beverages** are taxed **at the highest tax bracket of 28% GST.**
- **Fat Tax of Kerala:** Kerala had also introduced a fat tax in 2016, which later **got incorporated into Goods and Services Tax in 2017.**

Need for the health tax in India

- **Rising burden** of disease
  - Non-communicable diseases are estimated to account for 66% of all deaths in 2019, an increase from 38% in 1990 (WHO).
- Existing GST in India does not differentiate between **healthy** and **unhealthy** beverages.
- Taxes on sugary soft drinks tied to the volume of sugar, may encourage manufacturers to reformulate and reduce the amount of sugar in the drinks.
- **Health Tax** is used by over **70 countries** as an effective tool for reducing consumption of **SSBs.**

Challenges in implementing a Health tax

- **The substitution effect:** Consumers, Children and teenagers especially, may switch to other high-calorie drinks that are relatively inexpensive.
- **Tax evasion:** Consumers may try to avoid paying diet-related taxes through cross-border purchases. E.g. saturated fat tax in Denmark, led Danes to purchase non-taxed products across the border.
- **Impact on Industries:** E.g., Fat tax was abolished in Denmark and Finland due to opposition from industry**.**

Way forward

- **Realistic timeline for Health tax** for designing and implementing a tax should be aligned with ongoing tax reform.
- **Monitoring and evaluation framework** to examine the effect of taxation on purchase, consumption, etc.

- **Supplementary interventions** along with taxation can be taken such as marketing restrictions on unhealthy food and beverages, etc.

Successful Case studies
- **Saudi Arabia:** A 50% SSB tax resulted in a 19% decrease in consumption of SSBs within a year.
- **Chile:** A tax rate increase of 18% in SSBs resulted in a decrease in the household monthly per capita consumption by 3.4%.

4.11. ZOONOTIC DISEASES

Why in the News?

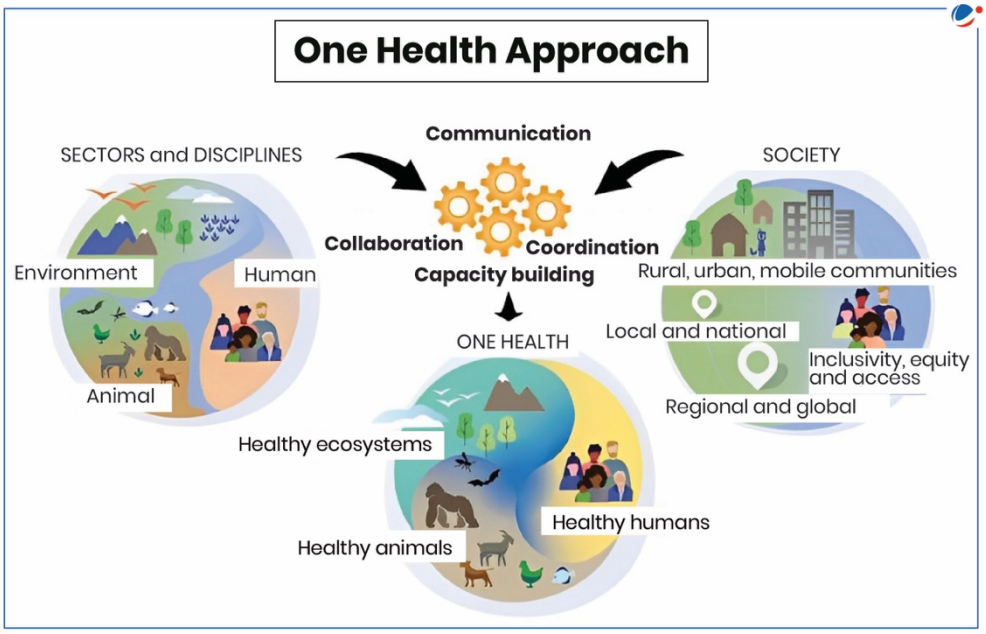
At the **National Conclave on "Augmented Zoonotic Diseases Surveillance at Human – Wildlife Interface"** it was highlighted that 75% of emerging infectious diseases are zoonotic diseases

About Zoonotic diseases

- These are diseases transmitted naturally **from vertebrate animals to humans** or vice versa.
- Zoonotic pathogens may be **bacterial**, **viral** or **parasitic**, or other unconventional agents.
- **Transmission** to humans: Through **direct contact** or through **food, water or the environment.**
- They are a **major public health issue** in India. Eg. **Rabies, Brucellosis, etc.**

Reasons for emerging Zoonotic diseases

- **Reduction in forest cover** increases close contact with populations and disease spreads.
- **Limited knowledge and skill to identify zoonotic diseases,** coupled with limited diagnostic facilities.
- Other reasons like **poor hygiene, environmental contamination, Animal husbandry malpractices on farms,** etc.



Way Forward

- **Need for a One Health approach** which is an **integrated, unifying approach** to balance and optimize the **health of people, animals and the environment.**
- Preparing **health adaptation plan** for climate sensitive zoonotic diseases, **vulnerability assessment**, etc.

4.12. PREPAREDNESS AND RESILIENCE FOR EMERGING THREATS (PRET) INITIATIVE

Why in the news?

Recently, **World Health Organisation (WHO)** launched Preparedness and Resilience For Emerging Threats (PRET) Initiative.

About Preparedness and Resilience For Emerging Threats (PRET) Initiative

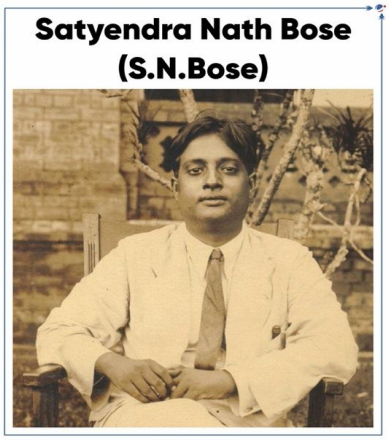
- **An innovative approach** for improving **disease pandemic preparedness**.
  - **Recognizes that the same systems, capacities, knowledge, and tools can be leverage**d and applied for groups of pathogens based on their mode of transmission (respiratory, vector-borne, foodborne etc.).
  - Incorporates **the latest tools and approaches for shared learning and collective action established during the COVID-19 pandemic** and other recent public health emergencies.
- PRET **recognizes that there are 3 tiers of systems and capacities**:
  - cross-cutting for all or multi-hazards,
  - relevant for groups of pathogens (respiratory, arboviruses etc.),
  - are specific to a pathogen.
- PRET operate under the aegis of the **International Health Regulations (IHR), 2005**.
  - IHR 2005 are a **legally binding agreement** of **WHO** to build the **capability to detect and report potential public health emergencies worldwide.**
  - IHR sets out the **core capacities that countries need to be able to detect and respond** effectively.
- The technical actions in **PRET are mapped to the IHR core capacities**, grouped according to five subsystems for **health emergency preparedness, response and resilience (HEPR).**

5. ACHIEVEMENTS OF INDIANS IN SCIENCE & TECHNOLOGY; INDIGENIZATION OF TECHNOLOGY AND DEVELOPING NEW TECHNOLOGY

5.1. SATYENDRA NATH BOSE

Why in the News?

The eminent physicist **S.N.Bose** was **remembered on his 50th death anniversary**.

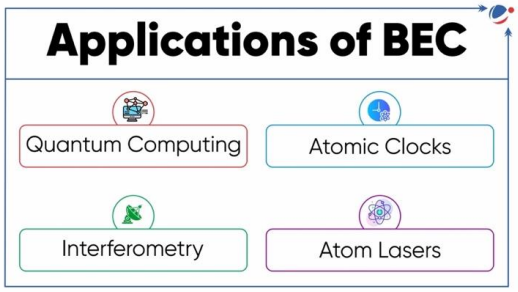


About S.N.Bose (1894-1974)

- He is referred as **"Father of the God Particle"**
- The **fundamental particle 'Bosons'** were named after him.

Scientific Contributions

- **Bose-Einstein Condensates (BEC):** A quantum phenomenon predicted by Bose and Einstein (1925). It is a **state of matter created when particles are cooled to near absolute zero** (-273.15 degrees Celsius/0 Kelvin).
  - **All the atoms become a single entity** at this point, and possess quantum properties, wherein each particle together functions as a wave of matter.
  - BEC is referred to as the **'fifth state of matter'**.
    - ✓ The other state of matter includes solid, liquid, gas, and plasma.
  - **Properties of BEC include**:
    - ✓ **Super fluidity**: Zero viscosity and can flow without resistance.
    - ✓ **Super conductivity**: Zero resistance leads to optimal conductivity.
    - ✓ **Coherence**: All particles in the BEC are in the same quantum state.
    - ✓ **Macroscopic Occupation**: A number of particles occupy a same quantum state, leading to a macroscopic wave function.



- **Bose-Einstein Statistics:** Earlier proposed as **a statistical procedure for counting possible states of a quantum system** composed of identical particles with integer spin for light quanta in 1924 by Bose.
  - The statistics **was extended to gas molecules** by **Einstein.**
  - Particles which obey Bose-Einstein Statistics principle are referred as **"Bosons".**
- **Other**:
  - **X-ray diffraction cameras:** Designed and constructed by him for rotation and powder photography.
  - Deduced **Planck's Black body radiation** law without any reference to classical electrodynamics.
    - ✓ Black body radiation refers to the spectrum of radiations emitted by any hot object.

5.1.1. HIGGS BOSON

Why in the News?

Nobel Laureate Physicist Peter Higgs passed away recently.

About Peter Higgs

- Peter Higgs **proposed the Higgs field in 1964** as a **new field** that **fills the entire Universe** and gives **mass** to all elementary particles.

- Also, he **proposed a new fundamental particle 'Higgs Boson'.**
- His idea was validated in 2012 at the **European Organization for Nuclear Research (CERN)'s Large Hadron Collider**.
- The discovery was followed by the award of a **Nobel Prize in 2013.**

Relationship between Higgs Field and Mass of Elementary Particles

- Idea of the Higgs field highlights that particles do not have a mass of their own, they get their mass by interacting with the Higgs field.
- **Intensity** of **interaction** between the field and the particle decides the quantity of mass of the particle.

About Higgs Boson

- It is an **elementary particle** with a very short life and it is popularly known as the **God particle**.
- It is a type of **boson**, a force-carrying subatomic particle.
  - **Other bosons** include **photons** (light, carrying electromagnetic force), **gluons** (particles that act as force carriers in the nucleus), etc.
- It **gets its mass** just like other particles—from its interactions with the Higgs field.
- **Importance/Relevance:**
  - The Higgs bosons have **confirmed the predictions of the standard model of particle physics and can proof particles beyond the standard model.**
  - It can be a unique portal to finding signs of **dark matter** due to its **distinctive characteristics** and properties and can provide clue about early universe.

Large Hadron Collider (LHC)

- **World's largest and most powerful particle accelerator**, set up in 2008 at CERN near Geneva.
- **Particle beams travelling close to the speed of light are collided** inside the LHC.
- Primary goal of the LHC project is to **understand the fundamental structure of matter**.

European Organization for Nuclear Research (CERN)

- Founded in 1954, researchers at CERN are probing fundamental structure of the universe and study basic constituents of matter the fundamental particle.
- **Mission**: To perform research in fundamental physics, etc.
- **Key Achievements**: Higgs Boson, W Boson, Z Boson, LHC, etc.

5.2. SATELLITE-BASED TOLL COLLECTION SYSTEM

Why in the news?

Government of India is planning to pilot-test a Global Navigation Satellite System (GNSS)-based Electronic Toll Collection (ETC) system on national highways.

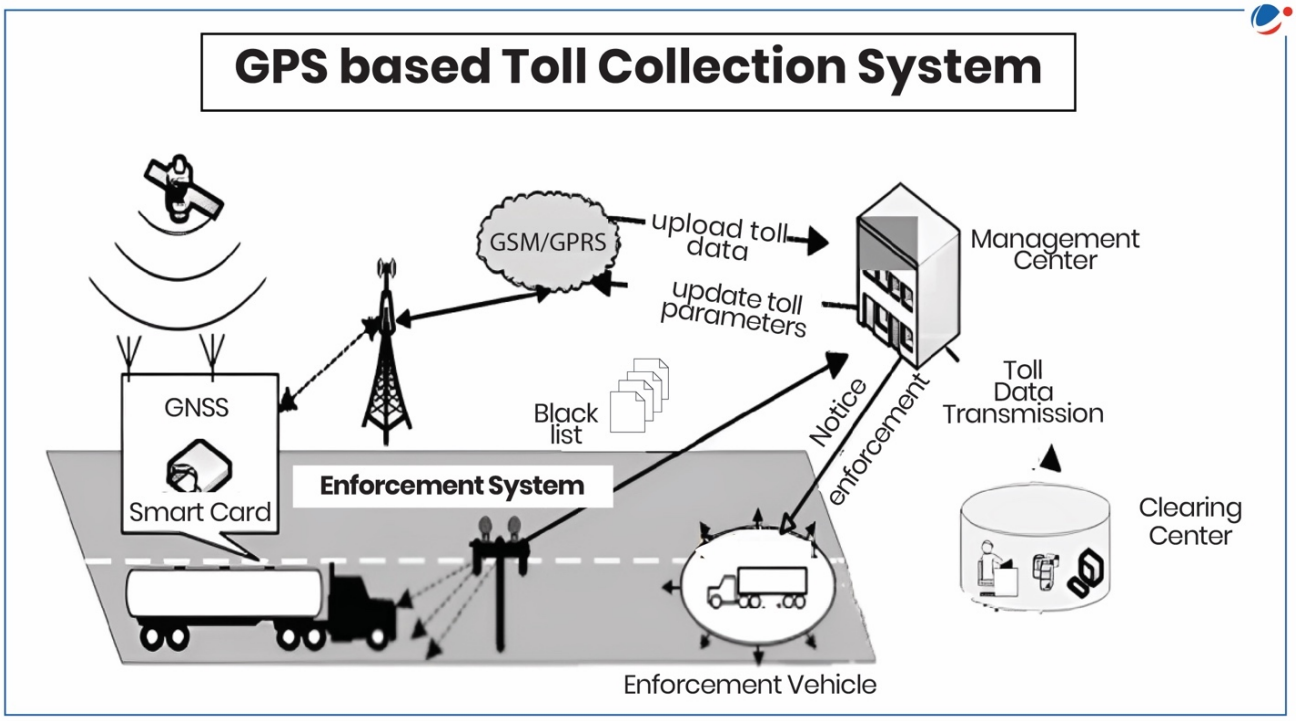
More about the news

- It will be implemented as an added facility along with **the FASTag,** which was made **mandatory in 2021.**

About GNSS-based toll collection

- **Working:** Uses satellite-based imaging to track the position of the vehicle and collect tolls based on the distance travelled.
- **Main components:**
  - **Online board Unit (OBU)**: GNSS-enabled device installed in a vehicle to determine vehicle route and calculate toll.
  - **Automatic number plate reader (ANPR) cameras**: Installed on the highways to recognize vehicle's number plate and deduct toll money.
- **Benefits:** Decrease the need for roadside tolling infrastructure; reduce congestion; enhance toll collection effectiveness, etc.

- **Challenges:** Signal interference or inaccurate readings; Privacy Concerns; need to equip older vehicles with GNSS technology etc.
- This system has already been implemented in countries like **Germany and Singapore.**
- India has its own **satellite navigation systems**, namely **GAGAN** (GPS-Aided GEO Augmented Navigation) and **NavIC** (Navigation with Indian Constellation).



Difference between FASTags & Satellite-based toll collection		
Parameters	**FASTags**	**GNSS-based Toll collection**
Technology	'Radio Frequency Identification' (RFID)	Satellite-based imaging and **ANPR cameras**
Equipment needed to be installed in Vehicles	FASTag (RFID Tag) affixed on the windscreen	OBU with GNSS connectivity
Calculation of Toll tax	Fixed rates	Based on real-time vehicle movement data
Requirement of Toll Plazas	Physical toll booths required for scanning **FASTag**	Not required

5.3. ADVANCED DRIVER ASSISTANCE SYSTEMS

Why in the news?

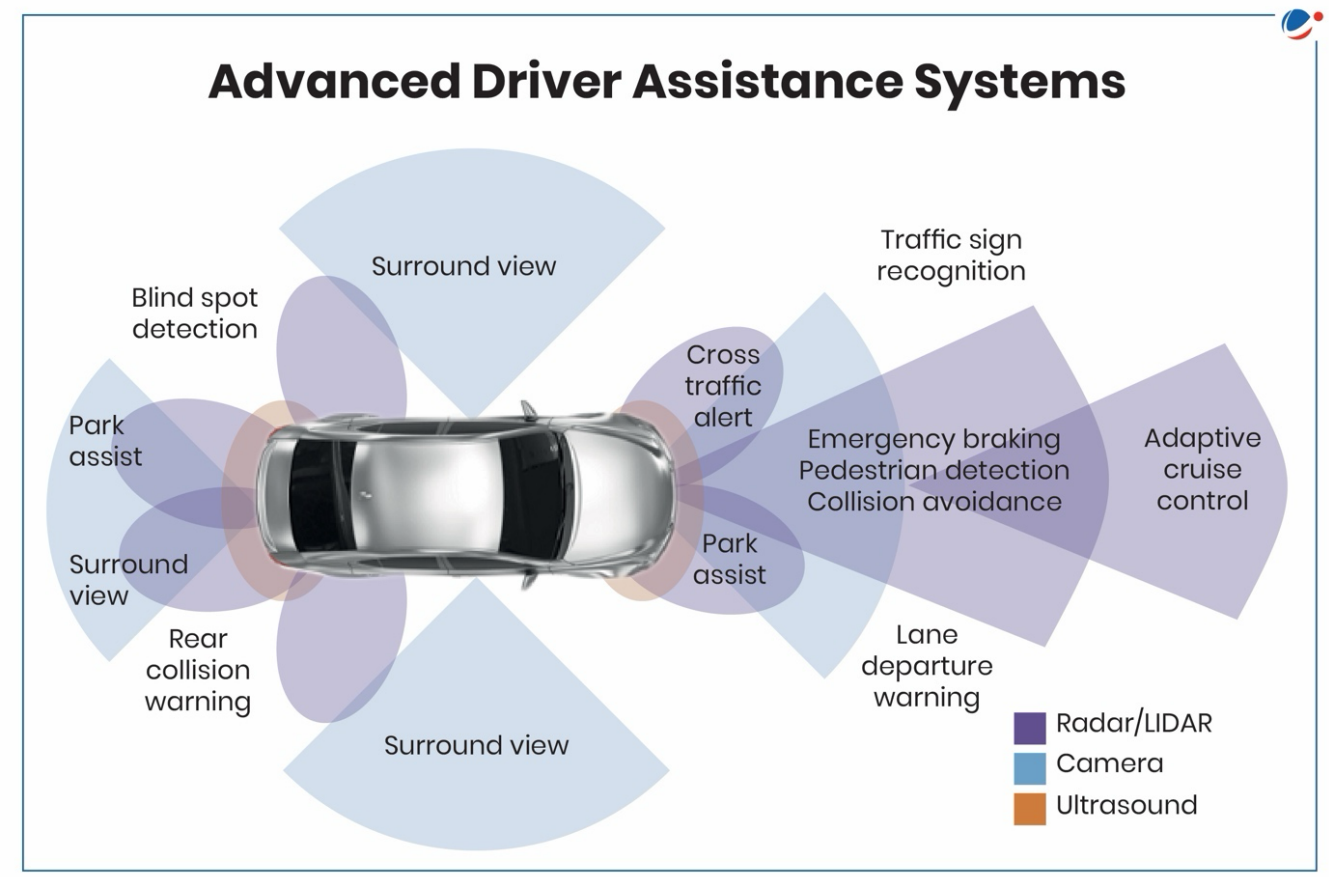
As per various reports there has been a surge in demand of Advanced Driver Assistance Systems (ADAS) from India.

What is ADAS?

- A **set of electronic systems which are integrated into vehicles** to enhance driver safety, improve vehicle performance, and provide convenience.
- Uses **sensors, cameras, radar, and other advanced technologies** to monitor the vehicle's surroundings and detect potential hazards.

Types of ADAS

- **Active ADAS: Actively intervene** and assist in critical driving situations. E.g. collision avoidance systems, lane keep assist systems, etc.
- **Passive ADAS:** Mainly intervene **to provide information and alerts to the driver**. E.g. blind spot monitoring systems, lane departure warning etc.



Benefits of ADAS

- Reduces the **number of fatalities** by providing assistance in emergency braking, etc.
- Optimise **traffic flow**, minimise congestion, and enhance the overall efficiency of road networks.
- Features such as **adaptive cruise control** and automated parking can make drivers less stressful.
- **Reduces fuel consumption** and greenhouse gas emissions through optimization in driving patterns.

Challenges in adoption

- **Non-Standardised Road Infrastructure in** India.
- Prevalent in premium and luxury cars due to its high cost.
- Requires real-time data updates and reliable connectivity.
- **Cyber Threats** may deceive or undermine the functionality of systems and pose risks to passengers and drivers' safety.
- **Other**: **Supply Chain Security Issues, Error and Malfunctions** (hardware or software faults, sensor failures, etc.), etc.

Conclusion

The adoption of ADAS can be facilitated by establishing effective regulations and standards for ADAS implementation.

6. MISCELLANEOUS

6.1. NUCLEAR ENERGY IN INDIA

NUCLEAR ENERGY IN INDIA AT A GLANCE

- Installed capacity of **8180 MW** will become **22480 MW by 2031-32,** which is about 1.8% of total electricity generation.**(Ministry of power)**

Significance

- **Clean, cost-efficient, and environment friendly** source of **energy.**
- Facilitating country's energy transition for meeting **goal of net zero economy.**
  - Also it will help in generation of hydrogen referred as **pink hydrogen.**
- **Strong civilian nuclear sector,** essential in global arena to promote peaceful use of nuclear technologies.

Initiative

- **Conclusion of fuel supply contracts** with several countries under IAEA.
- **Resolution** of issues related to **Civil Liability for Nuelear Damage (CLND)** Act & Creation of Indian Nuclear Insurance Pool.
- **Amendment of Atomic Energy Act** to enable Joint Ventures of Public Sector Companies to set up nuclear power projects.
- **Enhanced project monitoring** through Pro-Active Governance and Timely Implementation **(PRAGATI Platform).**
- **Global Centre for Nuclear Energy Partnership** for training in the field of nuclear technology.
- **Partnership with private sector** to develop Bharat Small Reactors **(Budget 2024)**

Constraints/Challenges /Concern

- **Safety concern:** E.g. Chernobyl (1986), Fukushima Daiichee accident (2011)
- **Land requirements:** Protests against government plans of land acquisition.
- **Import dependency on fuel requirements:** Uranium requirement is fulfilled through import.
- **Manufacturing and manpower needs:** Current manufacturing capability lacks heavy engineering components and delicate and precision-engineered equipment.

Way Forward

- **Structured plan for effective management of radioactive wastes.**
- **Building societal awareness and decoding negative connotations** around nuclear power generation.
- **Optimal regulatory regime** to assess the safety requirements and compliances.
- **Public-private partnership with necessary policy support,** free flow of authentic information and careful impact assessment on different stakeholders.

6.1.1. FAST BREEDER REACTOR

Why in the news?

Recently, a core-loading process in the **indigenous Prototype Fast Breeder Reactor** (PFBR) was initiated at Madras Atomic Power Station in Kalpakkam, Tamil Nadu.

More about the News

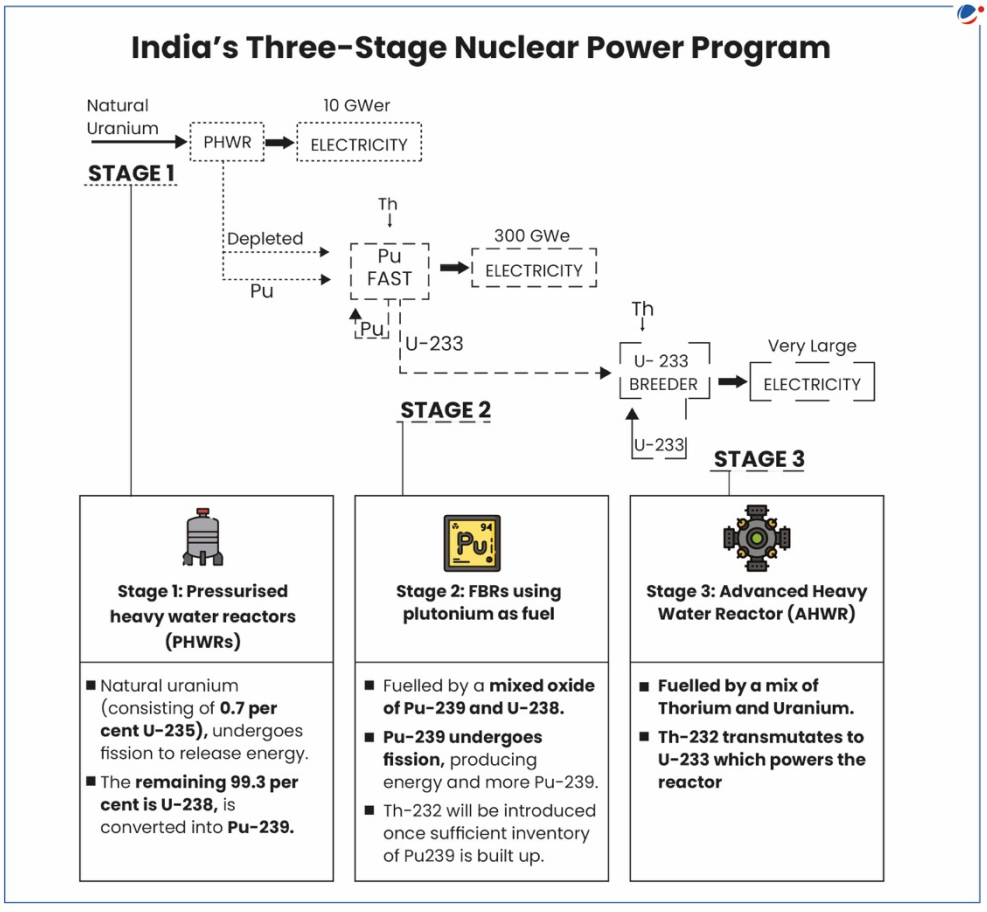
- **Core loading** is the process of **placing nuclear fuel assemblies inside the core** of a nuclear reactor.

What is Fast Breeder Reactor (FBR)?

- FBR is a nuclear reactor that uses fast neutron to **generate more nuclear fuel than they consume** while generating power.
- FBR will use **Uranium-Plutonium Mixed Oxide** (MOX) fuel.
- The **Uranium-238 "blanket"** surrounding the fuel core will undergo nuclear transmutation to **produce more fuel,** which is why they are termed "**breeders**."

Significance of FBR

- **Operationalization of PFBR** will mark the start of stage II of India's three-stage nuclear power programme.
- **Paves way for third stage:** In FBR, Thorium-232 (Th-232) will also be used as blanket.
  - By **transmutation** (conversion of one element to another), Thorium will create fissile U-233 which will be used as fuel in the third stage.
- **Technological advancement**: India will be **second country after Russia** to have a commercial operating FBR.
- **Reduced waste**: Uses the **spent fuel from the first stage**.



India's 3 stage Nuclear Power Program

- **Dr Homi J Bhabha**, devised **this program in 1950s** to make the most of India's limited uranium reserves and abundant thorium reserves.
  - India holds only **about 2-3% of the world's uranium reserves**, but it possesses one of the largest shares of global thorium reserves.

Key Initiative/Conventions/Organisation facilitating the growth of Nuclear Energy

- **Nuclear Energy Summit:** First ever Nuclear Energy Summit was held recently. It was hosted by the International Atomic Energy Agency (IAEA) and the Belgian government.
  - **India** participated in it.
- **Convention on the Physical Protection of Nuclear Material (CPPNM), 1979**
- **Convention on Supplementary Compensation (CSC), 1997, e**stablished a minimum national compensation amount. India has ratified it in 2016.
- **International Convention for the Suppression of Acts of Nuclear Terrorism (Nuclear Terrorism Convention or ICSANT), 2005,** India has ratified it.
- **Nuclear Energy Agency (NEA):** Operates within the framework of the OECD.
- **Declaration to Triple Nuclear Energy (DTNE),** adopted at COP28 of UNFCCC.

6.1.2. SMALL MODULAR REACTOR (SMR)

Why in the News?

China launches the world's first fourth-generation nuclear reactor which a used **Small Modular Reactor (SMR) design.**

More about the News

- Fourth-generation nuclear reactors are being developed globally to meet the criteria of sustainability, enhanced safety, economics, and proliferation resistance.

About Small Modular Reactor (SMR)

- These are advanced nuclear reactors with power capacity of up to **300 MW(e) per unit.** These are:
  - **Small**: physically a fraction of the size of a conventional nuclear power reactor.
  - **Modular**: making it possible for systems and components to be factory-assembled and transported as a unit to a location for installation.
  - **Reactors**: harnessing nuclear fission to generate heat to produce energy.
- **SMRs advantages over traditional reactors:**
  - **Low cost and construction time** due to factory-built SMRs.
  - **Simpler and Safer** due to reduced fuel requirements.
  - They can be deployed incrementally to match increasing energy demand.
  - Have **increased safety** and lower impacts in case of accidents

Bharat Small Reactors (BSRs)

- In **Budget 2024-25,** government has announced to partner with private sector to develop **Bharat Small Reactors (BSRs).**
- This announcement marks a historic shift in India's nuclear policy, as the **Atomic Energy Act of 1962** did not permit private sector participation in nuclear energy generation.
- BSRs are aligned with global trends where **Small Modular Reactors (SMRs)** are gaining attention.
- Unlike **SMRs, BSRs** are based on India's **existing Pressurized Heavy Water Reactor technology.**

ANEEL (Advanced Nuclear Energy for Enriched Life)

- **An American company** has developed a **fuel ANEEL** (named after India's scientist, Dr Anil Kakodkar).
- ANEEL is a mix **Thorium and Uranium** of a certain level of enrichment, called **HALEU (High Assay Low Enriched Uranium).**
  - **HALEU has an enrichment level of 5-20%,** whereas most current reactors are enriched up to 5%.
- **Potential Benefits**
  - ANEEL can be used in the **existing Pressurized Heavy-Water Reactors (PHWRs)** of **India's nuclear fleet.**
  - Reduction in nuclear waste etc.

Project Proryv & Floating Nuclear Power Plant

- Chairman of India's Atomic Energy Commission recently visited "Proryv" or "Breakthrough" project site in Russia.

- **Project Proryv** seeks to create new technological platform with **closed nuclear fuel cycle**.
  - ✓ In **closed nuclear fuel cycle**, spent fuel is **reprocessed and recycled (Low Radio-active Waste).**

- **Floating Nuclear Power Plant (FNPP)**
  - It is a site with one or more nuclear reactors, **located on a platform at sea.**
  - Usually, **SMRs** are installed on ships.
  - Presently, **Russia is only country** having operational FNPP.
  - **Benefits:** Produces low-carbon power and heat, lower construction costs, and less vulnerable to earthquakes.

6.1.3. NUCLEAR FUSION

NUCLEAR FUSION AT A GLANCE

- **Nuclear fusion** is the process by which **two light atomic nuclei combine** to form a single heavier one while releasing massive amounts of energy.
  - Recently US scientists have achieved **Net Energy Gain (NEG)** for second time **in nuclear fusion reaction.**

Advantages

- **Abundant fuels** such as Deuterium can be extracted from water.
- **Reliable power** as they continue to produce energy for longer periods.
- In fusion, amounts of fuel used is less so **less chances of disaster & also** it is more efficient.

Initiatives

- **India**
  - **International Thermonuclear Experimental Reactor (ITER),** collaboration of 35 nations to build the world's largest tokamak.
  - **Korea Superconducting Tokamak Advanced Research (KSTAR)** fusion reactor.
  - **Joint European Torus (JET):** First device to produce controlled fusion power.
- **Global**
  - India joined the **ITER** project.
  - **ITER-India, Institute for Plasma Research (IPR),** designs, builds and deliver the Indian in-kind contribution to ITER
  - Constructed indigenous **tokamak ADITYA and semi-indigenous Steady State Superconducting Tokamak (SST-1).**

Constraints/Challenges /Concern

- **High temperature required-** Temperatures of over 100 million degrees Celsius are required to make deuterium and tritium fuse **(as per IAEA).**
- **Neutron radiation** during the reaction can travel tens of centimeters out into containment structure.
- Development of new materials that can withstand **extreme conditions expected inside a power plant.**

Way Forward

- **International cooperation:** Can play key role in achieving the net Energy Gain (NEG).
- **Intense Research & Development:** For developing fusion technologies.
- **Participation of private-sector companies,** industry and academia.
- **Formulating a national strategy.**

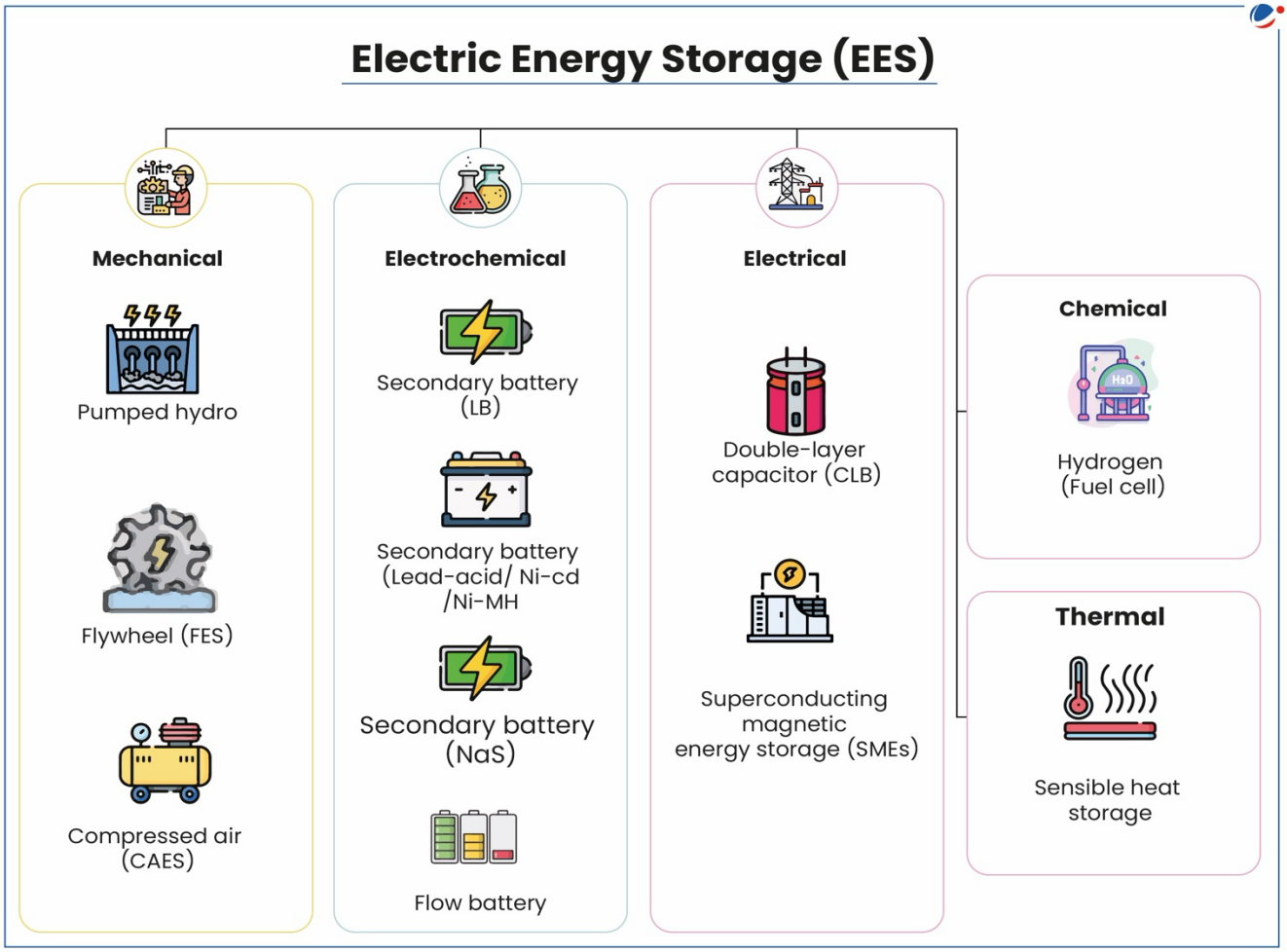
6.2. BATTERY ENERGY STORAGE SYSTEM (BESS)

Why in the News?

Recently, Solar Energy Corporation of India Limited (SECI) commissioned India's largest BESS in Chhattisgarh.

About Battery Energy Storage System (BESS)

- It is **categorized under the electrochemical storage** system (refer infographics for types of Electric Energy Storages) which uses different **electrochemical reactions to store electricity**.
  - Energy Storage Systems (ESS) have a multitude of applications in the **energy sector and can be used independent of or as a part of, power system infrastructure** at various levels in **generation, transmission, and distribution**.
- **Types of BESS**
  - **Standard (non-flow) batteries:** Consists of pairs of plates **(electrodes)** immersed in **electrolyte** and separated by non-conducting materials.
    - ✓ Lead-Acid (PbA) battery
    - ✓ Nickel-Cadmium (Ni-Cd) battery
    - ✓ Lithium-Ion (Li-Ion) battery
    - ✓ Sodium-Sulfur (Na-S) battery
  - **Flow batteries:** Uses **tanks of electrolyte** and **membrane to control the flow of electrons** and pumps to control the flow of electrolyte.
    - ✓ Redox Flow Battery (RFB)
    - ✓ Hybrid Flow Battery (HFB)



Need of domestic manufacturing of BESS

- **Economic:** Reduction of battery cell **imports**, growth of mining sector etc.
- **Social:** Increasing opportunity for **skill development**, incubation centres and **entrepreneurship** programmes.
- **Environmental:** Assistance in meeting **Panchamrit targets** (COP 26 of UNFCCC) of the government.
- **Other**: Improves **grid stability,** bringing down peak deficits, etc.

Initiatives undertaken for BESS

- **Legal status for ESS** as a Generator, Transmission or Distribution element, issued by Ministry of Power (MoP) on in 2022.
- **Bidding Guidelines for Battery Energy Storage Systems (BESS)** notified by the MoP in 2022.
- **National Framework for Promoting Energy Storage Systems** unveiled by the MoP in 2023.
- **Battery Waste Management Rules, 2022** to promote circular economy in BESS sector.
- **Scheme for Viability Gap Funding (VGF)** for development of BESS, 2023

Challenges of battery manufacturing in India

- Extremely **low reserves of Raw materials** like lithium, cobalt, nickel and battery-grade graphite,
- **Policy uncertainty** such as discontinuation of tax holidays, reduction of accelerated depreciation benefit, etc.
- **Other challenges: Lack of high-quality R&D infrastructure, Absence of EV and storage policies , financing and cheaper imports.**

Way Forward

- **Demand creation:** Implementation of a **soft loan facility** for Discoms/transmission companies to deploy energy storage and battery solutions.
- **Phased manufacturing programme: Incentivising advanced cell manufacturing**, supported adequately by states to encourage investors.
- **Taxation: Re-design GST rates** to discourage imports and encourage domestic procurement of batteries.
- **Recycling and sustainability:** Ensure **effective implementation of Extended Producer Responsibility (EPR)** and digitize waste management to move from '**End-of-Life' approach** to '**circular economy**' in BESS.

6.2.1. SODIUM ION BATTERY

Why in the News?

South Korean scientists develop sodium ion battery that can be charged in seconds.

About Sodium Ion Battery (SIB)

- An **electrochemical energy storage device** that utilizes **sodium ions as charge carriers** to **store and release electrical energy.**
- SIBs are currently evolving as a viable **substitute for lithium-ion batteries (LIBs).**
- **Applications of SIBs:** In stationary energy storage, electric two- and three-wheelers, and electric micro cars etc.
- **Comparison of Sodium Ion Battery and Lithium-Ion Battery**

Specifications	Sodium Ion Battery	Lithium-Ion Battery
Occurrence	**Sodium is 500-1000 times more abundant** than lithium.	**Lithium availability** is limited to few countries.
Charging time	Charges faster	Slow charging rate

Safety	**Safer**, as they do not explode or catch fire easily	**Less safe,** prone to catching fire or exploding
Operation and use	**Higher operating temperature range** and thus can be used in more extreme temperatures	**Lower operating temperature range** and can cause fire if operated in higher temperatures.
Applicability	Can be used in **small as well as large-scale energy storage applications**	**Suitable for portable devices and electric vehicles.**

- **Limitations of Sodium Ion Battery**
  - **Shorter lifespan** as compared to Lithium-ion batteries
  - **Infant technology** and lack of a well-established supply chain
  - **Limitations of flexibility into various shapes** (e.g. prism, cylinder)
  - **Cycle life of 5,000 times**, significantly lower than the cycle life of commercial lithium iron phosphate batteries, which is 8,000-10,000 times.

6.3. NOBEL PRIZES

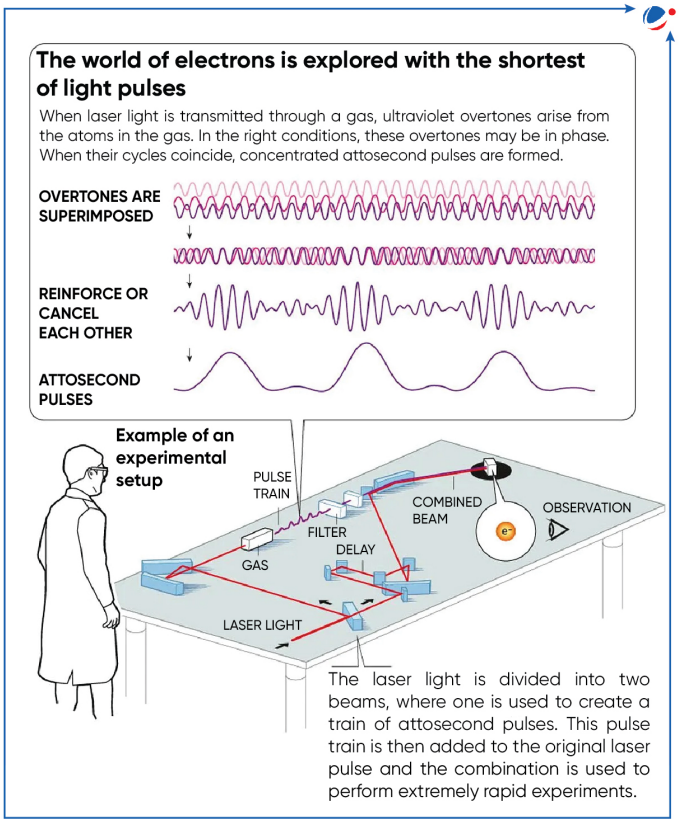
6.3.1. NOBEL PRIZE IN PHYSICS 2023

Prize awarded for: Experimental methods that generate **attosecond pulses of light** for the study of **electron dynamics in matter.**

Awardees: Pierre Agostini, Ferenc Krausz, and Anne L'Huillier

About Electron Dynamics

- **Electron dynamics**, in simple terms, refers to the behaviour **and movement** of electrons within **atoms and molecules.**
- **Atoms' natural time scale** is incredibly short. **Atoms can move and turn** in millionths of a billionth of a second, known as **femtoseconds** (Femtosecond is equal to 10^{-15} second).
  - Just as the naked human eye cannot discern the individual beats of a hummingbird's wing, scientists were **not able to observe the individual movements of an electron**.



How did the discovery overcome this challenge?

Generation of attosecond pulses of light (Anne L'Huillier)

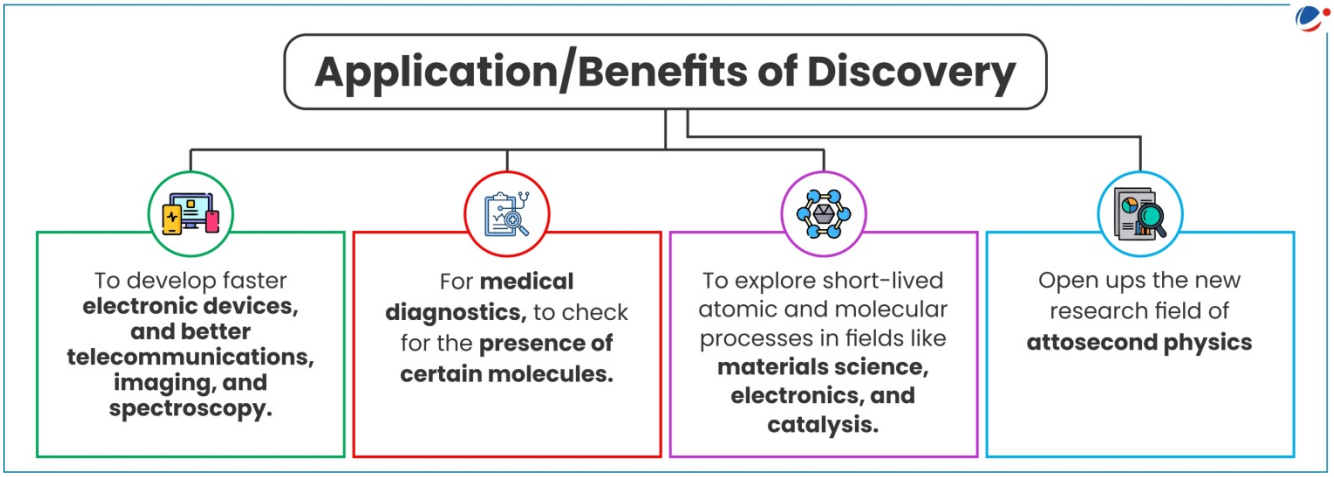
- **In 1987, Anne L'Huillier** and her colleagues transmitted an **Infrared laser beam** through a **noble gas** and it produced multiple overtones.
- **Mechanism:**
  - When the peak of one overtone **merges with the peak of another**, they undergo **constructive interference** and produce a **larger peak.**
  - Similarly when the peak of one overtone merges with the **trough of another**, however, they undergo destructive interference, **'cancelling' themselves out.**

- **By combining a large number of overtones** in this way, physicists fine-tune a setup to produce **light pulses for a few hundred attoseconds**.

Production of pulse train (Pierre Agostini and Ferenc Krausz)

- **In 2001, Pierre Agostini and Ferenc Krausz** were able to produce **verified attosecond pulses in a 'train'**: a pulse followed by a gap, followed by a pulse, and so forth.
  - By 2017, experts were able to produce a **pulse as short as 43 attoseconds.**

Resultantly, these experiments produced **pulses of light** that were measured in **attoseconds**. **These pulses can be used to provide images** of the processes inside atoms and molecules (including electron dynamics).



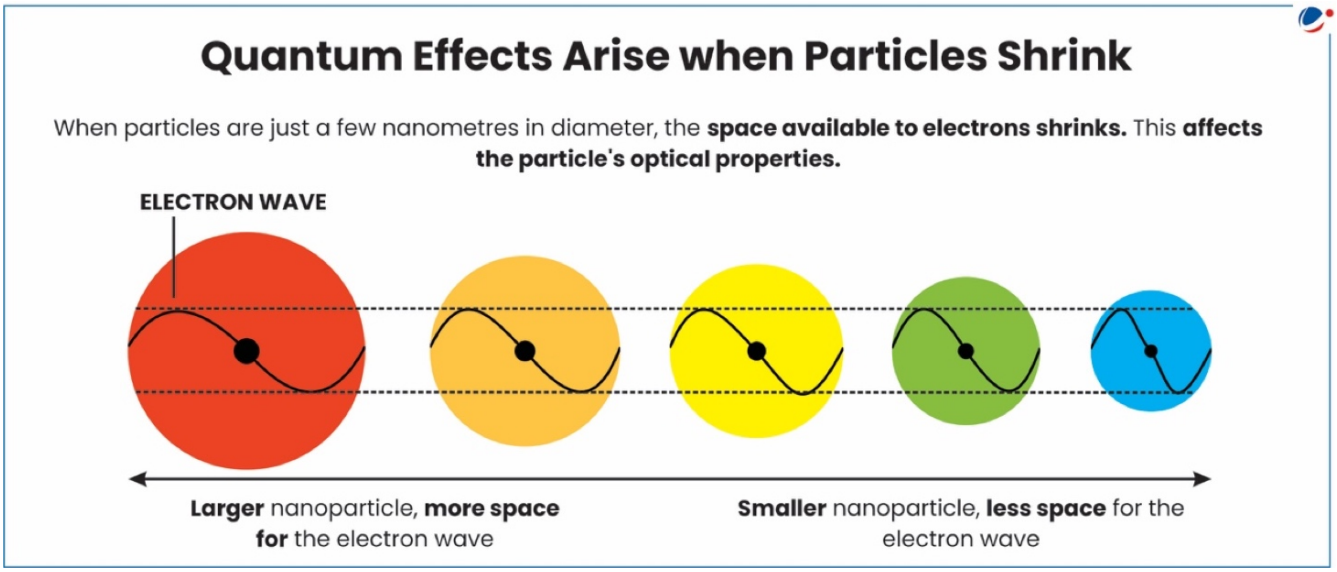
6.3.2. NOBEL PRIZE IN CHEMISTRY 2023

Prize awarded for: The discovery and development of **quantum dots.**

Awardees: **Moungi G. Bawendi, Louis E. Brus and Aleksey Yekimov.**

About Quantum dots (QDs)

- Quantum dots are **man-made semiconductor particles**, whose sizes are normally not more than **10 nanometers.** They exhibit unique optical properties due to their small physical size.
  - Their properties can be changed by changing their size, for example they have different colours depending on their size.
- **Properties of QDs:** They exhibit **quantum confinement (electrons are confined in small regions)**, which leads to many unique optical and transport properties.
  - **Fluorescence:** When excited by an external electric or light source, QDs emit photons of a specific wavelength.
  - **Tunable Emission:** Emit light of different colours depending on their size.
  - **Photostability:** Less prone to **photobleaching** (loss of fluorescence over time) compared to traditional organic dyes.
  - **Material Variety:** Made from different semiconductor materials, such as **cadmium selenide (CdSe), lead sulfide (PbS), and indium arsenide (InAs)**.
  - **Biocompatibility:** Used in **biological applications** without causing harm to **living cells.**



Applications of Quantum Dots

- **Electronics:** Television screens based on QLED technology, and LED lamps.
- **Healthcare:** In cancer treatment for targeted drug delivery, Nano medicine, biochemists and doctors may use them to map biological tissue etc.
- **Other potential uses:** In quantum computing, thinner solar cells, flexible electronics, tiny sensors, and encrypted quantum communication etc.

6.3.3. NOBEL PRIZE IN PHYSIOLOGY OR MEDICINE 2023

Prize awarded for: Discoveries concerning nucleoside base modifications that enabled the development of **effective mRNA vaccines against COVID-19.**

Awardees: Katalin Karikó and **Drew Weissman**.

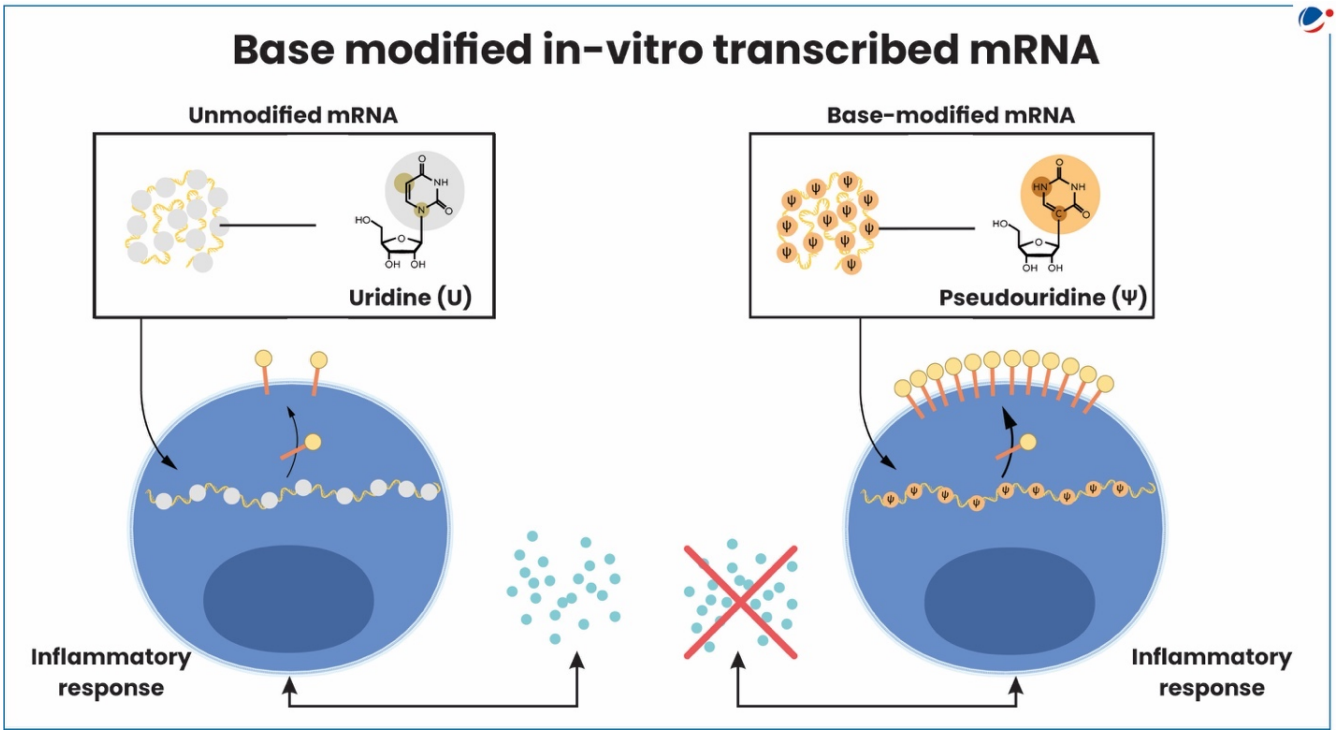
About Vaccination and COVID-19

- A Vaccination works by stimulating the formation of an **immune response to a particular pathogen.**
- Vaccines based on **killed or weakened viruses** have long been available such as vaccines against **polio, measles, and yellow fever.**
- As technology evolved, instead of the whole virus, **just a part of the viral genetic code**, began to be introduced through vaccines (DNA-based vaccines).
- However, the **large-scale development** of DNA vaccines requires **cell culture** (growing of cells under controlled conditions) and **takes time.**
    - When you get a DNA vaccine, your **cells translate the gene particle from the virus or bacteria into a protein that your body recognizes as a foreign element**. Your immune system then creates antibodies that fight these particular proteins.
- During the **COVID-19 outbreak, mRNA technology** proved crucial as it requires significantly less time.
    - However, posed significant challenges. These challenges were addressed in the work of Nobel Laurates.

Work of Nobel laureates

- **Understanding the concerns with mRNA vaccines**
    - **Issues with In vitro transcribed mRNA vaccines:**
        - ✓ **Instability**: They were considered **unstable** and **challenging to deliver**, requiring the **development of sophisticated delivery systems**.
        - ✓ **Inflammatory reactions**: The cells **recognize in vitro transcribed mRNA as a foreign substance,** which leads to their activation and the release of **inflammatory signaling molecules.**

- ✓ **Inefficient protein production in cells and tissues.**
  - They questioned why this **synthetic mRNA was considered to be a foreign substance** while mRNA from mammalian cells did not give rise to the same reaction.
  - This led them to realize **some critical properties** must distinguish **synthetic mRNA** from **mammalian cells mRNA.**
- **Breakthrough by them**
  - **Understanding**: Karikó and Weissman knew that **nucleoside bases in RNA from mammalian cells are frequently chemically modified**.
  - **Hypothesis**: They hypothesised that the **absence of altered bases** in the in vitro transcribed RNA could explain the **unwanted inflammatory reaction**.
  - **Testing**: On testing, they produced different variants of mRNA, each with unique **chemical alterations in their bases**, which they delivered to **dendritic cells.**
  - **Result**: **Inflammatory response was almost abolished** when base modifications were included in the mRNA.



Applications of the discovery

- **Covid-19 Vaccination**: Base-modified mRNA vaccines encoding the **SARS-CoV-2 surface protein** were developed at an unprecedented pace.
  - E.g., mRNA vaccines developed by **Pfizer/ BioNTech and Moderna.**
- **Rapid vaccine development:** Pave the way for using the new platform for vaccines against other infectious diseases.
- **Broad applicability**: Technology may also be used to **deliver therapeutic proteins and treat some cancer types.**

6.4. SUPERCONDUCTIVITY

Why in the news?

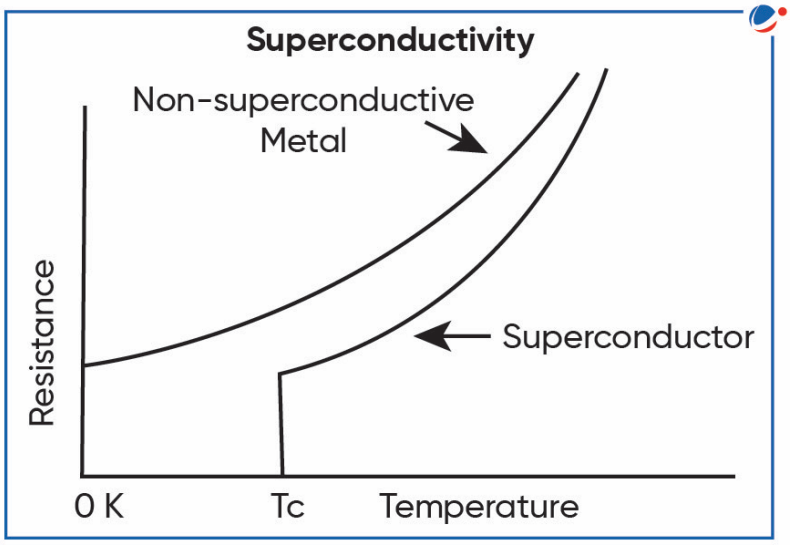
Recently, the claims of material **LK-99 depicting the room temperature superconductivity** proved inconsistent.

Superconductivity

- A phenomenon in which **certain materials exhibit zero electrical resistance** and the **expulsion of magnetic fields** when **cooled below a critical temperature (T_c)**.
- Discovered by **Heike Kamerlingh Onnes** in 1911.
- Currently, **superconductivity** can be achieved only at very low temperatures, **more than 250 degrees Celsius below zero.**
  - **Materials like Mercury, Lead, Aluminum, Tin, Niobium**, etc., become superconducting at **T_c**.
  - In some cases, **materials can exhibit superconductivity at slightly higher temperatures** as well, but under increased pressure conditions.
  - Scientists are looking for a material that **can display superconductivity at room temperature.**

Superconductivity at Room Temperature

- **A room-temperature superconductor** is a material capable of exhibiting superconductivity at operating temperatures, i.e. above 0 °C (273.15 K; 32 °F) - temperatures.
- Obtaining room temperature superconductivity is **affected by many aspects, like**
  - **Difficult to achieve conditions like extreme pressure conditions,** and materials may not be able to withstand these extreme conditions.



Achieving a room-temperature superconductivity will lead to

- **High efficiency and low-cost energy transmission** through grids. Ex: Superconducting Generators, etc.
- Better **Magnetic Resonance Imaging (MRI) technology**
- Reduced cost for **Magnetic levitation (Maglev) train technology**
- **Efficient and less energy-consuming supercomputers** can be manufactured etc.
- **Enable efficient and rapid energy storage and retrieval**, addressing the intermittency issues of renewable energy sources.
- Utilised in accelerators and **Nuclear Magnetic Resonance (NMR)** for various experiments like the Large Hadron Collider.

6.5. DEEP TECH STARTUPS

Why in the news?

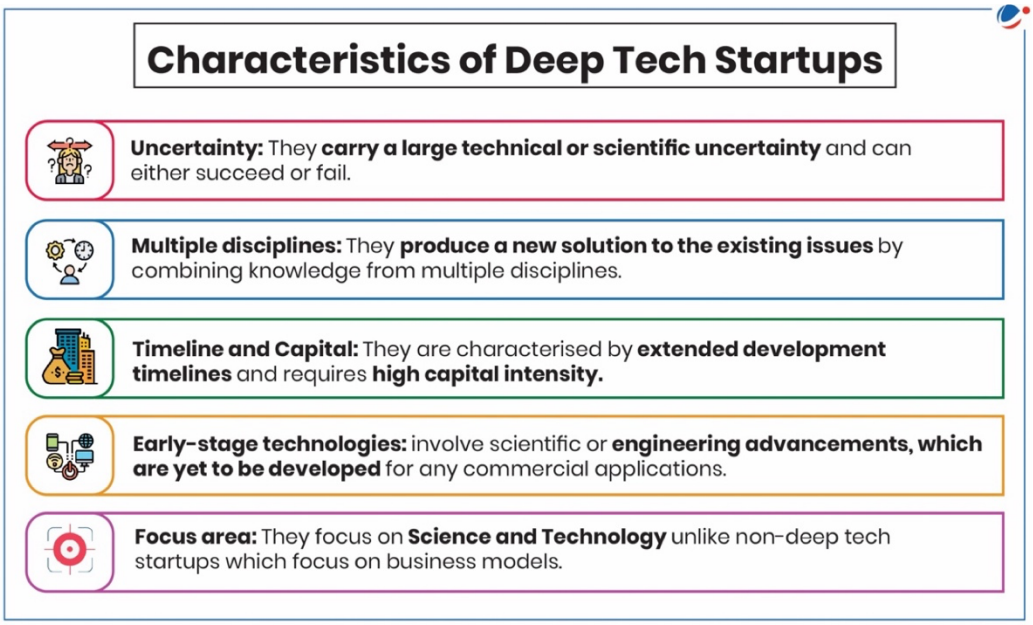
Draft National Deep Tech Startup Policy (NDTCP), 2023 has been released.

What is a Deep Tech Startup?

- A startup that typically produces a solution along an unexplored pathway based on **new knowledge** within a **scientific or engineering** discipline or by **combining knowledge from multiple disciplines.** E.g., Moderna, etc.
- Majority of them operate on a **business-to-business (B2B) model**, indicating their focus on **serving enterprise clients** and **providing technology solutions** tailored to **specific industry needs.**

Key Highlights of Draft NDTCP 2023

- **Investment** in basic and **curiosity-driven scientific research.**
- Strengthening **Intellectual Property Regime.**
- Encourage participation of **public/private industries** especially MSMEs and Startups to create an ecosystem for the development of cutting-edge and dual-use technologies.
- Establishing **Frontier Scientific Infrastructure (FSI),** in academic institutions and R&D establishments.
- **Regulatory sandboxes** shall be established across different deep technology domains.



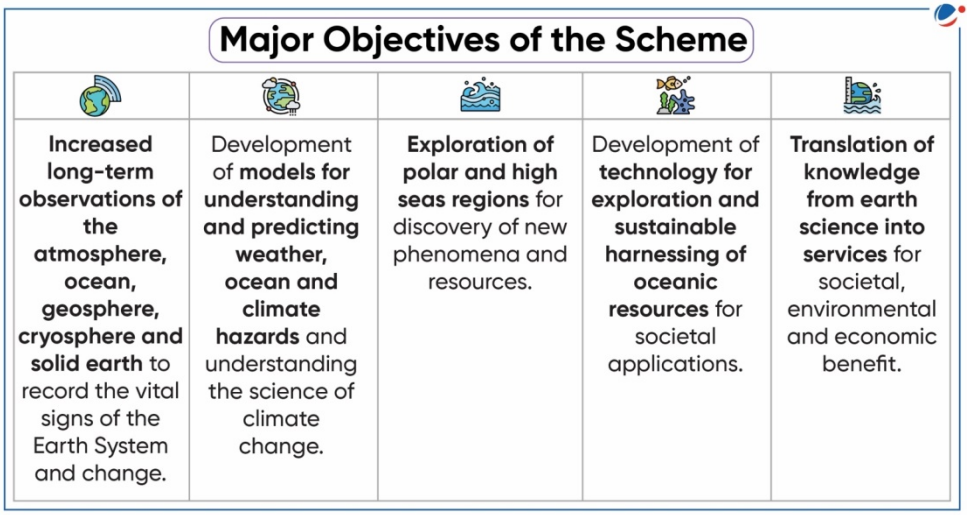
6.6. PRITHVI VIGYAN (PRITHVI) SCHEME

Why in the news?

Union Cabinet has approved the overarching scheme **PRITHvi VIgyan (PRITHVI).**

About PRITHvi VIgyan (PRITHVI)

- **Ministry:** Ministry of Earth Sciences (MoES)
- **Tenure**: 2021-26
- **Overall cost**: ₹ 4,797 crore
- It encompasses **five ongoing sub-schemes**



Sub-schemes	Objectives
ACROSS (Atmosphere & Climate Research-Modelling Observing Systems & Services)	• Development of global advanced weather prediction models
O-SMART (Ocean Services, Modelling Application, Resources and Technology)	• Oceanographic research activities with the objectives for providing forecast and services for sustainable harnessing of oceanic resources.
PACER (Polar Science and Cryosphere Research)	• Integrates all scientific programs regarding studying polar region
SAGE (Seismology and Geosciences)	• Strengthening earthquake monitoring and research on the Earth's solid components

REACHOUT (Research, Education, Training, and Outreach)	• Raise awareness in general public about various schemes/mission of MoES

Significance of integrated R&D efforts under PRITHVI

- **Improve** understating of the **Earth System sciences**.
- **Enable development** of **integrated multi-disciplinary earth science research**.
- **Address challenges** of weather and climate, ocean, cryosphere, seismological science and services.
- **Convert research into practical solutions for future disasters** arising from Climate change, etc.
- **Understand** and **predict weather accurately** due to increased cross-disciplinary coordination.

Related Development
Matsya 6000

- Under **project Samudrayaan,** Indian scientists are planning to send three people **6000 meters underwater** in an **indigenously developed submersible** called **'Matsya 6000'.**
  - **Samudrayaan mission** is part of **Deep Ocean Mission.**
  - **Aim:** Deep ocean exploration
- **Matsya 6000** is developed by **National Institute of Ocean Technology (NIOT)**, **Chennai** under Ministry of Earth Sciences**.**
  - Facilitates in **exploring mineral resources rich in Nickel, Cobalt, Rare Earths,** etc., and **collection of samples**.
  - **Matsya** has an **endurance of 12 hours** under normal operation and 96 hours in case of emergency.

7. APPENDIX

Appendix: Indian Scientist and their Contribution

SCIENTIST	Contribution/Key Work
 **Prafulla Chandra Ray**	▶ Established **the first Indian research school in chemistry.** ▶ Popularly known as **Father of Indian Chemistry** ▶ Also conducted research on platinum, iridium and sulphides of organic substances.
 **Srinivasa Ramanujan**	▶ Contributed to several **mathematical concepts** like **infinite series,** continued fractions, number theory and mathematical analysis. ▶ Introduced a **summation,** now known as the **Ramanujan sum** which is currently used in **signal processing.** ▶ Also credited for his work in **'Modular functions'** which are used to reveal properties of **Black Holes** by astrophysicists. ▶ In his famous letter to Hardy in 1919, he introduced the **"mock theta functions"** which are used today in **'String Theory'** in theoretical physics. ▶ Discovered **Ramanujan number** i.e., 1729 which is the smallest number which can be expressed as the sum of two cubes in two different ways- 1729= $1^3 + 12^3 = 9 + 10$ ▶ His ideas have contributed to **the development of game theory.**
 **C. V. Raman**	▶ In 1922, he published his work on the **'Molecular Diffraction of Light',** which ultimately led to his discovery of **'Raman Effect'** in 1928. ▶ He was honoured with **Nobel Prize in Physics** for **Raman** Effect. - Raman effect refers to **change in wavelength** of light that occurs when a light beam is deflected by molecules. ▶ Postulated **Raman spectroscopy** to understand composition of structures, crystallographic orientation of the sample and change in vibrational frequency for chemical bond in Raman effect.
 **Homi Jehangir Bhabha**	▶ As a student, he worked with a Nobel Prize winner, Niels Bohr in Copenhagen and played a major role in the development of the **Quantum Theory.** ▶ Published papers on the **Absorption of Cosmic Radiation, electron-positron** scattering (later renamed **Bhabha scattering).** ▶ Chief architect of India's nuclear energy program by taking several initiatives such as: - First chairman of the **Atomic Energy Commission of India** (Known as **Father of Indian Nuclear Power)**

	- Founded and directed **Tata Institute of Fundamental Research (TIFR)** and **Atomic Energy Establishment,** Trombay, later renamed the **Bhabha Atomic Research Centre (BARC).** - Pioneered the use of thorium to extract uranium from it rather than relying on the meager reserves of uranium in India. - Established the **Cosmic Ray Research Unit** at Indian Institute of Science at Bangalore.
 **Vikram Sarabhai**	▶ Founded the **Physical Research Laboratory (PRL)** in Ahmedabad in 1947. ▶ Established the **Indian National Committee for Space Research** in 1962, which was later, renamed ISRO. ▶ Played key role in setting up **Thumba Equatorial Rocket Launching Station** in Thiruvananthapuram. ▶ Worked on India's first satellite **'Aryabhata'.** ▶ **Some of the other well-known institutions established by him are:** Faster Breeder Test Reactor (FBTR), Kalpakkam; Variable Energy Cyclotron Project; Electronics Corporation of India Limited (ECIL), Hyderabad etc.
 **A.P.J. Abdul Kalam**	▶ Project director of India's **first Satellite Launch Vehicle (SLV-III)** which successfully deployed the **Rohini satellite.** ▶ Made an effort to develop the **Polar Satellite Launch Vehicle (PSLV)** and SLV-III. ▶ Directed projects which sought to develop ballistic missiles. ▶ Worked on **Integrated Guided Missile Development Programme (IGMDP)** and played a major part in developing many missiles under the mission including Agni, Prithvi etc.
 **Meghnad Saha**	▶ Formulation of **'equation of the reaction** - isobar for ionization', which later became known as **Saha's 'thermo-ionization equation'** or **the Saha Equation.** ▶ Theory of **high-temperature ionization** of elements and its application to stellar atmospheres, as expressed by the Saha equation, is fundamental to modern astrophysics.
 **Subrahmanyan Chandrasekhar**	▶ Played an important role in the study of structure and evolution of the stars including his most notable contribution of **'Chandrasekhar Limit' (1.4 of solar masses).** - **Chandrasekhar limit** determines if a star dies as a white dwarf, or has the mass to exceed this, launching a supernova to create a black hole or neutron star. ▶ Also developed theories on **star atmospheres, black holes,** the illumination of the sunlit sky, star structures and star mass. ▶ In 1983, Chandra was awarded the **Nobel Prize in Physics** for his work on the physical **processes involved in the structure** and **evolution of stars.**

 **Prasanta Chandra Mahalanobis**	▶ Founded the **Indian Statistical Institute.** ▶ Established the **National Sample Survey** (1950) and set up **Central Statistical Organisation** to coordinate statistical activities. ▶ Shaped India's second Five-year Plan (1956-61), also called the **Mahalanobis Plan** focused on the development of public sector and rapid industrialisation. ▶ Propounded **Mahalanobis distance,** a statistical measure.
 **Tessy Thomas**	▶ Contributed to various fields such as Guidance, Control, Inertial Navigation, Trajectory Simulation and Mission Design. ▶ Played a leading role on **Agni I-V series** of missile systems**,** Aeronautical Systems Cluster Laboratories. ▶ Also worked on **aeronautical systems,** including manned and unmanned aerial vehicles, lighter than air systems, aero engines, **early warning airborne systems** and **subsonic cruise missiles.**
 **C.N.R. Rao**	▶ Main research interests are in solid state and materials chemistry. ▶ Also, worked on metal oxides, **carbon nanotubes,** and other materials and **two-dimensional systems,** including graphene, boron-nitrogen-carbon hybrid materials, and molybdenum sulfide for energy applications and green hydrogen production. ▶ He has contributed also to studies of synthesis, properties of **transition metal oxides** and of **phase transitions.**
 **Gagandeep Kang**	▶ Known for her **inter-disciplinary research** studying the transmission, development and prevention of enteric infections and their sequelae in children in India. ▶ Also, developed national **rotavirus** and typhoid surveillance networks. ▶ Investigating the **complex relationships** between infection, gut function and physical and **cognitive development.**

8. SCIENCE AND TECHNOLOGY PREVIOUS YEAR QUESTIONS 2013-2023 (SYLLABUS-WISE)

GS-III: Technology

Developments and their applications and effects in everyday life

- How does e-Technology help farmers in production and marketing of agricultural produce? Explain it. (2023 10 Marks)
- Discuss several ways in which microorganisms can help in meeting the current fuel shortage. (2023, 10 Marks)
- What is the basic principle behind vaccine development? How do vaccines work? What approaches were adopted by the Indian vaccine manufacturers to produce COVID-19 vaccines? (2022, 15 Marks)
- Elucidate the relationship between globalization and new technology in a world of scarce resources, with special reference to India. (2022, 15 Marks)
- What is cryptocurrency? How does it effect global society? Has it been affecting Indian Society also? (2021, 15 Marks)
- How is science interwoven deeply with our lives? What are the striking changes in agriculture triggered off bythe science-based technologies? (2020, 10 Marks)
- COVID-19 pandemic has caused unprecedented devastation worldwide. However, technological advancements are being availed readily to win over the crisis. Give an account of how technology was sought to aid management to the pandemic. (2020, 15 Marks)
- Describe the benefits of deriving electric energy from sunlight in contrast to the conventional energy generation? What are the initiatives offered by our government for this purpose? (2020, 15 Marks)
- What are the areas of prohibitive labour (whereby law prohibited ex manual scavenging) that can be sustainably managed by robots? Discuss the initiatives that can propel research in premier research institutes for substantive and gainful innovation. (2015 15 Marks)
- Can overuse and the availability of antibiotics without doctor's prescription, the contributors to the emergence of drug-resistant diseases in India? What are the available mechanisms for monitoring and control? Critically discuss the various issues involved. (2014 12.5 Marks)
- What do you understand by Fixed Dose Drug Combinations (FDCs)? Discuss their merits and demerits. (2013 10 Marks)
- What do you understand by Umpire decision review in cricket? Discuss its various components. Explain how silicon tape on the edge of a bat may fool the system? (2013 10 Marks)

Achievements of Indians in science & technology

- Discuss the work of 'Bose-Einstein Statistics' done by Prof. Satyendra Nath Bose and show how it revolutionized the field of Physics. (2018, 10 Marks)
- Discuss India's achievements in the field of Space Science and Technology. How the application of this technology has helped India in its socio-economic development? (2016 12.5 Marks)

Indigenization of technology and developing new technology

- What is the main task of India's third moon mission which could not be achieved in its earlier mission? List the countries that have achieved this task. Introduce the subsystems in the spacecraft launched and explain the role of the Virtual Launch Control Centre' at the Vikram Sarabhai Space Centre which contributed to the successful launch from Sriharikota. (2023, 15 marks)
- How is S-400 air defence system technically superior to any other system presently available in the world? (2021 10 Marks)
- How have digital initiatives in India contributed to functioning of education system in country? Elaborate your answer (2020 15 Marks)

- What is India's plan to have its own space station and how will it benefit our space programme? (2019 10 Marks)
- With growing energy needs should India keep on expanding its nuclear energy programme? Discuss the facts and fears associated with nuclear energy. (2018, 15 Marks)
- Why is IRNSS needed? How does it help in navigation? (2018, 15 Marks)
- India has achieved remarkable successes in unmanned space missions including the Chandrayaan and Mars Orbiter Mission, but has not ventured into manned space mission, both in terms of technology and logistics? Explain critically. (2017, 10 Marks)
- Give an account of the growth and development of nuclear science and technology in India. What is the advantage of fast breeder reactor programme in India? (2017 15 Marks)
- What do you understand by 'Standard Positioning Systems' and 'Protection Positioning Systems' in the GPS era? Discuss the advantages India perceives from its ambitious IRNSS programme employing just seven satellites. (2015 12.5 Marks)

Awareness in the fields of IT, Space, Computers, robotics, nanotechnology, bio-technology

- Introduce the concept of Artificial Intelligence (AI). How does AI help clinical diagnosis? Do you perceive any threat to privacy of the individual in the use of AI in healthcare? (2023, 10 Marks)
- Launched on 25th December 2021, James Webb Space Telescope has been much in the news since then. What are its unique features which make it superior to its predecessor Space Telescopes? What are the key goals of this mission? What potential benefits does it hold for the human race? (2022 15 Marks)
- What are the research and development achievements in applied biotechnology? How will these achievements help to uplift poorer section of the society? (2021 15 Marks)
- The Nobel Prize in Physics of 2014 was jointly awarded to Akasaki, Amano and Nakamura for the invention of Blue LEDs in 1990s. How has this invention impacted the everyday life of human beings? (2021 15 Marks)
- What do you understand by nanotechnology and how is it helping in health sector? (2020, 10 Marks)
- How can biotechnology help to improve the living standards of farmers? (2019, 15 Marks)
- Why is there so much activity in the field of biotechnology in our country? How has this activity benefitted the field of biopharma? (2018 15 Marks)
- Stem cell therapy is gaining popularity in India to treat a wide variety of medical conditions including Leukaemia, Thalassemia, damaged cornea and several burns. Describe briefly what stem cell therapy is and what advantages it has over other treatments? (2017 10 Marks)
- How does the JUNO mission of NASA help to understand the origin and evolution of earth? (2017 10 Marks)
- Why is nanotechnology one of the key technologies of the 21st century? Describe the salient features of Indian Government's Mission on Nanoscience and Technology and the scope of its application in the development process of the country. (2016 12.5 Marks)
- Scientific research in Indian universities is declining, because a career in science is not as attractive as our business operations, engineering or administration, and the universities are becoming consumer oriented. Critically comment. (2014 12.5 Marks)
- How does the 3D printing technology work? List out the advantages and disadvantages of the technology. (2013 5 Marks)
- What is an FRP (fiber reinforced plastic) composite material? How are they manufactured? Discuss their applications in aviation and automobile industries. (2013 5 marks)

Issues relating to intellectual property rights

- How is the Government of India protecting traditional knowledge of medicine from patenting by pharmaceutical companies? (2019, 15 Marks)
- India's Traditional Knowledge Digital Library (TKDL), which has a database containing formatted information on more than 2 million medicinal formulations is proving a powerful weapon in country's fight against erroneous patents. Discuss the pros and cons of making this database publicly available under open-source licensing. (2015 12.5 Marks)

- In a globalized world, Intellectual Property Rights assume significance and are a source of litigation. Broadly distinguish between the terms—Copyrights, Patents and Trade Secrets. (2014 12.5 Marks)
- Bringing out the circumstances in 2005 which forced amendment to the section 3(d) in Indian Patent Law, 1970, discuss how it has been utilized by the Supreme Court in its judgement in rejecting Novratis' patent application for 'Glivec'. Discuss briefly the pros and cons of the decision. (2013 10 Marks)

Previous Year Questions	Scan the QR code to download the soft copy of syllabus-wise segregated PYQs from 2013-2023 (Science & Technology).	

WEEKLY FOCUS- SCIENCE AND TECHNOLOGY

S. No.	Topic	Lean More
1.	5G Technology Challenges and Opportunities	
2.	Clean Coal Technologies	
3.	AI and National Security	
4.	Data-Driven Innovations and Privacy	
5.	Space Exploration: Changing dynamics & pathway to the future	
6.	Cryptocurrency: A tool of Economic Empowerment or a Regulatory Nightmare?	
7.	Universal Immunisation Towards A Healthier And A Safer World	

S. No.	Topic	Lean More
8.	India's Vaccination Drives: Strategy, Obstacles and Opportunities	
9.	Quantum Technology in India: Exploring the possibilities ahead	
10.	Web 3.0_A revolution in the making	
11.	Research and Development Ecosystem in India: Harnessing Innovation for Growth	
12.	Ethics of Emerging Technology	
13.	Agricultural Technology in India: Innovating for a Greener Tomorrow	
14.	SpaceTech Industry: From Curiosity to Reality	

Heartiest Congratulations

to all Successful Candidates

Aditya Srivastava

79 in **TOP 100** Selections in **CSE 2023**

from various programs of **Vision IAS**

Animesh Pradhan

Ruhani

Srishti Dabas

Anmol Rathore

Nausheen

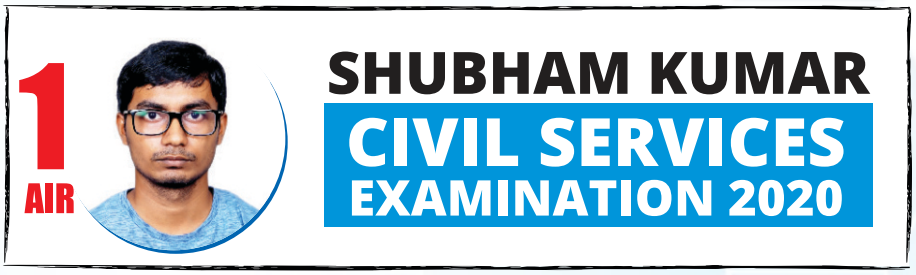
Aishwaryam Prajapati

39 Selections in **TOP 50** in **CSE 2022**

Ishita Kishore

Garima Lohia

Uma Harathi N



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