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Science & TECH

For Civil Services Examination

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1 SPACE TECHNOLOGY

SPACE ECONOMY IN INDIA

Context: According to a recent report from the **World Economic Forum (WEF)**, the global space economy will reach a value of **$1.8 trillion by 2035**, nearly identical to the scale of the **world semiconductor industry.**

What is the Space Economy?

- The Space Economy is defined by the OECD as the **full range of activities** and the **use of resources that create value and benefits** for human beings in the course of **exploring, researching, understanding, managing, and utilizing space.**
  - Also covers the goods and services produced in space for use in space.

Current Status of Global Space Economy:

- **Economic Growth in Space Sector**: **The Space Report 2022** estimates that the space economy was worth **$469 billion in 2021 – a 9% increase from a year earlier.**
- As per SpaceTech Analytics, **India is the sixth-largest** player in the industry internationally having **3.6% of the world's space-tech companies (as of 2021). The U.S.** holds the leader's spot housing **56.4%** of all companies in the space-tech ecosystem.
- **Global space market is** projected to reach **$1 trillion** by **2040.**

India's Space Potential:

- ISRO is the **6th largest space agency globally**, renowned for its high success rate in satellite launches and space missions.
- ISRO has signed **six agreements with four countries between 2021-2023** for launching foreign satellites, indicating a **potential revenue of $141 million,** highlighting its commercial viability.
- India ranks **fifth globally in the number of space companies, boasting over 400 private space entities.**

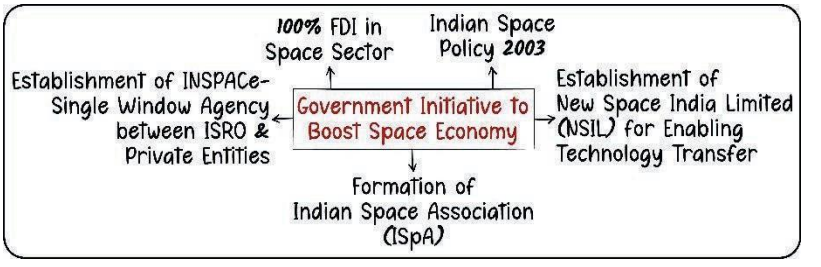
Reason for Growth of Indian Space Industry:

- **Cost-effectiveness:** ISRO charged only **$15 million for launching 104 satellites** in one go in 2017, while SpaceX charges around $60 million for a single satellite launch.
- **Proven Capability:** ISRO has demonstrated its **ability to launch satellites into different orbits,** such as polar, sun-synchronous, geostationary, etc.
- **Credibility:** ISRO has launched **more than 300 satellites for various foreign states** between 1999-2022, with a success rate of over 90%.
- **Collaboration:** ISRO has been supporting the **development of space capabilities and applications in other countries**, especially developing countries, by providing training, consultancy, technical assistance, etc.
- **Supporting Private Sector:** ISRO has been encouraging the **participation of private players and startups by providing guidance,** support, authorization and access to its facilities.
- **Increased FDI Cap**: The Finance Ministry notified **amended rules under the Foreign Exchange Management Act** to **allow up to 100 percent Foreign Direct Investment (FDI)** for the **space sector.**

Challenges in the Development of Space Economy:

- **Lack of Regulatory Ecosystem for Startups:** Indian start-ups lack regulatory clarity hindering their takeoff.

- **Minimal Share in Global Economy:** With its share estimated at **only 2% of the global market**, India must collaborate with partners to expand its presence in the global space market.
- **Lack of robust Dispute Settlement Mechanism**: Unavailability of robust dispute settlement mechanism as witnessed in Antrix-Devas case further discourages private investment in the space sector.
- **Lower Budgetary Allocation::** Compared to the US and China, India's space budget is significantly smaller. In 2019-20, the US spent 10 times more and China 6 times more than India on their space programs.



- **Brain Drain:** India faces a talent drain in its space sector, as leading minds seek better opportunities and supportive environments at organizations like NASA and ESA.
- **Lack of Skilled Workforce**: The space sector requires a highly skilled workforce in areas like aerospace engineering, astrophysics, and rocket science.
- **Absence of linkage between academia and industry**: India needs to bridge the gap between current education and industry needs.

Way Forward:

- **Enabling Ecosystem:** There is a need of a culture of accelerators, incubators, venture capitalists and mentors that is found in leading space faring countries like the US and European countries.
- **Formulation of Regulations for Emerging Areas:** The space industry is constantly evolving, with new areas like space tourism and asteroid mining emerging. Robust global regulations are required to fully harness the potential of the space sector.
- **Integrating space into the National Cyber Security Strategy:** India must integrate cybersecurity measures into its national space policy, aligning it with the **National Cyber Security Strategy and National Security Strategy** to bolster offensive and defensive capabilities.
  - With **ISRO facing over 100 cyberattacks daily**, India should follow the US example by establishing **satellite hacking sandboxes** for vulnerability testing.
- **Increasing Space Budget:** The space budget allocation must be **increased from 0.04% to at least 0.5% of GDP** to boost research centers and space standards.
- **Indian Space Resilience Agency:** India must **enhance space supply-chain resilience and security** within QUAD's space cooperation, establishing a central Indian space resilience agency for joint monitoring and incident response exercises.
- **Creation of Space Force:** India may create a Space Force, mirroring the U.S., to strengthen satellite network defense and take **assertive actions against adversary networks in the evolving space security landscape.**
- **Involve private sectors and Incentivise Startups:** India should open doors for private sectors and incentivize space startups, mirroring its satellite launch program success, with a conducive regulatory and tax environment akin to the US and Luxembourg.

Conclusion: India's space industry is poised for significant growth with ongoing advancements and increased private sector involvement. Strategic investments and international collaborations will be key to maintaining its competitive edge and achieving new milestones in space exploration and technology.

Private Space Companies in India:

- **Skyroot Aerospace:** Developing Vikram-S, a small satellite launch vehicle scheduled for a maiden flight in 2023.
- **Dhruva Space:** Specializing in nanosatellites and microsatellites, with multiple launches already accomplished and more planned.
- **Agnikul Cosmos:** It builds dedicated, fully customizable & transportable launch vehicles for small satellites to Low Earth Orbits (LEO) called Agnibaan.
- **OneWeb**: Building a global satellite broadband constellation, with over 400 satellites launched and completion slated for 2023.

Significance of Private Sector Participation:

- **Innovation**: Introducing new technologies, products, and services to meet diverse customer needs.

- **Competition:** Offering lower costs and better quality through a competitive environment.
- **Collaboration:** Partnering with government agencies, academic institutions, and international entities for mutual benefit.
- **Commercialization:** Creating new markets and revenue streams from space assets and services.
- **Socio-Economic Development:** Providing space-based solutions for sectors like education, healthcare, and agriculture, driving societal progress.

Keywords: Integrated Satellite Communications, Mission Shakti, FDI in Space Sector, NewSpace India Limited, Start-ups in Space Sector.

PREVIOUS YEAR QUESTIONS		
1.	Discuss India's achievements in the field of Space Science and Technology. How has the application of this technology helped India in its socio-economic development? (12.5 marks)	2016

THE INDIAN SPACE POLICY 2023

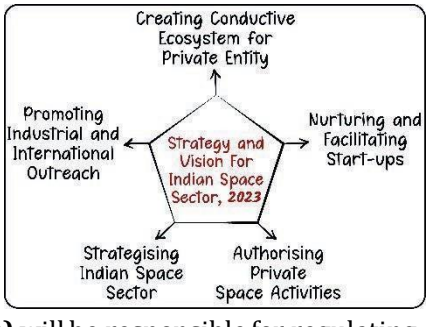
Context: The Indian Space Research Organisation **(ISRO)** recently unveiled the **Indian Space Policy 2023,** a long-anticipated development that has been in the pipeline for several years.

Aim: To promote the growth of the Indian space industry and to make India a leader in the global space sector.

Vision: To foster a thriving commercial presence in space by empowering and nurturing the **private sector.** This reflects the recognition that the involvement of private entities is vital across the entire spectrum of the space economy.

The objectives of India's space program are as follows:

- To augment India's space capabilities.
- To enable and encourage the development of a commercial space sector in India.
- To use space as a driver of technology development and derive benefits in allied areas.
- To pursue international relations in the space sector.



The policy creates four new entities that will oversee the implementation of the policy:

- **The Indian National Space Promotion and Authorisation Centre (IN-SPACe)** will be responsible for regulating and promoting the commercial space sector in India.
- **The Indian Space Research Organisation (ISRO)** will continue to be the **national space agency of India** and will focus on research and development in the space sector.
- **The Indian Space Applications Centre (ISAC)** will be responsible for developing and applying space technologies for the benefit of the Indian people.
- **The Indian Space Education and Research Centre (ISERC)** will be responsible for promoting space education and research in India.

Some of the key highlights of the Indian Space Policy 2023:

- **Allowed Entry to NGEs:** The policy allows non-government entities (NGEs) t**o participate in end-to-end space activities,** including the launch of satellites, the operation of space stations, and the provision of space-based services.
  - The policy encourages NGEs to invest in research and development in the space sector.
- **Establishment of a Regulatory Body:** The policy provides for the establishment of a regulatory body, IN-SPACe, to oversee the commercial space sector in India.
  - It will be a single window clearance and authorisation agency for space launches, establishing launch pads, buying and selling satellites, and disseminating high-resolution data among other things.
- **Vision for India:** The policy sets out a vision for India to become a leader in the global space sector.
  - The Indian Space Policy 2023 is a positive step for the Indian space sector. The policy is expected to promote the growth of the Indian space industry and to make India a leader in the global space sector.

Some of the potential benefits of the Indian Space Policy 2023:

- **Increased Economic Growth:** The Indian space sector is a major contributor to the Indian economy. The policy is expected to boost the sector and create new jobs.
- **Improved National Security:** The policy will help India to develop new space-based technologies for national security purposes.
- **Enhanced International Cooperation:** The policy will help India to cooperate with other countries in the space sector.
- **Increased Access to Space-based Services:** The policy will make it easier for Indian businesses and individuals to access space-based services, such as communication, navigation, and Earth observation.

The Indian Space Policy 2023 is a positive step for India. The policy is expected to benefit the Indian economy, national security, international cooperation, and access to space-based services.

Keywords: The Indian Space Policy 2023, Indian National Space Promotion and Authorisation Centre (IN-SPACe), Indian Space Applications Centre (ISAC)

INTERNATIONAL SPACE STATION

Context: The International Space Station (ISS) has recently completed 25 years.

About International Space Station:

- **ISS:** It is a multi-nation construction project and its main construction was completed between 1998 and 2011. It is a **co-operative programme between Europe, United States, Russia, Canada and Japan.**
- **Orbit:** The space station orbits in Low Earth orbit (LEO) at an altitude of approximately **430 kilometers,** with its orbital path taking it over **90% of the Earth's population.**
- **Average Speed:** The International Space Station **circles Earth every 90 minutes** at a speed of **8 kilometers per second.**
- **Launch:** The first segment of the ISS viz. Zarya Control Module was Russian and launched **November 20, 1998**. The ISS was completed over the course of 42 assembly flights.

Significance of ISS:

- **Global Collaboration:** Represents one of the largest international collaborations in history, involving space agencies from multiple countries.
- **Scientific Research:** Serves as a unique laboratory for conducting experiments in various fields such as biology, physics, astronomy, and materials science, leading to advancements in knowledge and technology.
- **Space Exploration Platform:** Acts as a stepping stone for future deep space exploration missions, providing valuable insights into long-duration spaceflight and human adaptation to space.
- **Technological Innovation:** Drives the development of cutting-edge technologies and systems necessary for sustained human presence in space, with applications on Earth as well.
- **Diplomatic Relations:** Fosters cooperation and goodwill among participating nations, transcending political differences and promoting peaceful collaboration in space exploration.
- **Educational Outreach:** Inspires future generations by engaging students and the public through educational initiatives and outreach programs, fostering interest in STEM fields.

Challenges Faced by ISS:

- **Aging Infrastructure:** Many components of the ISS have been in orbit for over two decades, leading to concerns about aging and degradation.
- **Technological Obsolescence:** Rapid advancements in space technology mean that some ISS systems and equipment may become outdated, requiring upgrades to remain functional and efficient.
- **Funding and Budgetary Constraints:** Operating and maintaining the ISS is costly, and securing sufficient funding from international partners to sustain operations poses a challenge, especially amid competing priorities and budgetary constraints.
- **Health Risks to Astronauts:** Long-duration spaceflight poses significant health risks to astronauts, including muscle atrophy, bone density loss, radiation exposure, and psychological challenges.
- **International Cooperation and Politics:** The ISS represents a symbol of international cooperation, but geopolitical tensions and strained diplomatic relations between partner countries could potentially impact collaboration and future operations.

- **Space Debris and Micrometeoroids:** The ISS is vulnerable to collisions with space debris and micrometeoroids, which could damage critical components and endanger the crew's safety.
- **Space Tourism and Commercialization:** The rise of space tourism and increased commercialization of space activities could introduce new complexities and challenges for ISS operations, including regulatory issues, competition for resources, and potential conflicts of interest.

Future of ISS:

- **Uncertainty in Future Operation:** Plans for the future operation of the ISS became uncertain with the start of **Russia's invasion of Ukraine in early 2022.**
- **Deorbiting ISS:** The ISS is scheduled to **end its lifetime in 2030**. NASA, Canadian Space Agency, and European Space Agency have committed to operating the space station till 2030.
  - **Russian space agency Roscosmos** has committed to the space station only till 2028.
  - NASA has requested ideas from the US aerospace industry to build the **"US Deorbit Vehicle" (USDV)** focused on the final deorbit activity.

Bharatiya Antariksh Station (BAS)

- ISRO is working in a phased manner to set up **India's first space station by 2035**.
- According to ISRO, It is likely to be **much smaller, weighing only 20 tonnes** as compared to **450 tonnes of the International Space Station and 100 tonnes of the Chinese Tiangong Space Station.**

Keywords: International Space Station, Bharatiya Antariksh Station (BAS), etc

PREVIOUS YEAR QUESTIONS		
1.	What is India 's plan to have its own space station and how will it benefit our space programme? (10 marks)	2019

SPACE TOURISM

Context: Entrepreneur and pilot **Gopi Thotakura** is set to become the **first Indian to venture into space as a tourist** on the **NS-25 mission of Blue Origin** Company.

Current Status of Space Tourism:

- **Growth of Space Tourism:** According to media reports, in 2023, the space tourism market was **valued at $848.28 million.** It is expected to grow to **$27,861.99 million by 2032.**
  - Global space tourism market is projected to grow at a **CAGR of 16.20%** from 2023 to 2032, reaching a market size of over USD 3.8 billion by 2032.
- **Accessibility: Recent years have witnessed significant milestones in space tourism, notably marked by the contributions of companies like SpaceX, Blue Origin, and Virgin Galactic.**
  - The current offerings of suborbital flights are the initial steps towards a more expansive future where space becomes a new arena for exploration, science, and leisure.
- **Cost Reduction:** With more competition and private player involvement, it will help in reducing the cost of traveling.
- Reusable rocket technology, spearheaded by SpaceX with its Falcon rockets, has dramatically reduced the cost of launching payloads into space.

Significance of Space Tourism:

- **Exploration and Adventure:** Space tourism offers individuals a unique opportunity to experience the thrill of space exploration firsthand and embark on an extraordinary adventure beyond Earth's boundaries.
- **Scientific Research:** Revenue generated from space tourism can fund scientific research and development of space technologies, which can further advance our understanding of the universe and contribute to technological advancements.
- **Economic Growth:** Space tourism has the potential to stimulate economic growth by creating job opportunities, supporting related industries, and attracting investments in infrastructure and space technology.
- **Inspiration and Education:** Space tourism boosts interest in STEM fields among all ages, promoting educational efforts and inspiring future scientists and astronauts.

- **Environmental Perspective:** Viewing Earth from space can offer a unique perspective on the planet's beauty, fragility, and the need for environmental conservation, promoting a greater sense of responsibility towards our planet.
- **International Collaboration:** Space tourism can facilitate international collaboration and cooperation among countries, fostering partnerships in space exploration, research, and technology development for the benefit of humanity as a whole.

Challenges:

- **High Cost:** Space tourism is currently very expensive, and it is unclear how prices will come down in the future.
- **Safety:** Space travel is a dangerous activity, and there is always the risk of accidents.
- **Legal and Regulatory Environment:** The legal and regulatory environment for space tourism is still in its early stages of development.
- **Health Effects:** Studying and understanding the long-term health effects of space travel on tourists is important to mitigate potential risks and provide adequate medical support during their journey.
- **Public Perception and Acceptance:** Convincing the public about the safety, value, and ethical implications of space tourism is a challenge. Addressing concerns regarding equity, resource allocation, and the potential diversion of funds from pressing societal issues is crucial for public acceptance.
- **Training and Preparation:** Preparing space tourists for the physical and psychological demands of space travel requires specialized training programs. Developing effective training methodologies and ensuring tourists are adequately prepared for their journey is a challenge.
- **Space Traffic Management:** As space tourism grows, managing the increased traffic in space and avoiding collisions between spacecraft becomes a critical challenge. Coordinating launches and establishing protocols for safe navigation are essential.
- **Insurance and Liability:** Determining insurance requirements and addressing liability issues associated with space tourism accidents or incidents is a complex challenge that needs to be addressed to protect both the industry and the tourists.

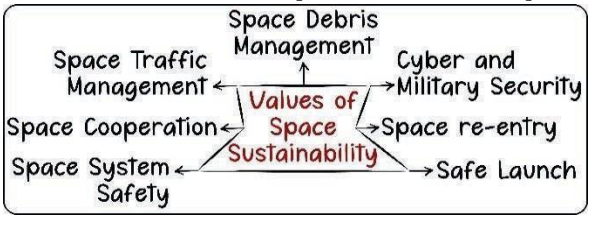
Way Forward:

- **Government support:** The Indian government can support the private sector in various ways, such as funding, tax breaks, and regulatory relief.
- **Technological Advancements:** ISRO's expertise can be leveraged to develop cost-effective and reliable reusable launch vehicles specifically for space tourism missions. This will bring down operational costs and make the experience more accessible.
- **Partnership with ISRO:** ISRO is a world-renowned space agency, and it can provide valuable support to private companies.
- **International collaboration:** The private sector can collaborate with international partners to share resources and expertise.
- **Develop Space Tourism Infrastructure:** Building dedicated spaceports and training facilities for space tourists will be crucial. Additionally, establishing safety protocols and emergency response mechanisms are essential.
- **Regulatory Framework:** The government needs to establish clear regulations for space tourism operations, ensuring safety and environmental responsibility while fostering industry growth.

Keywords: SpaceX, Blue Origin, Orbital, Sub Orbital, Space Safety, Reusable Rocket Technology.

SPACE SUSTAINABILITY

Context: NASA is planning to weed out space junk from the Earth's orbit under the first phase of its new Space Sustainability Strategy.



About Space Sustainability

- Space sustainability is **the practice of using space resources for peaceful purposes and socio-economic benefits** such that it does not harm the environment or compromises with the needs of future generations.

Challenges to Space Sustainability:

- **Space Debris:** Space debris is a major problem. It can damage satellites and other spacecraft, and it can even pose a threat to human life.

- As per **ESA's Space Environment Report 2022**, over 30,000 pieces of space debris have been recorded and are being tracked on a regular basis by **space surveillance networks.**

- **Environmental Impact:** Space activities can have a negative impact on the environment. **E.g**, Rocket launches can release pollutants into the atmosphere with various gasses.
- **Limited Space Resources:** As space activities grow, competition for orbital slots, radio frequencies, and landing sites increases, making sustainable and fair resource allocation vital to prevent conflicts and ensure equal access for all nations.
- **Space Traffic Management:** As satellite numbers and space missions increase, effective space traffic management becomes crucial to avoid collisions and maintain safe, efficient spacecraft operations.
- **Space Weather:** Space weather, including solar flares and geomagnetic storms, threatens space sustainability by disrupting satellite functions and terrestrial communications.

Initiatives on Space Sustainability:

- **Indian:**
  - Project **NETRA by ISRO** to monitor space debris to aid planning on protecting space assets.
  - Recently, ISRO attained a significant milestone in space debris reduction, stating that its **PSLV-C58/XPoSat mission left Zero debris in Earth's orbit.**
- **Global:**
  - **COPUOS 2019:** As outer space is considered a shared natural resource, the **United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) in 2019** adopted a set of 21 voluntary, non-binding guidelines to ensure the long-term sustainability of outer space activities.
  - **Outer Space Treaty, 1967:**
- **About**: The United Nations' Outer Space Treaty is an **international agreement binding member states to only use outer space for peaceful purposes.**
  - It provides **principles governing the activities of states in the exploration and use of outer space**, including the Moon and other celestial bodies.
  - **India ratified the treaty in 1982.**
- **Objective**: It primarily addresses the **peaceful use of outer space** and **prohibits the placement of nuclear weapons in space.**
  - It also contains provisions related to space debris and the return of space objects to Earth.

Suggestions for Space Sustainability:

- **Creating international agreements:** We need to create international agreements that will help to regulate space activities and to protect the environment.
- **Space Debris Mitigation:** Implement measures to reduce the creation of space debris, such as designing satellites and rockets for controlled re-entry or disposal in designated orbits.
- **Space Traffic Management:** Develop effective systems to monitor and regulate space traffic, ensuring safe distances between satellites and debris and preventing collisions.
- **International Cooperation:** Foster international collaboration and agreements to promote responsible space activities, information sharing, and adherence to guidelines and best practices.
- **Satellite End-of-Life Disposal:** Encourage satellite operators to plan for the safe disposal of their satellites at the end of their operational lives to avoid contributing to the debris problem.
- **Sustainable Satellite Design:** Promote the development and use of sustainable satellite technologies, including efficient power systems, miniaturization, and modular designs, to minimize the environmental impact of space activities.
- **Education and Awareness:** Increase public awareness about space sustainability issues, emphasizing the importance of responsible space practices and the preservation of space resources.

Space Debris

Space Debris or Space Junk, refers to non-functional, human-made objects left in space, encompassing everything from large spent rocket stages to tiny paint flecks.

- The majority of space debris consists of rocket-launching material and decommissioned satellites.

Causes of Space Debris:

- **Rapid Satellite Launches:** The surge in satellite launches significantly contributes to space debris. Example, SpaceX's Starlink project accounts for half of all active satellites and plans to expand from 12,000 to potentially 42,000 satellites.
- **Decommissioned Satellites:** Old satellites that complete their missions often remain in orbit as space junk. There are about 3,000 such decommissioned satellites currently orbiting Earth.
- **Anti-Satellite Weapon Tests:** Countries like the USA, China, and India have increased debris through anti-satellite missile tests.
- **Industry Expansion:** The booming space industry, driven by both government and private sector investments, continuously adds to the debris problem as more missions are launched.
- **Persistent Orbital Debris:** Debris from missions within LEO may eventually re-enter Earth's atmosphere, but debris in higher orbits, such as geostationary orbits, can remain aloft much longer, posing a persistent threat.
- **Fragmentation:** Collisions, explosions, and natural degradation of older satellites and debris lead to further fragmentation, compounding the space debris issue.

Conclusion: Space sustainability is an important issue that we need to address in order to ensure equitable benefits for all of humanity. By working together, we can ensure that space is utilized in a manner that benefits everyone.

SPACE HABITATION

Context: The discussion surrounding NASA's aim to establish residences and sustainable communities on the moon by 2040 has sparked a broader debate on the potential for human habitation of celestial bodies beyond Earth.

About Space Habitation:
Space habitation refers to **establishing permanent or semi-permanent human settlements beyond Earth,** on celestial bodies like the Moon or Mars. NASA has a **long history of space habitation studies** and a validated proof of concept in the International Space Station.

Potential Benefits:
- **Scientific Advancement:** Studying extraterrestrial environments and potential life forms.
- **Resource Acquisition:** Accessing resources like water ice on the Moon or minerals on Mars.
- **Expansion of Humanity:** Mitigating risks associated with Earth-based threats and ensuring human survival.
- **Technological Innovation:** Driving advancements in areas like life support systems, radiation shielding, and space construction.
- **Global Cooperation:** It will Strengthen global alliances and expanded exploration capabilities could enhance international readiness to safeguard Earth against catastrophic events like **certain asteroid impacts.**

Challenges:
- **Technical Hurdles:** Developing sustainable life support systems, reliable radiation protection, and cost-effective transportation are significant challenges.
- **Psychological Concerns:** The isolation and harsh environment of space can negatively impact human psychology and require careful consideration.
- **Economic Feasibility:** The immense costs of establishing and maintaining space habitats need to be addressed through public-private partnerships or resource utilization.
- **Legal and Ethical Issues:** Ownership rights, governance structures, and environmental concerns regarding extraterrestrial settlements require international cooperation and clear frameworks.

Way forward:
Advanced Medical Research: Invest in medical research to better understand and mitigate the effects of microgravity and radiation on human health. Develop new treatments and countermeasures to protect astronauts.
Improved Radiation Shielding: Innovate and implement more effective radiation shielding materials and technologies. This includes using water, hydrogen-rich compounds, or magnetic fields to protect inhabitants.
Robust Psychological Support: Develop comprehensive psychological support programs, including virtual reality for relaxation, regular communication with loved ones, and mental health monitoring and counseling.

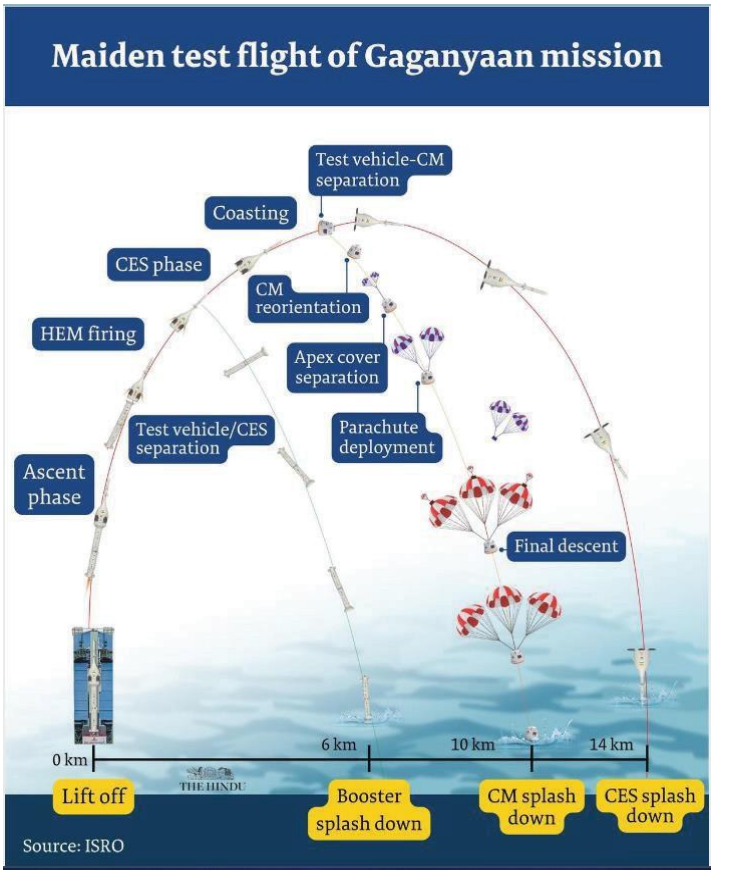
Enhanced Life Support Systems: Focus on creating more efficient and reliable closed-loop life support systems. Research in areas like bioregenerative systems, which use plants and microbes to recycle air and water, is essential.
Innovative Habitat Design: Design and test new habitat structures that are lightweight, durable, and capable of self-repair. Utilize 3D printing and in-situ resource utilization (ISRU) to construct habitats using local materials on the Moon or Mars.

Conclusion: Space habitation, though challenging, holds immense potential for scientific discoveries, resource acquisition, and even a solution for Earth's future. India's growing space sector can be a key player through research, private partnerships, and global collaboration.

Keywords: Space Resources, Space Debris, Traffic Management, Habitation, International Space Station.

GAGANYAAN MISSION

Context: Recently, the Indian Space Research Organisation (ISRO) successfully performed the **first test vehicle development flight (TV-D1)** for India's first human space flight Gaganyaan.



More on News:

- The Flight Test Vehicle Abort Mission-1 (TV-D1) will demonstrate the performance of the Crew Escape System of the Gaganyaan project.
- It marks the first in a series of tests for launching an **Indian astronaut into space by 2025.**

About the Mission:

- **About:** Gaganyaan mission is a space mission to demonstrate ISRO's human spaceflight capability by launching a human crew of three members to an orbit of 400 km and bringing them safely back to earth.
- **Aim:** To demonstrate the capability to launch human beings (three crew members) to low earth orbit and bring them back safely to earth by landing them in either the Bay of Bengal or the Arabian Sea.
- **Launch Vehicle: Launch Vehicle Mark-3 (LVM3)**
- **Total cost of Programme: 9023.00 crores**

Integral Components of the Gaganyaan Spacecraft

1. **Orbital Module:** The Central Hub of the Gaganyaan Mission, Orbital Module (OM), which will orbit the Earth, will comprise Crew Module (CM) and Service Module (SM). The OM will be equipped with advanced avionics systems.
2. **Service Module:** It comprises propulsion system, thermal system, power systems, avionics systems and deployment mechanisms, which aim to provide necessary support to Crew Module while in orbit.
3. **Crew Module:** Crew Module will have an Earth like environment in space for the crew. It will include crew interfaces, human centric products, life support system, avionics and deceleration systems.

Significance of the Gaganyaan Mission:

- **Significant achievement for India:** It will make **India the fourth country** to send humans to space after the United States, Russia, and China.
- **Scientific Exploration:** It is a significant step towards India's ambitious goals in space exploration, including setting up an **Indian Space Station by 2035** and sending an **Indian astronaut to the moon by 2040.**
- **Advanced Technology Capability:** Enables India to undertake human space exploration and scientific missions, advancing its technological prowess.
- **Economic Opportunities and Employment Creation:** Generates employment and human resource development in science and R&D, potentially boosting tourism.

- **Space Diplomacy:** Strengthens India's ties with other spacefaring nations through collaborations and international agreements.
- **Innovation Environment:** The mission will help promote innovation and creativity in the country by inspiring the next generation of students.
- **Private Sector Growth:** The success of the mission will encourage the private sector to invest in space technologies.
- **Human Beneficial Technology:** Technology developed for Gaganyaan Mission can be utilized for betterment of the society.
- **International Collaboration:** India's technological demonstration will pave the way for future international space collaboration.
- **Industry-Academia Partnership:** The mission will help promote Academia-Industry partnership in carrying out development activities for national development.

Challenges with Gaganyaan Mission:

- **Long Delay in the Project:** Delays in the project, exacerbated by the COVID-19 pandemic and supply chain disruptions.
- **Risks of Failure:** Human spaceflight entails inherent risks, as seen in historical failures like the Russian Soyuz FG rocket incident.
- **Radiation Exposure:** Astronauts face increased radiation levels in space, posing health risks such as cancer and central nervous system harm.
- **Challenges of Gravity:** Transitioning between gravity fields poses challenges that can impact hand-eye and head-eye coordination.
- **Harsh Environment:** Space presents a hostile environment with no atmosphere. In such conditions, without pressure, it creates challenges for the human body.
- **Indigenous technology:** Dependency on indigenous technology requires extensive research, development, and testing to ensure mission safety.
- **Developing a Reliable and Safe Spacecraft:** Developing a reliable and safe spacecraft for human transport is a significant challenge, especially for ISRO's first human-rated spacecraft.
- **Training the Astronauts for the Mission:** Training astronauts for space missions requires preparation for living and working in space, posing unique challenges.
- **Securing the Necessary Funding for the Mission**. The Gaganyaan mission is a costly project, and ISRO is working to secure the necessary funding from the Indian government.

Conclusion: Despite facing these challenges, ISRO is confident in its ability to successfully complete the Gaganyaan mission, which is a significant achievement for India. This mission holds the potential to inspire a new generation of scientists and engineers, making it a beacon of hope for the future of space exploration.

Keywords: Crew module, Service module, Pressurized Volume, Orbital Module, Gravitational Force.

CHANDRAYAAN 3

Context: ISRO's (Indian Space Research Organisation) Chandrayaan 3 lander has successfully made a soft landing on the lunar south pole.

More on News:

- Chandrayaan-3 is India's **third lunar mission as well as second attempt to achieve a soft landing** of a robotic lander on the moon's surface.
- India has become **the fourth country to soft land on the Moon after the United States, the erstwhile Soviet Union, and China** and the first to touch down near the lunar south pole.

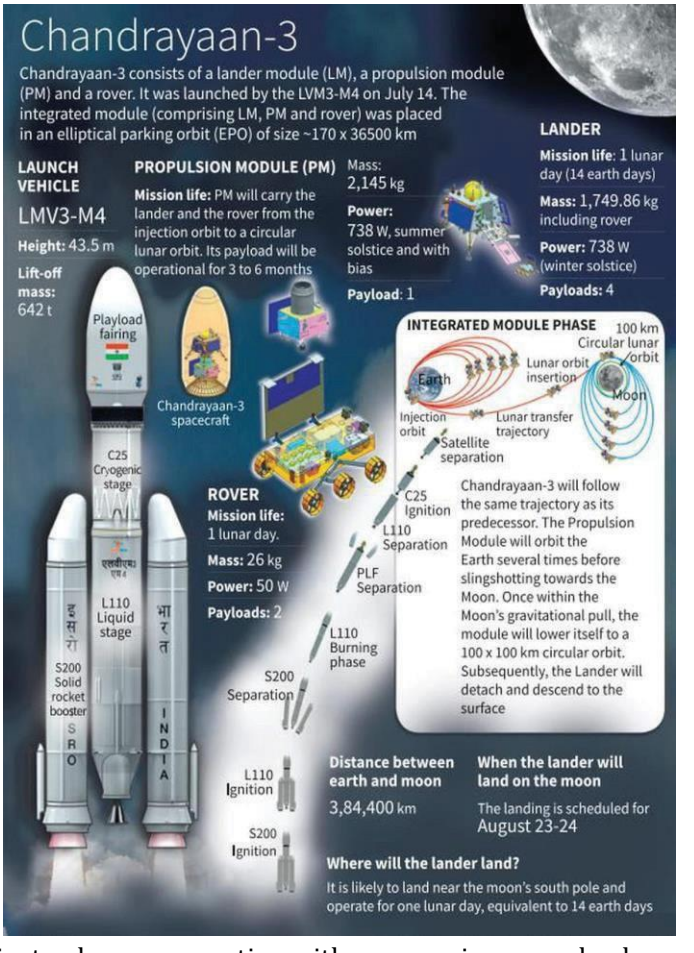
Components of Chandrayaan 3:-

Chandrayaan-3 is comprised of **three essential components**:

- **Propulsion Module:** This module transports the lander and rover configuration to a 100 km lunar orbit. It is equipped with the Spectro-polarimetry of Habitable Planet Earth (SHAPE) payload, enabling the study of Earth's spectral and polarimetric measurements from lunar orbit.
- **Lander Module (Vikram):** The Lander Module carries a scientific payload designed to study the lunar surface and atmosphere. It includes:
  - **Chandra's Surface Thermophysical Experiment (ChaSTE):** Measures thermal conductivity and temperature.

- **Instrument for Lunar Seismic Activity (ILSA):** Detects seismic activity around the landing site.
- **Langmuir Probe (LP):** Estimates plasma density and variations. Additionally, it accommodates a passive Laser Retroreflector Array from NASA for lunar laser ranging studies.

- **Rover Module (Pragyan):** This module carries instruments for studying the lunar surface and subsurface. It includes:
  - **Alpha Particle X-ray Spectrometer (APXS):** Determines elemental composition in the vicinity of the landing site.
  - **Laser Induced Breakdown Spectroscopy (LIBS):** Analyzes elemental composition in the surface and subsurface layers.



Significance of Chandrayaan-3 Mission:

- **Leadership in Space Technology:** It demonstrates India's prowess by joining the elite nations capable of lunar soft landings and showcases indigenous cryogenic engines, positioning India as a leader in space technology.
- **Global Hub in the New Space Economy:** Chandrayaan-3 enhances India's position as a global hub in the New Space economy, fostering strategic partnerships and collaborations.
- **Strategic Significance of Soft Landing:** The soft landing capability has strategic implications, contributing to advancements in Standard Refuelling and Docking technology and Smart Space Robot technology, enabling interplanetary science missions and sample retrieval.
- **Investigation of Lunar Properties:** Chandrayaan-3 investigates lunar properties with seven science payloads, confirming the presence of water ice, validating lunar molten history, and detecting subsurface water ice, providing valuable insights.
- **Insights for Defense and Aerospace:** Soft landing capability contributes insights to India's missile defense program, while reusable launch vehicle technology aids in cost reduction for future launches.

About Chandrayaan 4 Mission

- It is a lunar sample return mission that will land and thereafter be able to bring back the sample of the lunar surface.
- **Rover:** This mission is expected to be more complex than its predecessor, Chandrayaan-3 which had a rover of 30 kg and Chandrayaan-4 plans to land a massive 350 kg rover.
- The rover will have an exploration area of 1 km x 1 km which is significantly larger than Chandrayaan-3's 500 meters x 500 meters.
- **Landing on the Moon:** The Chandrayaan 4 mission aims to perform a precise landing on the Moon's rim (area yet to be explored).

Conclusion: Despite these challenges, ISRO is confident that it will successfully complete the Chandrayaan-3 mission, which is a significant achievement for India. This mission will inspire a new generation of scientists and engineers and serves as a beacon of hope for the future of space exploration.

Achievements of Chandrayaan 1:

- Chandrayaan 1 was India's first lunar mission launched by the ISRO in October 2008.
- Chandrayaan 1 **discovered evidence of water molecules on the moon, confirming the presence of lunar water,** a significant scientific breakthrough.
- The mission also mapped the moon's surface in high resolution and provided detailed images and data on the moon's topography, mineralogy, and elemental composition.

Keywords: Communications Relay Satellite, Laser Doppler Velocimeter, Water on Moon, etc

PREVIOUS YEAR QUESTIONS		
1.	India has achieved remarkable successes in unmanned space missions including the Chandrayaan and Mars Orbiter Mission, but has not ventured into manned space missions. What are the main obstacles to launching a manned space mission, both in terms of technology and logistics? Examine critically. (10 marks)	2017
2.	What is the main task of India's third mood 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. (15 marks)	2023

ADITYA-L1 MISSION

Context: Recently, the **Indian Space Research Organisation (ISRO) launched Aditya L-1**, its first space-based mission to study the Sun, from the **Satish Dhawan Space Centre** in **Sriharikota**.

About Aditya-L1 Mission:

- Aditya-L1 is the **first Indian space mission** to observe the Sun and the solar corona.
  - The meaning of Aditya is **"Sun God"**.
- It will be placed in **a halo orbit** around the **first Lagrange point (L1**) of the Sun-Earth system which allows it to look at the Sun continuously.
  - At these positions, the gravitational pull of the celestial bodies equals the centripetal force, thus the **forces acting on the third body cancel each other out**.
- **PSLV-C57**: It is the **25th mission** using Polar Satellite Launch Vehicle (PSLV C-57)

Objectives of Aditya-L1 Mission are:

- **Study:**
  - Solar upper atmospheric (chromosphere and corona) dynamics.
  - Chromospheric and coronal heating.
  - Physics of the partially ionized plasma.
  - Initiation of the Coronal Mass Ejections (CME).
  - Solar Flares.
- **Observe:**
  - In-situ particle and plasma environment providing data for the study of particle dynamics from the Sun.
  - Physics of solar corona and its heating mechanism.
  - Diagnostics of the coronal and coronal loops plasma: Temperature, Velocity and Density.
  - Development, dynamics and origin of CMEs.

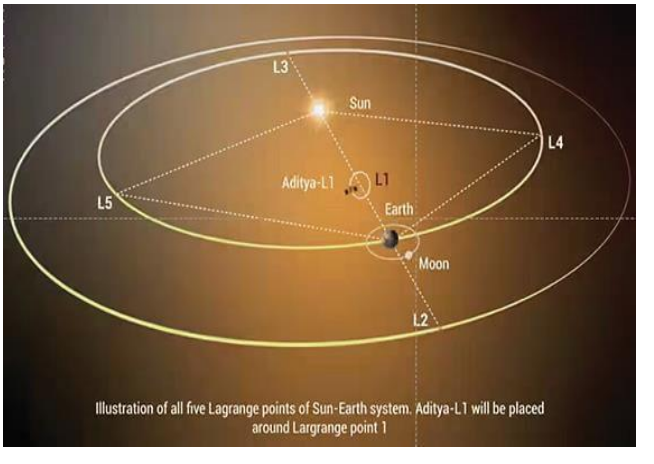


Illustration of all five Lagrange points of Sun-Earth system. Aditya-L1 will be placed around Largrange point 1

Significance of Aditya L-1 Mission:

- **Observe Solar Activities:** The mission aims to comprehend how **solar storms** generate high-energy charged particles that can potentially damage satellites and disrupt our modern way of life.
- **Space Weather Prediction**: It will monitor the **near-Earth space environment** and contribute to refining space weather forecasting models.
  - **Severe space weather** impacts telecommunication and navigational networks, high-frequency radio communications, air traffic on polar routes, electric power grids, and oil pipelines at high latitudes of the Earth.
- **International Leadership and Prestige:** The ambitious mission marks the country's inaugural journey into space-based solar studies**. ISRO will join the ranks of NASA and the European Space Agency** to station a solar observatory there.
- **Scientific Discovery:** Solar missions often lead to unexpected discoveries and new insights into the Sun's behavior.
  - **For example**, the Parker Solar Probe, launched by NASA, has provided new data about the solar wind.
- **Other Advantages**: Apart from the primary pursuit of the scientific goals, the impact of the mission extends to critical aspects of industry and society.

- **For example,** space-based solar studies help create scientific and technical jobs, enhance safety on Earth, and increase international collaboration among different countries.

Other Mission for Solar Study:

- **United States: Parker Solar Probe** touched Sun's corona in **December 2021**, collaborated with ESA on Solar Orbiter, active missions include ACE, STEREO, SDO, and IRIS.
- **Japan:** JAXA launched **Hinotori (ASTRO-A) in 1981**,
  - JAXA's other solar exploratory missions are Yohkoh (SOLAR-A) launched in 1991; SOHO (along with NASA and ESA) in 1995; and Transient Region and Coronal Explorer (TRACE), along with NASA, in 1998..
- **Europe**: ESA's **Ulysses** launched in 1990, launched **Proba-2 (Project for On-Board Autonomy)** in 2009,
  - Upcoming missions include **Proba-3,** scheduled for 2024 and **Smile**, scheduled for 2025.
- **China**: **Advanced Space-based Solar Observatory (ASO-S)** launched in October 2022 by National Space Science Center, CAS.

Challenges:

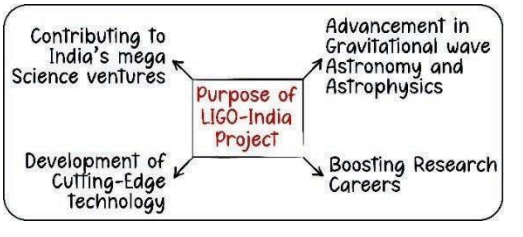
- **L1 Point Distance**: Navigating a spacecraft requires precise calculations and maneuvers to ensure it remains on its desired trajectory. The Sun's gravitational pull and the spacecraft's high speed can complicate navigation.
- **Exposure to Sun's Heat**: Proximity to the Sun exposes spacecraft to extreme temperatures and intense radiation.
  - To withstand these conditions, solar missions require **advanced materials and thermal protection systems** to ensure the functioning of moving components.
- **Power Generation**: Solar missions must use solar panels to generate power. However, as they get closer to the Sun, sunlight becomes too intense for conventional solar panels to generate power for the spacecraft's operation.
- **Communication**: The interference from the Sun's **radio emissions** with a spacecraft transmitting data over such vast distances hinders communication.
- **Data Collection:** Precise calibration of scientific instruments is crucial to ensure data collection accuracy during a solar mission, but the extreme environment makes it a challenging task.

Conclusion: The successful launch of Aditya-L1 is expected to garner increased investor interest in the Indian space sector and trigger more funding for private players. Several private sector players, including Larsen & Toubro (L&T), MTAR Technologies, and Ananth Technologies, have played a pivotal role in the Indian Space Research Organisation's (Isro's) solar observatory mission.

Keywords: Halo orbit, Lagrange point (L1), PSLV-C57, Chromospheric and coronal heating, Coronal Mass Ejections, Parker Solar Probe.

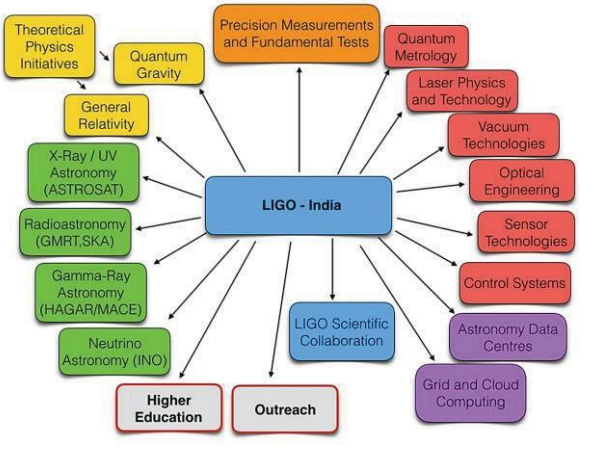
LIGO–INDIA

Context: The United States and India have jointly unveiled plans to construct a Laser Interferometer Gravitational-Wave Observatory (LIGO) in India.



About LIGO-India:

- The Laser Interferometer Gravitational-Wave Observatory (LIGO) - India is a planned advanced gravitational-wave observatory to be located in India as part of the worldwide network, whose concept proposal is now under active consideration in India and the USA.
- To be completed by 2030, location of the LIGO India observatory is in the **Hingoli district of Maharashtra.**



Potential Benefits of LIGO–India:

- **Improved understanding of the universe:** LIGO–India will help to improve our understanding of the universe by detecting gravitational waves from a variety of sources, including merging neutron stars and black holes. This will allow scientists to study the physics of these events and to learn more about the structure and evolution of the universe.

- **Development of new technologies**: LIGO–India will help to develop new technologies that can be used in other fields, such as medical imaging and seismology. This will have a positive impact on society as a whole.
- **Inspiration of a new generation of scientists and engineers**: LIGO–India will inspire a new generation of scientists and engineers by providing them with the opportunity to work .
- LIGO-India would strengthen the capabilities of multi-messenger astronomy by detecting gravitational waves in conjunction with other telescopes, enabling a more comprehensive study of astrophysical phenomena.
- **Global Collaboration**: LIGO-India's inclusion in the network would promote international collaboration, fostering knowledge exchange, shared resources, and joint research efforts in the field of gravitational wave astronomy.
- **Customized Services:** NavIC can be tailored to regional needs, fostering innovation and economic growth in various sectors.

About LIGO:
- **Purpose:** International network of laboratories detecting gravitational waves.
- **Precision Requirement:** Designed to measure minuscule changes in distance, even smaller than the length of a proton, due to weak gravitational waves.

Operational LIGO:
- **Global Network**: Operational in the **United States (Hanford and Livingston), Italy (Virgo), and Japan (Kagra).**
- **Simultaneous Operation: Four comparable detecto**rs need to operate simultaneously globally for accurate gravitational wave detection.

Working Mechanism:
- **Instrument Design: Two 4-km-long vacuum chambers** arranged at right angles, each with mirrors at ends.
- **Detection Principle:** Gravitational waves cause one chamber to elongate and the other to compress, creating a **phase difference in returning light rays.**
- **Confirmation:** Detection of **phase difference serves as confirmation** of gravitational wave presence.

Gravitational Waves:
- Ripples in space-time predicted by Einstein's General Theory of Relativity in 1915.
- They travel at the speed of light, carrying information about their origins and providing insights into gravity.

First Detection of Gravitational Waves:
- **Landmark Event**: LIGO in the US detected gravitational waves in **2015, leading to a Nobel Prize in Physics in 2017.**
- **Source**: Waves originated from the **merger of two massive black holes**, each about **29 and 36 times the mass of the Sun, 1.3 billion years ago**.
- **Strength:** Black hole mergers produce some of the strongest gravitational waves.

Space-based Gravitational Wave Observatories:
- **LISA (Laser Interferometer Space Antenna):** Joint **NASA-ESA mission** aiming to detect low-frequency gravitational waves using three spacecraft forming a triangle.
- **Evolved LISA (eLISA):** ESA's follow-up mission to LISA, enhancing sensitivity and extending observation times for gravitational wave detection. It involves scientists from **eight European countries** – Denmark, France, Germany, Italy, The Netherlands, Spain, Switzerland, and the UK.
- **LISA Pathfinder: ESA mission, launched in 2015,** demonstrating technologies crucial for future space-based gravitational wave observatories.

Conclusion: LIGO-India project holds immense potential for advancing gravitational wave research and enhancing our understanding of the universe. By joining the global network of gravitational wave detectors, it opens up new avenues for collaboration, discovery, and unlocking the secrets of the cosmos

Keywords: Gravitational waves, astronomy, General Theory of Relativity, Hingoli, Vacuum Chamber, Black Holes.

DEVELOPMENTS RELATED TO ISRO

INSAT-3DS SATELLITE

Context: INSAT 3DS was successfully launched by ISRO, with the aim of enhancing weather forecasting and disaster warning capabilities.

About INSAT 3DS:

- Indian National Satellite 3DS is an exclusive meteorological satellite designed for enhanced meteorological observation of land and ocean surfaces for weather forecasting and disaster management.
- It is the **third in a series of INSAT 3D satellites.** Its predecessors were INSAT-3D (launched in 2013), and INSAT-3DR (2016).
- **Development:** It is a byproduct of the collaborative efforts of ISRO and the Indian Meteorological Organisation (IMO).
- **User-Funded Project:** The satellite is funded by the Ministry of Earth Science, and configured around ISRO's I-2k bus platform with a lift-off mass of 2275 kg.
- **Payload:**
  - **Meteorology:** Equipped with 6-channel imager and 19-channel sounder for enhanced meteorological observation.
  - **Communication:** It includes Data Relay Transponder (DRT) and Satellite aided search and Rescue (SAS&R) transponder.

How does INSAT 3DS Work?

- The Data Relay Transponder (DRT) instrument enhances weather forecasting capabilities by receiving meteorological, hydrological, and oceanographic data from automatic data collection platforms or automatic weather stations (AWS).

Significance of INSAT 3DS

- Provides more accurate weather information.
- Providing real-time information. It will be crucial for disaster management.
- It will be helpful in analysing environmental impact on different geographies (from forests to oceans to glaciers).

Keywords: INSAT-3D, Indian Meteorological Organisation (IMO), I-2k bus platform, Data Relay Transponder (DRT)

CONTROLLED RE-ENTRY OF MEGHA-TROPIQUES-1 (UD)

Context: ISRO is gearing up for a challenging experiment of **controlled re-entry of a decommissioned low Earth orbiting satellite, namely Megha-Tropiques-1 (MT1)**.

About Megha-Tropiques-1 (MT1).

- MT1 was launched in 2011, as a joint satellite venture of **ISRO and the French space agency CNES** for tropical weather and climate studies.
- **Mission life: 3 years,** the satellite continued to provide valuable data services for more than a decade supporting regional and global climate models till 2021.
  - The **orbital lifetime of MT1, weighing about 1000 kg**, would have been more than 100 years in its **20 deg inclined operational orbit of 867 km altitude.**
- **About 125 kg on-board fuel** remained unutilised at its end-of-mission that could pose risks for accidental break-up.
- This left-over fuel was estimated to be sufficient to achieve a fully controlled atmospheric re-entry to impact an **uninhabited location in the Pacific Ocean.**

Controlled Re-Entries:

- **United Nations/Inter-Agency Space Debris Coordination Committee (UN/IADC)** guidelines suggest that LEO objects should be **deorbited at their end-of-life**, either through controlled re-entry to a safe zone or by moving them to an orbit with a **shorter lifetime of less than 25 years to mitigate space debris.**
- It is also recommended to carry out **"passivation" of on-board energy sources** to minimise the risk of any post-mission accidental break-up.
- Controlled re-entries involve **deorbiting to very low altitudes** to ensure impact occurs within a targeted safe zone.
- Usually, large satellites/rocket bodies which are likely to **survive aero-thermal fragmentation** upon re-entry are made to undergo controlled re-entry to limit ground casualty risk.
- However, all such satellites are specifically **designed to undergo controlled re-entry at end-of-life.**

Key Word: French Space Agency, Controlled Re-Entries, United Nations/Inter-Agency Space Debris Coordination Committee (UN/IADC), Deorbiting, Aero-Thermal Fragmentation, etc.

REUSABLE LAUNCH VEHICLE – TECHNOLOGY DEMONSTRATOR (RLV-TD)

About: ISRO's RLV-TD is a **flying test bed** for developing a **fully reusable launch vehicle.**
Aims to drastically **reduce launch cost**s (potentially by 80%) for space access.

Key Features:

- **Winged design** combining aircraft and launch vehicle complexity.
- Evaluates technologies like **hypersonic flight, autonomous landing, and reusability**.
- Utilizes **advanced materials** and requires a highly skilled workforce.

Objectives:

- Test **aerodynamics** of hypersonic flight.
- Evaluate **autonomous navigation and control systems.**
- Demonstrate **integrated flight management.**
- Assess **thermal protection systems** for re-entry.

Significance:

- Reusable launch vehicles offer a **cost-effective and reliable path** for frequent space missions.
- RLV-TD paves the way for India's **future two-stage orbital launch vehicle.**

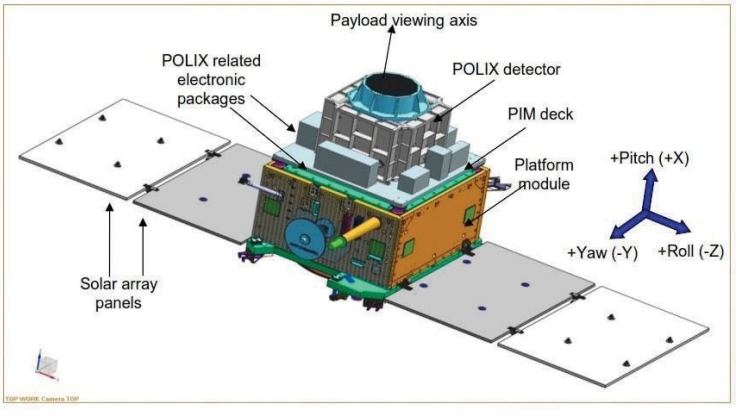
Keyword: Launch cost, Winged design, Hypersonic, Thermal protection, Two-stage orbital launch vehicle.

X-RAY POLARIMETER SATELLITE

Context: ISRO (India) launched its first **X-Ray Polarimeter Satellite on** 1 January 2024 on a PSLV rocket, and it has an expected operational lifespan of at least five years.

More on News

- X-Ray Polarimeter Satellite (XPoSat) will be launched by the **Polar Satellite Launch Vehicle (PSLV)** from the Satish Dhawan Space Center in Sriharikota.
- **Aim:** It is India's pioneering **polarimetry mission** aimed at studying various dynamics of astronomical sources in extreme conditions.
- It is only the world's second polarimetry mission using X-ray after **NASA's Imaging X-ray Polarimetry Explorer (IXPE)** that was launched in 2021.



About XPoSat

- **XPoSat, India's pioneering X-ray Polarimeter Satellite,** marks the country's first dedicated mission to delve into the dynamics of astronomical X-ray sources.
- **Key Objectives:**
  - To **measure polarization of X-rays emanating** from about 50 potential cosmic sources through **Thomson Scattering by POLIX payload.**
  - To carry out long term spectral and temporal studies of **cosmic X-ray sources by XSPECT payload**.
  - To carry out **polarization and spectroscopic measurements** of X-ray emissions from cosmic sources by POLIX and XSPECT payloads respectively in the common energy band.
  - To study **black holes and neutron stars** in Space.
- **Payloads: It comprises two payloads:**
  - **X-ray Polarimeter (POLIX):** POLIX is expected to observe about **40 bright astronomical sources** of different categories during the planned lifetime of XPoSat mission of **about 5 years.**
  - **X-ray Spectroscopy and Timing (XSPECT):** It can provide **fast timing and good spectroscopic resolution** in soft X-rays.
    - XSPECT would **observe several types of sources** viz X-ray pulsars, blackhole binaries, low-magnetic field neutron star (NS) in LMXBs, AGNs and Magnetars.
- **Significance of Mission**: India has become the **2nd country in the world after the United States to send a specialized astronomy observatory** to study black holes and neutron stars in our galaxy.

- **NASA** launched Imaging X-ray Polarimetry Explorer **(IXPE) in 2021.**

Conclusion: It is a significant step towards the understanding and exploring of high-energy astrophysical phenomena and in India's space research and exploration vision for humankind's knowledge of the universe.

Keyword: PSLV, Polarimetry, Imaging X-ray Polarimetry Explorer (IXPE), POLIX, XSPECT.

PREVIOUS YEAR QUESTIONS		
1.	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? (15 marks)	2022

AWARENESS IN THE FIELD OF GEO-SPATIAL TECHNOLOGY

NATIONAL GEOSPATIAL POLICY

Context: The Government is implementing the National Geospatial Policy 2022 (NGP) and has substantially expanded the access and usage of spatial data.

National Geospatial Policy 2022:

- **Citizen-Centric Policy:** It is a policy centered around citizens, leveraging Geo-Spatial technology to support national development, boost the economy, and foster an information-rich society.

Vision:

- To establish a **comprehensive topographical survey** and mapping system, including a high-accuracy Digital Elevation Model (DEM), by the year 2030.
- To become a **global leader in the Geospatial domain**, fostering an ecosystem for innovation and excellence.
- To develop a c**oherent national framework for Geospatial technology**, enabling the transition towards a digital economy and enhancing citizen services.
- **Development of robust Geospatial infrastructure,** including skills, knowledge, standards, and businesses in the Geospatial sector.
- To strengthen national and sub-national arrangements for the generation and management of Geospatial information.

Institutional Framework:

- **National Level: Geospatial Data Promotion and Development Committee (GDPDC).**
  - It serves as the apex body responsible for formulating and implementing strategies to support the Geospatial sector.
- **The Department of Science & Technology (DST)** remains the nodal department of the government for the Geospatial sector. The GDPDC works in conjunction with the DST, providing suitable recommendations to assist the department in fulfilling its responsibilities concerning the Geospatial regime.

Milestones Towards Realization of Policy's Vision:

- **Year 2025:** Establish a supportive policy and legal framework that promotes the liberalization of the Geospatial sector and facilitates the democratization of data, leading to increased commercial opportunities and the development of value-added services.
- **Year 2030:** Conduct high-resolution topographical surveys and mapping with a focus on urban and rural areas, achieving a precision of 5-10 cm. Additionally, map forests and wastelands with a resolution of 50 cm to 100 cm, enabling better land management and resource planning.
- **Year 2035:** Acquire precise Bathymetric Geospatial Data for inland waters and sea surface topography to support the Blue Economy. Establish Digital Twins for major towns and cities, replicating physical assets and processes. Develop an interconnected network of smart and dynamic Digital Twins at a national level.

Significance:

- Leveraging geospatial technology and data can play a transformative role in accomplishing the **Sustainable Development Goals (SDGs)**, driving positive change across various sectors.
- Embracing this initiative promotes the **growth of start-ups and reduces reliance on foreign resources,** fostering self-sufficiency and economic development.

- Geospatial data is crucial in **managing critical information** across a diverse range of domains, including military operations, disaster response, environmental monitoring, and urban planning.
- By harnessing the power of geospatial technology, governments and organizations can make informed decisions, enhance efficiency, and address challenges related to data management effectively.

Way Forward:
- Given the number of people and organizations involved in a disaster preparation scenario, security measures must be taken to provide users and applications only with data on a need-to-know basis.
- A clear roadmap should be drawn and SOP should be developed in National Geospatial Policy 2022 for the National Securities Issues for the country wherein it is the three services, Para military or Critical Infrastructure Sectors.

Keywords: Geospatial, High resolution, Critical Infrastructure, Blue Economy,

GLOBAL POSITIONING SYSTEM (GPS)

Context: Recently, the Delhi High Court sought the Cente's stand in a plea challenging the order of the Civil Aviation Ministry, prohibiting the carrying of receive-only **Global Positioning System (GPS) devices** on aircraft.

About Global Positioning System (GPS):
- It is a **satellite-based radio-navigation system** used for monitoring and control.
- **Origin:** The U.S. Department of Defence started the **GPS program in 1973** and launched the first satellite in 1978.
- GPS is a U.S.-owned utility that provides users with positioning, navigation, and timing (PNT) services.
- **This System consists of Three Segments:**
  - **Space (Satellites):** The satellites circling the Earth, transmitting signals to users on geographical position and time of day.
  - **Ground control:** The Control Segment comprises Earth-based monitor stations, master control stations and ground antenna. Control activities include tracking and operating the satellites in space and monitoring transmissions.
  - **User equipment:** GPS receivers and transmitters including items like watches, smartphones and telematic devices.
- **GPS Satellite Constellation**: The modern **GPS consists of 24 satellites** moving around the earth in six orbits.
- **Standard Positioning Service (SPS):** The services provided by the GPS system are designed to meet the **SPS** performance standard, the latest edition of which was published in April 2020.
  - In essence, the **SPS standard tells application developers and users** anywhere in the world what they can expect from the GPS system

Applications:
- **Aviation:** Modern aircraft are fitted with multiple GPS receivers which provide pilots (and sometimes passengers) with a real-time aircraft position and map of each flight's progress.
- **Marine:** GPS is also used to position and map dredging operations in rivers, wharves and sandbars, so other boats know precisely where it is deep enough for them to operate.
- **Farming:** High-accuracy GPS maps soil sample locations, allowing farmers to see where the soil is most fertile across individual fields or entire farms.
- **Surveying:** Surveyors use GPS to accurately map and accurately measure the earth's surface and underwater features.
- **Sports and Fitness Tracking:** GPS-enabled sports watches and fitness trackers provide real-time data on distance, speed, elevation, and heart rate, allowing users to set goals, track their workouts, and analyze their performance over time.
- **Unmanned Aerial Vehicles:** Unmanned Aerial Vehicles (UAVs), commonly known as drones, rely heavily on GPS technology for navigation, stabilization, and geofencing.

Limitations of GPS:
- **Time-Keeping:** Good timekeeping is essential to ensure the GPS system works as well as possible.
- For example, not adjusting for the 38-microsecond offset between the satellites' clocks and the ground could lead to an error of 10 km within a single day.
- **Indoor Limitations of GPS:** GPS is generally useless indoors as radio waves will be blocked by physical barriers, such as walls, and other objects.
- **Accuracy Constraints:** Regular GPS cannot pinpoint locations to greater than 3-m accuracy.

- Due to these limitations, GPS cannot be used to, for instance, track the movement patterns of retail customers in a store and analyze their shopping habits.

Keywords: Radio-Navigation System, PNT, Standard Positioning Service, Satellite Constellation

PREVIOUS YEAR QUESTIONS		
1.	What do you understand about '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. (12.5 marks)	2015

GPS SPOOFING

Context: Recently, the Directorate General of Civil Aviation (DGCA) has issued an advisory circular on interference with the **Global Navigation Satellite System (GNSS)** in airspace, highlighting the threats of GNSS jamming and spoofing pose for aircraft operations.

About GPS Spoofing:

GPS Spoofing: Global Positioning System (GPS) spoofing is an attack aimed at **overriding a GPS-enabled device's** original location.

- Attacker uses a **radio transmitter** that broadcasts fake GPS signals and interferes with GPS receivers nearby. As a result, those devices display **fake GPS locations.**

Global Navigation Satellite System (GNSS):

- GNSS is a general term describing any satellite constellation that provides **positioning, navigation, and timing (PNT) services** on a global or regional basis.
- While GPS is the most prevalent GNSS, **other nations** have fielded their own systems to provide complementary, independent PNT capability.

Findings of EASA on GPS Spoofing:

- **Rise in GPS Spoofing:** European Aviation Safety Agency (EASA) reports an increase in GPS spoofing since 2022, with growing sophistication.
- **Geographical Hotspots:** GPS spoofing incidents are observed mainly around conflict zones and regions like the south and eastern Mediterranean, Black Sea, Baltic Sea, and Arctic areas.
- **Concerning Incidents:** About 20 business jets and commercial flights reported GPS spoofing near the Iran-Iraq border, raising significant concerns.

Implications of GPS Spoofing:

- **Course Deviation:** GPS spoofing can divert aircraft from their intended course, leading to potential intrusions or collisions.
- **Navigation Errors:** Interference with Global Navigation Satellite Systems (GNSS) can result in false data for fuel computation, flight management systems, and navigation displays.
- **Safety Risks:** Incorrect GPS data can result in misjudgments of altitude, speed, and direction, increasing the likelihood of accidents, especially during critical phases of flight such as takeoff, landing, and approach.
- **Security Threats:** GPS spoofing can be used maliciously to disrupt aviation operations, posing security threats to airports, airspace, and air traffic management systems.
- **Financial Losses:** Disruptions caused by GPS spoofing incidents can result in flight delays, diversions, and cancellations, leading to financial losses for airlines, airports, and passengers.
- **Reputation Damage:** Airlines and aviation authorities may suffer reputational damage due to incidents of GPS spoofing, eroding public trust and confidence in air travel safety and security.

Steps Taken by India:

- **Committee Formation:** India formed a committee on GPS spoofing, leading to the **issuance of advisories to Indian airlines** by the civil aviation regulator.
- **Threat Monitoring Network:** Indian authorities establish a mechanism for air navigation service providers to set up a threat monitoring and analysis network in coordination with the regulator, aiming for proactive and reactive threat monitoring.
- **Incident Analysis:** GNSS interference reports are analyzed to develop a robust and immediate threat response capability in the event of a spoofing incident.

Way Forward:

- **Signal Authentication:** Implementing technologies that authenticate GPS signals to verify their integrity and detect spoofed signals.

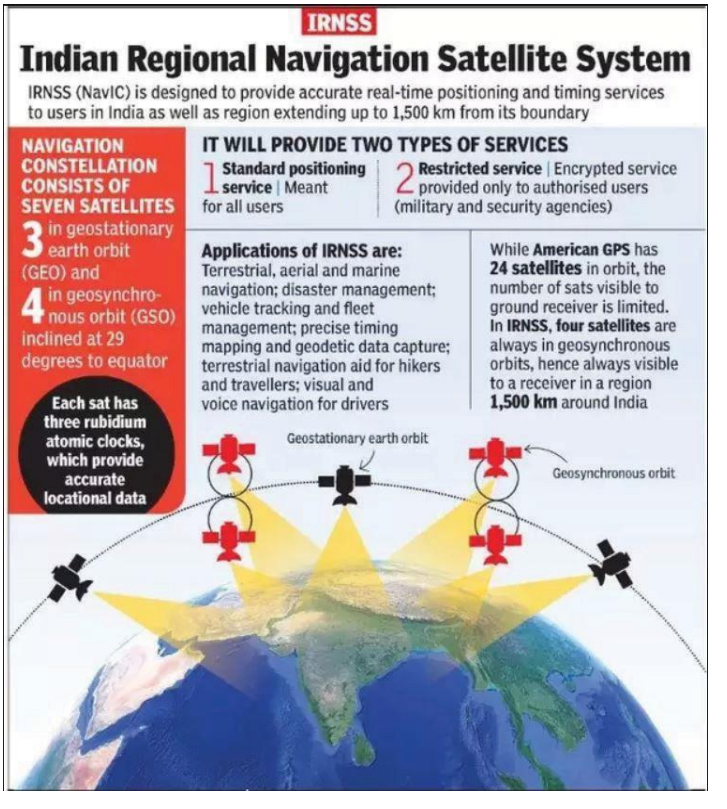
- **Encryption:** Employing encryption techniques to secure GPS signals and prevent unauthorized access or manipulation.
- **Multi-Sensor Fusion:** Integrating data from multiple sensors, such as radar, inertial navigation systems, and ground-based navigation aids, to cross-validate position information and detect anomalies.
- **Jamming Detection:** Deploying systems capable of detecting and mitigating GPS signal jamming, which can indicate the presence of spoofing attacks.
- **Anti-Spoofing Software:** Developing software solutions that analyze GPS signals in real-time to detect spoofing attempts and take corrective actions to maintain navigation accuracy.
- **Regulatory Measures:** Implementing regulations and standards to address GPS spoofing threats, including mandatory security protocols for aviation systems and equipment.
- **Education and Training:** Providing training programs for pilots, air traffic controllers, and aviation personnel to recognize and respond to GPS spoofing incidents effectively.
- **Collaboration:** Fostering collaboration between aviation stakeholders, government agencies, research institutions, and industry partners to share information, best practices, and technological innovations for combating GPS spoofing.

Conclusion: Spoofing is a serious concern, which needs to be tackled smartly and securely. There is a need to make use of GPS spoofing detection software, which warns users of spoofing instances and prevents their devices from responding to fake GPS data.

Keywords: GNSS, Hotspots, Satellite-Based-Navigation, Threat Monitoring, Anti-Spoofing.

INDIA'S NAVIGATION SYSTEM

Context: The Indian Space Research Organisation (ISRO) launched the **first of the second-generation satellites** for its navigation constellation successfully.



About NavIC:

- NavIC was erstwhile known as **Indian Regional Navigation Satellite System (IRNSS).**
- NavIC is **designed with a constellation of 7 satellites** and a network of ground stations operating 24 x 7.
- Three satellites of the constellation are placed in geostationary orbit, and four satellites are placed in inclined geosynchronous orbit.
- The ground network consists of a control center, precise timing facility, range and integrity monitoring stations, two-way ranging stations, etc.
- Each of the seven satellites currently in the named NavIC, weighed much less around 1,425 kg at liftoff.

Services Offered:

- **Types of Services:** Standard Position Service (SPS) for civilian users and Restricted Service (RS) for strategic users.
- **Frequency Bands:** These two services are provided in both L5 and S bands.
- **Coverage:** The NavIC coverage area includes India and a region up to 1500 km beyond the Indian boundary.
- **Accuracy:** NavIC signals are designed to provide user position accuracy better than 20m and timing accuracy better than 50ns.
- **Signals Interoperability:** NavIC SPS signals are interoperable with the other global navigation satellite system (GNSS) signals namely GPS, Glonass, Galileo, and BeiDou.
- **Constant Speed:** Unlike GPS, NavIC uses satellites in high geo-stationary orbit. The satellites move at a constant speed relative to Earth, so they are always looking over the same region on Earth.

IMO Recognised NavIC:

- India's indigenous navigation system, NAVIC (Navigation with Indian Constellation), has gained recognition and approval from the **International Maritime Organization (IMO).** This endorsement reinforces the credibility and reliability of NAVIC for maritime navigation and opens up opportunities for its implementation globally.
- An impressive number of 17,000 small satellites are expected to be launched worldwide b etween now and 2030, showcasing the increasing demand for satellite-based technologies and services.

Advantages of Regional Navigation System: NavIC:

- **Improved Accuracy:** NavIC provides highly accurate positioning tailored for the Indian region, crucial for transportation, agriculture, and disaster management.
- **Enhanced Coverage:** With strategically placed ground stations, NavIC ensures consistent signal availability even in challenging terrains.
- **Reliability:** NavIC's dedicated service for India means users can rely on its signals without external dependencies, crucial for safety and security.
- **Better Signal Penetration:** NavIC signals penetrate congested urban areas and dense forests more effectively, ensuring reliable reception.
- **National Sovereignty:** NavIC reduces reliance on foreign systems, enhancing technological independence and sovereignty.
- **Customized Services:** NavIC can be tailored to regional needs, fostering innovation and economic growth in various sectors.

Roadmap and Future Prospects for NavIC Adoption:

- To advance NavIC's adoption, ISRO launched **second-generation Navigation satellites** in May 2023.
  These satellites **enhance interoperability with other satellite-based navigation systems** and extend utility. By introducing signals in the **L1 frequency**, in addition to the existing L5 and S frequency signals, **these satellites facilitate compatibility with commonly used systems like GPS.**
- This expansion **aims to broaden NavIC's usage,** particularly in wearable devices and personal trackers utilizing low-power, single-frequency chips.
- Such strategic endeavors align with **India's pursuit of technological sovereignty** and its ambition to **become a prominent player in space exploration.**

Significance of The Integration of NavIC in Smartphones

- **Reduced Dependence on Foreign Systems:** This will reduces india's reliance on foreign global navigation systems like **GPS**.
  - This showcases technological independence and capability to develop and deploy critical infr astructure autonomously.
- **Enhanced National Security**: NavIC integration ensures that India can control and secure **its vital navigation infrastructure, which is crucial for national security and defense applications.**
  - This will **mitigates the risk of disruption**s or compromises in navigation services during critical situations.
- **Improved Accuracy and Reliability:** NavIC provides highly accurate and reliable positioning and timing information, especially in the Indian subcontinent and surrounding regions.
- This is essential for various applications including **disaster management, agriculture, urban planning, and transportation**, leading to more efficient decision-making and resource allocation.
- **Expansion of Use Cases and Innovation:** The integration of NavIC opens up opportunities for a wide range of location-based services, navigation apps, and innovative solutions tailored to local preferences and requirements.
  - This **fosters entrepreneurship**, supports a thriving app development ecosystem, and innovation in technology.

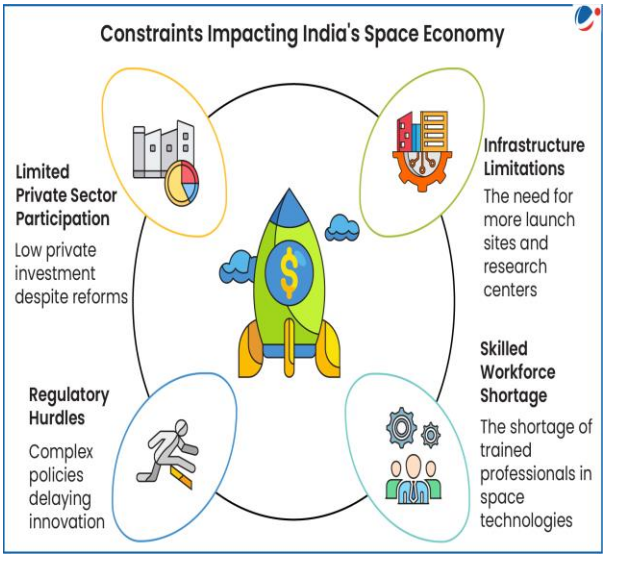
Keywords: Second-generation Satellites, Indigenous, Indian Regional Navigation Satellite System, Polar Satellite Launch Vehicle, International Maritime Organization.

2 BIOTECHNOLOGY

BIOTECHNOLOGY

About Biotechnology

Definition: According to the United Nations Convention on Biological Diversity, **Biotechnology** encompasses any technological application that **utilizes biological systems, living organisms, or their derivatives** to create or modify products and processes for specific purposes.

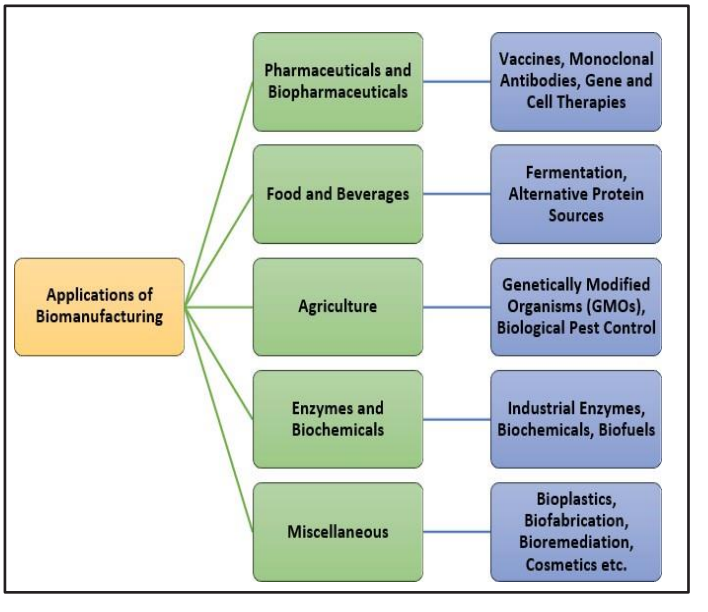


- India ranks as the **12th largest biotechnology economy** and holds the second-highest number of plants approved by the US Food and Drug Administration (USFDA).
- **Branches of Biotechnology:** Red Biotechnology (vaccines and medications); Green Biotechnology (agricultural development); White Biotechnology (industrial manufacturing); Blue Manufacturing (marine and aquatic application).
- **Major Segments of biotechnology in India:** Bio-Pharma, Bio-Services, Bio-Agriculture Services, Bio-Industrial Processes, Bioinformatics.

SCHEME FOR BIO-MANUFACTURING AND BIO-FOUNDRY

Context: Recently, the **Finance Minister of India** proposed a new scheme of bio-manufacturing and bio-foundry in the **Interim Budget 2024-25.**

About Bio-manufacturing and Bio-foundry:



Bio-manufacturing:

- **Biomanufacturing:** It is the use of **biological systems** that have been engineered, or that are used outside their natural context, to **produce a product.**
  - Example **microorganisms and cell cultures** produce molecules and materials on a commercial scale.
- **Key Aspects**: It includes selection or engineering of host organisms, optimization of growth conditions, genetic modification for enhanced productivity, and downstream processing to extract and purify the desired product.

Bio-foundry:

- **BioFoundry:** Biofoundry is a place where **biomanufacturing meets automation**. A bio-foundry is a **specialized facility or laboratory** equipped with **automated tools and technologies** for the high-throughput design, construction, and testing of biological systems.
  - **High-throughput (HT)** refers to the use of automated equipment to quickly **test large numbers of samples** for biological activity.
- **Goals of Bio-Foundries**: Includes **accelerating the engineering** of biological systems, **improving reproducibility,** and **standardizing the design and construction** processes.

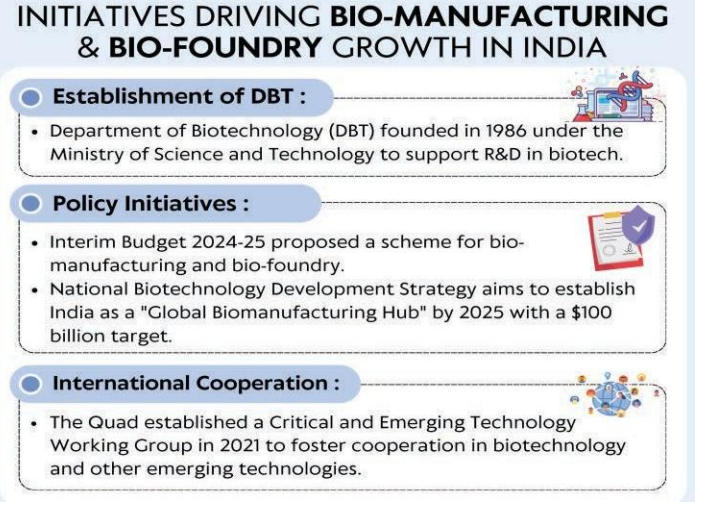
Significance of Bio-Manufacturing and Bio-Foundry in India:

- **Economic Growth:** India's bioeconomy surged from $10 billion in 2014 to $80 billion in 2022, and it's projected to $300 billion by 2030.

- **India as Global Biomanufacturing Hub:** As per the **Australian Strategic Policy Institute,** India is among the top performers in the field of biomanufacturing. India has huge potential in **low-cost biomanufacturing of products** like enzymes, reagents, research materials, and equipment, whose cost is 33% less than the US.
- **Sustainable Practices:** Bio-manufacturing emphasizes on use of renewable resources, for sustainable and environmentally friendly production.
  - **Example:** Development of biodegradable polymers, bio-plastics, bio-pharmaceuticals and bio-agri-inputs to achieve **net zero goals by 2070**.
- **Diversification of Industries**: Bio-foundries provide a platform for rapid prototyping and testing of biological systems, facilitating innovation across sectors like agriculture, energy, etc.

Challenges Associated with Bio-Manufacturing and Bio-Foundry in India:

- **Technological Barriers:** Lack of **cutting-edge technology** with inadequate automation infrastructure, bioprocessing technologies, synthetic biology tools, etc. to scale up the bio-manufacturing sector.
- **Regulatory Framework:** Absence of regulatory guidelines for scientific developments in **synthetic biology**, may raise problems related to **product safety and compliance due to less government oversight.**
- **Ethical Considerations:** The public perception and ethical considerations over **genetically modified organisms** (GMOs) and **synthetic biology** can impact the acceptance of **bio-manufactured products**.
- **Concerns over Potential Chinese Dominance**: China has expressed its intention to capture this market, leading to rising concerns about its **dominance in the industry**.



Way Forward:

- **Establishment of QUAD-led Bio-Manufacturing Hub in India:** The QUAD should create a bio-manufacturing hub in India, leveraging **U.S. funding**, advanced **biotech from other member nations**, and India's skilled, cost-effective workforce.
- **Investment in Technology Infrastructure:** India should conduct comprehensive global technology studies (involving Quad, BRICS, ASEAN, Asia Pacific) to grasp synthetic biology's applications, and risks. Increasing **biotech incubators will boost start-ups and research** which is crucial for the industry's success.
- **Strengthening physical infrastructure**: Invest in upgrading India's physical infrastructure for biomanufacturing including increasing fermentation and improving manufacturing capabilities.
- **Resolving Ethical Concerns:** Addressing ethical concerns proactively and involving the public in decision-making can **build trust, mitigate resistance, and shape policies**.
- **Establishment of Regulatory Guidelines**: Develop tailored regulations for synthetic biology to **ensure safety, compliance, and responsible practices** to foster industry growth.
- **Ensure Quality Education and Training**: Establish permanent university training facilities with international experts by leveraging India's new policies on foreign universities to promote scholar exchanges.

Conclusion: The **integration of bio-manufacturing and bio-foundry** in India holds immense potential for driving **economic growth, fostering innovation,** and addressing global challenges. With **strategic investments, regulatory reforms, and capacity building**, India can position itself as a leader in bio-manufacturing, contributing to a **sustainable and bio-based future.**

Key Words: Biotechnology economy, Bio-foundry, GMOs, High-throughput (HT), Ethical Concern

PREVIOUS YEAR QUESTIONS		
1.	What are the research and developmental achievements in applied biotechnology/? How will these achievements help to uplift the poorer sections of the society? (15 marks)	2021

GENETIC ENGINEERING

About Genetic Engineering: Genetic engineering is a revolutionary field that involves **manipulating an organism's genetic material to create new traits or modify existing ones** through techniques like **gene editing and recombinant DNA technology.**

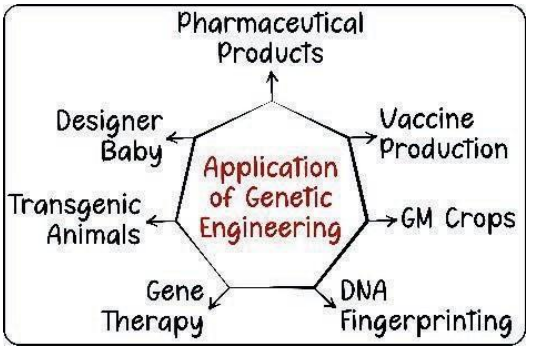
- The first genetically modified organism (GMO) was created in **1973**.

Recombinant DNA Technology:

- It involves the **manipulation of DNA molecules to create new combinations of genetic material**. This technology allows scientists to selectively introduce, delete, or modify specific genes within an organism's DNA.
- It finds its application in **agriculture, medicine, forensics and biotechnology**, by enabling the production of genetically modified organisms and the development of innovative therapies.

Applications of Genetic Engineering:

- **Agriculture:** Genetically modified crops which are resistant to herbicides, pests, or diseases are now widely grown around the world. They can help farmers to increase crop yields and reduce the use of pesticides. **Example:** Bt Cotton, GM-Mustard (Stay by Supreme Court)
- **Medicine:** Genetic engineering is used to produce a variety of medical products, including vaccines, hormones, and blood clotting factors.
  - **Example:** Genetically modified bacteria are used to produce insulin and other drugs for the treatment of diabetes.
- **Environmental Remediation:** Genetically modified organisms are being used to clean up polluted sites.
  - **Example**: Pseudomonas bacteria for bioremediation of Oil Spill sites, genetically modified algaes to preserve corals.
- **Industrial Applications:** It enables the production of valuable proteins, enzymes, and biofuels through engineered microorganisms.
  - **Example:** Use of genetically modified microbes such as alpha-amylase for flavor enhancement in the beer industry.



- **Research and Development:** It provides tools for studying gene function, understanding disease mechanisms, and developing new therapeutic strategies.

Genome Editing

Genome editing is a form of genetic engineering that enables scientists to make precise alterations to an organism's DNA by utilizing enzymes known as nucleases, capable of cutting DNA at specific locations.

Various Techniques of Gene Editing: Gene editing techniques involve Site-Directed Nuclease (SDN) Technology which involves precise modification of specific DNA sequences.

- **CRISPR-Cas9**: It is a new and powerful genome editing tool which uses a guide RNA to target a specific DNA sequence.
- **Zinc Finger Nucleases (ZFNs):** ZFNs are proteins that can bind to specific DNA sequences. When ZFNs are attached to a DNA-cutting enzyme, they can be used to cut the DNA at a specific location.
- **Transcription activator-like effector nucleases (TALENs):** TALENs are proteins that can also bind to specific DNA sequences. When TALENs are attached to a DNA-cutting enzyme, they can be used to cut the DNA at a specific location.

Challenges:

- **Ethical Concerns:** Genetic engineering raises ethical questions regarding the manipulation of living organisms to create "designer babies" and making heritable changes that could have unforeseen consequences.
- **Safety Risks:** There is a risk of unintended side effects, such as the creation of genetically modified organisms with unpredictable traits or potential harm to ecosystems.
- **Biodiversity Loss:** GM organisms could potentially outcompete natural species, leading to reduced biodiversity. There are also concerns of gene flow from GM Crops to other wild species.
- **Regulation and Oversight:** Establishing effective regulations and oversight to ensure responsible use of genetic engineering technologies and prevent misuse or unintended consequences.
- **Accessibility and Equity**: Genetic engineering technologies need to be accessible and affordable to ensure equitable distribution of benefits.

- **Public Perception:** Genetic engineering often faces public skepticism and concerns about long-term effects on human health and the environment.
- **Intellectual Property:** The patenting and ownership of genetically engineered organisms raise complex legal and economic issues, limiting access for smaller organizations and researchers.

Recent Developments and Applications of Genetic Engineering:

- **Gene Drives Technology:** These are designed to spread a particular set of genes throughout a population rapidly. This technology could potentially control or eradicate vector-borne diseases like malaria by modifying the mosquito populations that transmit the disease.
- **Synthetic Biology:** In recent developments, scientists have created synthetic life forms by writing DNA code. This field aims to redesign existing biological organisms and even craft entirely new forms of life.
- **CRISPR-Cas9 for gene editing** which has made it more accurate, cheaper, and quicker than before.

Application of Gene Drive Technology

- Use of gene drive technology for controlling the population of mosquitoes, by interfering with their reproduction was being discussed.
- CSIRP technology could be used to genetically modify the midgut of mosquito to **secrete antimicrobial substances that are detrimental to Plasmodium parasite's development** and reduces lifespan of female mosquitoes.

Way Forward:

- **Strengthening Regulatory Frameworks** to guide the use and deployment of genetic engineering technologies.
- **Enhancing Ethical Oversight:** Dedicated ethical review boards at national and international levels should be set up to oversee genetic engineering experiments, particularly those involving humans.
- **Application for Altruistic Science:** Research must be designed to increase human health and wellbeing. Early stage and uncertain application should be avoided to minimize the risk.
- **Cross-sectoral Applications:** Encourage the integration of genetic engineering across various sectors such as agriculture, medicine, environmental remediation, and industrial applications.
- **Increasing Awareness**: Launch comprehensive educational campaigns to inform the public about the benefits and risks associated with genetic engineering.

Indian initiatives:

- The first Indian research laboratory dedicated to genetic engineering was **established in 1982.**
- **The National Biotechnology Policy,** which was released in **2008.** The policy aims to promote the development and use of biotechnology in India for the benefit of society.
- **The National Biosafety Framework,** which was released in **2009.** The framework sets out the regulatory framework for the use of genetically modified organisms in India.
- **The National Centre for Genetic Engineering and Biotechnology,** which is a government-funded research institute that conducts research on genetic engineering.
- The **National Centre for Biological Sciences,** which is a government-funded research institute that conducts research on genome sequencing.

Conclusion: Genetic engineering holds immense promise for the future, offering unprecedented opportunities to improve human health, enhance agricultural productivity, and address pressing environmental challenges. With careful regulation and ethical considerations, this powerful tool can pave the way for remarkable advancements, shaping a world where scientific innovation and responsible stewardship coexist harmoniously.

Keywords: Recombinant DNA Technology, Genetically modified organism (GMO), CRISPR-Cas9, Bt Cotton, Ethical Concern, Biodiversity, Gene Drives Technology

CRISPR-CAS9

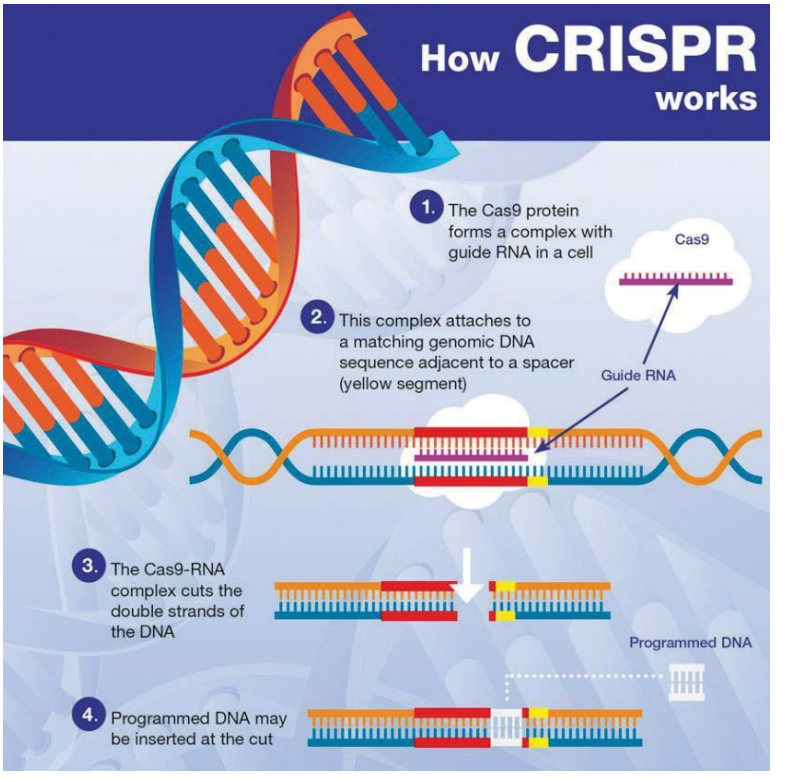
Context: Casgevy and Lyfgenia, the first **CRISPR-based gene therapies** have received approval from **the Food and Drug Administration (FDA)** for **sickle cell anemia and beta-thalassemia treatment.**

About CRISPR-Cas9

- CRISPR-Cas9 **(Clustered Regularly Interspaced Short Palindromic Repeats-CRISPR-associated protein 9**)is a gene-editing tool that has revolutionized the way scientists can make precise changes to DNA. This relatively new technology has already been used to make a variety of modifications to the DNA of plants, animals, and even humans.

Application of CRISPR:

- **Agricultural Advancements:** Create crops that are resistant to pests, diseases, and herbicides. This could lead to increased crop yields and reduced food prices.
- **Drug Development:** Develop new treatments for diseases such as cancer, HIV/AIDS, and malaria.
- **Genetic Disease Research**: CRISPR-Cas9 facilitates the study of gene functions and the modeling of genetic diseases in organisms, contributing to advances in biomedical research.
- **Environmental Conservation:** Create organisms that can degrade pollutants. This could help to clean up polluted sites.
- **Biotechnological Innovations**: Sparks innovation in various biotechnological applications, including synthetic biology, bioengineering.



Challenges:

- **Off-Target Effects:** CRISPR-Cas9 can sometimes edit unintended locations in the genome, leading to potential genetic alterations with unknown consequences.
- **Delivery:** Efficiently delivering CRISPR-Cas9 components into target cells or tissues remains challenging.
- **Ethical Concerns:** The ability to modify human embryos raises ethical dilemmas, such as the potential for designer babies or unintended societal consequences.
- **Regulatory Frameworks:** Developing appropriate regulations and guidelines to ensure responsible and safe use of CRISPR-Cas9 technology is a complex task.

Way Forward:-

- **Ethical and Regulatory Frameworks:** Establishing comprehensive ethical guidelines and regulatory frameworks to address concerns regarding the misuse or unintended consequences of CRISPR-Cas9.
- **Technological Advancements:** Continual innovation to enhance CRISPR-Cas9 and develop novel gene-editing tools for more precise and versatile applications.

Advancement by India in CRISPR-Cas9 technology

- **Sickle Cell Anemia**: Scientists in Delhi are using Gene Editing tools to target inherited sickle cell Anemia.
- **Agri-food**: CRISPR CAS-9 is being used to edit the banana genome to nutrition and disease resistance.
- **Minimize side-effects:** Researchers are replacing **Streptococcus pyogenes Cas9** with **Francisella novicida** to reduce off-target effects.

Conclusion: CRISPR is being used to develop new tools to characterize pathogenic agents, diagnose infectious disease, and develop vaccines and therapeutics to mitigate the effects of an outbreak. If the benefits of CRISPR can be adequately balanced with the risks involved with its use, the biotechnology, public health, and medical communities will make great strides in strengthening global health security.

Keywords: Gene therapy, Sickle cell anemia, DNA, HIV/AIDS

GENE THERAPY FOR DISEASE TREATMENT

Context: Recently **gene therapy (Casgevy)** has been approved by the UK drug regulator to cure sickle cell disease and thalassemia.

- India has also conducted the **first human clinical trial of gene therapy for 'haemophilia A'** at Christian Medical College – Vellore.

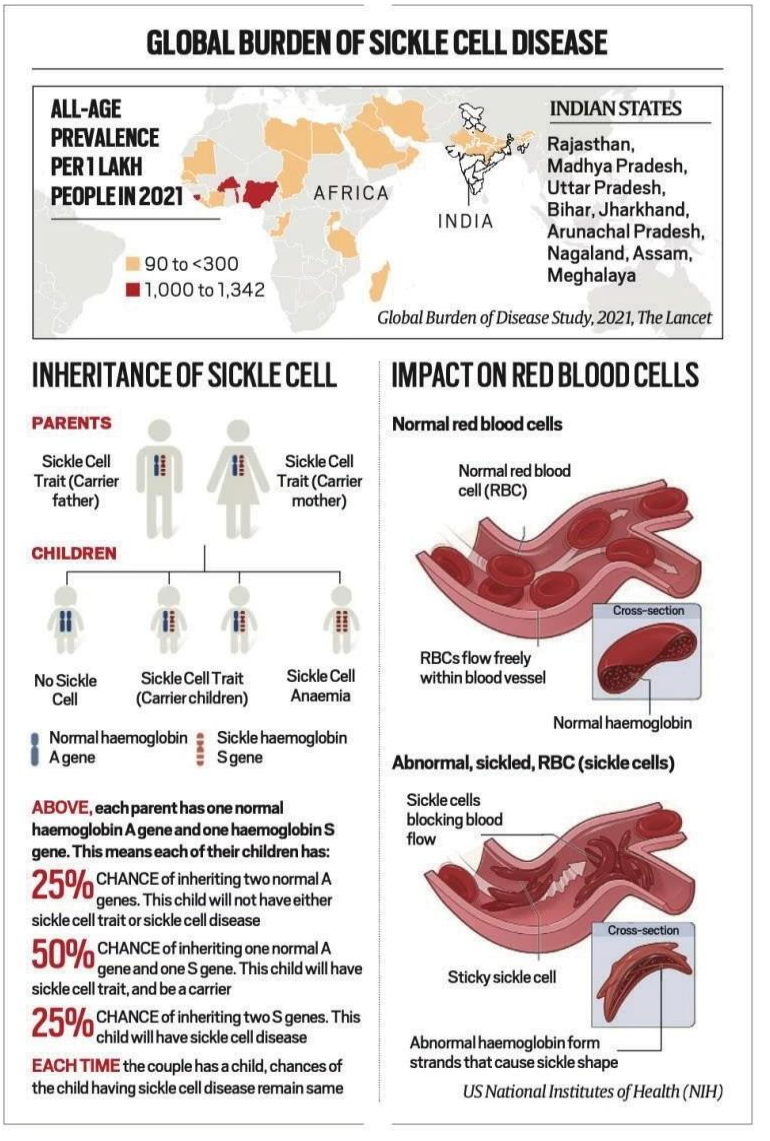
About Casgevy Therapy:

- This is the **first licensed therapy in the world** based on gene editing technology CRISPR-Cas9.
- It is a one-time therapy **that edits the faulty hemoglobin gene** that causes both sickle cell disease and thalassemia, potentially curing the person for life.
- The therapy uses the **patient's own blood stem cells,** which are precisely edited using Crispr-Cas9.
- The therapy targets the **BCL11A gene** to leverage the body's mechanisms for **producing more fetal hemoglobin**, thereby alleviating symptoms of related conditions.

- **Haemoglobin:** A protein in the red blood cells that carries oxygen to organs and tissues.
- **Foetal Haemoglobin, naturally** present in everyone at birth, does not carry the same abnormalities as adult haemoglobin.

Administration of the Therapy:

- **Apheresis:** Extracting blood stem cells from the bone marrow and filtering the blood for different components.
- **Harvesting and Editing:** The cells are then sent to the manufacturing site, which takes about six months to be edited and tested.
- **Conditioning:** Before a transplant with the edited cells, the doctor gives a conditioning medicine for a few days to clear the bone marrow of other cells that will be replaced by the modified cells.
- **Transplantation:** The patient is administered with edited cells that reside in the bone marrow. They start making red blood cells with normal hemoglobin.



Challenges of the treatment:

- **High Cost of Treatment:** A high proportion of people with these conditions live in poorer countries and are unlikely to be able to afford the therapy ($2 million per patient).
- **Side effects:** Similar to those associated with autologous stem cell transplants, including nausea, fatigue, fever and increased risk of infection.
- **Absence of Local Manufacturing Facilities**: The harvested blood stem cells must be sent across countries for editing.
- **Earlier Treatment:** Permanent treatment has been a bone marrow transplant. However donor rejection has remained the major challenge.

Gene Therapy For Haemophilia:

- It is based on the transfer of a **non-pathogenic and non-replicating recombinant adeno-associated virus (AAV)**, the viral DNA of which has been replaced by a bioengineered gene cassette.
- **Roctavian** is the first gene therapy to treat haemophilia A. The active substance in Roctavian, **valoctocogene roxaparvovec, is based on a virus (adeno-associated virus or AAV)** which has been modified to not cause disease in humans.

About Sickle Cell Disease:

- **Genetic Disorder:** The genetic error in sickle cell disease leads to red blood cells assuming a crescent shape.
- Unlike the **disc-shaped normal cells,** the sickle-like cells cannot move around easily in the vessels, resulting in **blocked blood flow.**
- **Effects:** severe pain, life-threatening infections, anemia, or a stroke.

- **Prevalence in India:** An estimated 30,000-40,000 children in India are born with the disorder every year.

About Thalassaemia:

- Thalassemia is **an inherited (i.e., passed from parents to children through genes) blood disorder** caused when the body doesn't make **enough hemoglobin.**
- **Symptoms:** Thalassaemia leads to **low levels of hemoglobin** and shows symptoms like fatigue, nausea, shortness of breath, and irregular heartbeats.
- **Treatment:** People with the condition need blood transfusions throughout their life. The transfusions also lead to excess iron accumulation in the body, which needs chelation.
- **Prevalence:** India also has the largest number of children with thalassaemia major in the world about **1-1.5 lakh.**

Hemophilia A:

- Hemophilia A, is a **rare and genetic bleeding disorder** caused by insufficient levels of a blood protein called factor VIII, which is a clotting protein.
- Hemophilia A is caused by disruptions or **changes (variants or mutations) to the F8 gene** located on the X chromosome.
- **Susceptibles:** Hemophilia A is **mostly expressed in males** but some females who carry the gene variant may have mild or, rarely, severe symptoms of bleeding

Keywords: Casgevy Therapy, Haemoglobin, BCL11A gene, Apheresis, Adeno-associated virus (AAV), Roctavian.

GENOME SEQUENCING

Context: The Genome India Project, a project funded and coordinated by the Department of Biotech nology (DBT), recently announced that it had finished sequencing 10,000 Indian genomes.

About Genome Sequencing

- It is the process of determining the complete DNA sequence of an organism's genome. It involves analyzing and decoding the order of nucleotide bases in the DNA, enabling scientists to study genetic variations, understand diseases, and unravel the complexities of an organism's genetic makeup.

India's Initiatives for Genome Sequencing:

- **About Genome India Project:** It is a research initiative in India that aims to collect genetic **samples of 10,000 Indian citizens** to carry out their **gene mapping** to construct a comprehensive 'Indian reference genome'.
- **IndiGen' Project:** It was undertaken by Council of Scientific and Industrial Research (CSIR) CSIR in April 2019 to conduct a "whole-genome sequence" of a 1,008 Indians.

Application of Genome Sequencing:

- **Medical Research and Diagnosis:** Genome sequencing can be used for genetic testing and diagnosis of hereditary diseases.
- **Drug development:** Genome sequencing can be used to identify new drug targets, optimize drug efficacy, and develop personalized medicine.
- **Agriculture:** Genome sequencing can help breed crops and livestock with desirable traits such as higher yield, disease resistance, and nutritional content.
- **Evolutionary Biology:** Genome sequencing can provide insights into the evolution and diversity of different species.
- **Forensics:** Genome sequencing can be used for forensic analysis, such as identifying victims of crimes and natural disasters.

Additional Information

- **A genome is defined as an organism's complete set of Deoxyribose Nucleic Acid (DNA), including all of its genes.**
- It is made up of DNA, which is a long molecule that is made up of four different bases: Adenine (A), Guanine (G), Cytosine (C), and Thymine (T).

- **Bioengineering:** Genome sequencing can aid in the design and development of synthetic biological systems and biomolecules for various applications.
- **Environmental science:** Genome sequencing can be used to identify genes that are responsible for the degradation of pollutants.

Issues Associated with Genome Sequencing:

- **Privacy:** Genome sequencing involves the analysis of an individual's DNA, which contains sensitive personal information that can reveal information about their health, ancestry, etc.
- **Regulatory Issues:** Lack of standard regulatory framework limits quality of the process and leads to potential misuse of data.

- **Informed consent**: There are challenges in obtaining informed consent from individuals, particularly in cases where the sequencing is done as part of a larger research study.
- **Genetic Discrimination:** There are concerns that genetic information obtained through genome sequencing could be used to discriminate against individuals in various contexts, such as employment, insurance, and education.
- **Other Issues**: Issues like financial constraints, technological challenges like cyber threats, and unavailability of skilled manpower hinders effective usage of genome sequencing.

Way forward:

Strengthening Privacy Protections: Implement robust data privacy laws specifically for genetic information to ensure secure storage and sharing.

Establishing Ethical Guidelines: Develop clear ethical standards to prevent genetic discrimination and ensure informed consent.

Increasing Accessibility: Subsidize genome sequencing costs and integrate it into public health systems to enhance equitable access.

Enhancing Interpretation Tools: Invest in advanced bioinformatics and healthcare professional training to improve data interpretation accuracy.

Creating Regulatory Frameworks: Formulate comprehensive regulations addressing the ethical, legal, and social implications of genome sequencing

Conclusion: Genome sequencing holds immense promise for the future, driving advancements in personalized medicine, agriculture, environmental science, and basic research. India's commitment to this field positions it to excel as a global leader in genome sequencing.

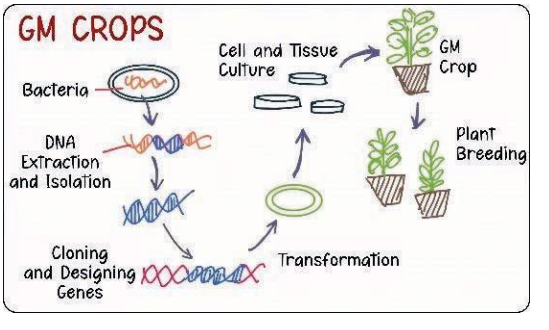
Genome Surveillance

- It is the process of **collecting and analyzing genetic data** from a population to track the spread of diseases, identify new strains of pathogens, and monitor the effectiveness of vaccination programs.
- **Scope:** Genome sequencing of infected individuals helps identify specific pathogen strains, track pathogen evolution, resistance to treatments, and detect emerging strains before causing infections.
- The **National Centre for Disease Informatics and Research (NCDIR)**, which is a government-funded research institute that conducts research on genome surveillance.

Keywords: Genome India Project, IndiGen, DNA sequence, Bioengineering, Genome Surveillance.

GM CROPS

Context: GEAC has recently approved confined field trials for **Pink Bollworm-resistant G cotton (Cry2Ai transgenic cotton seed).**



About GM Crops and Organisms

- **GM crops**, or **Transgenic crops,** are modified by integrating specific genes of interest into their DNA to alter traits. This can be done to improve the crop's yield, nutritional value, or resistance to pests and diseases.
- **Genetically Modified Organism (GMO)** is any living organism whose genetic material has been modified to include certain desirable techniques. E.g Used for large-scale insulin, vaccines production, etc.

Use of Variety Techniques for GM Crops:

- **Recombinant DNA Technology:** This technique uses enzymes to cut and paste genes from different organisms.
- **Gene Gun:** Particles of a heavy metal are coated with the gene to be introduced, and then fired with mechanical force into cells, where they get integrated.
- **Agrobacterium-mediated transformation:** It uses a bacterium called Agrobacterium to transfer genes into cells, randomly within the target DNA, i.e., at non specific locations.

Benefits of GM Crops:

- **Increased Crop Yields:** GM crops are often engineered to be resistant to pests, diseases, or environmental stress, resulting in higher crop yields.

- **Reduced Pesticide Use:** Some GM crops produce their own insecticides, reducing the need for external chemical pesticides and minimizing environmental impact.
- **Enhanced Nutritional Value:** Genetic modifications can improve the nutritional content of crops, such as increasing vitamin or mineral levels, potentially addressing nutritional deficiencies in certain regions.
- **Improved Crop Quality:** GM crops can be engineered to have improved traits like longer shelf life, better taste, or enhanced appearance, benefiting both farmers and consumers.
- **Adaptability to Climate Change:** GM crops can be engineered to withstand weather fluctuations, enhancing resilience.
- **Global Consumption Record:** People worldwide have consumed biotech crop products for over 20 years without reported health issues.

BT cotton's success transitioned India into a cotton-exporting country. Similarly genetically engineered oilseeds can reduce edible oil imports

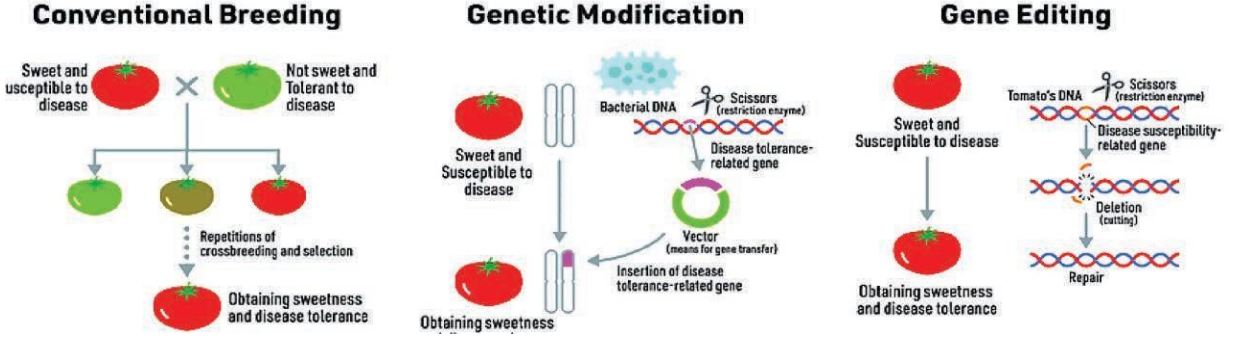
Risks of GM Crops:

- **Allergic Reactions:** GM crops may contain proteins that can cause allergic reactions in some people.
- **Gene Transfer:** There is a risk that genes from GM crops might transfer to wild plants or animals, potentially creating new pests or diseases.
- **Ethical Concerns:** Ethical concerns such as potential for GM crops to be used to create "designer foods" or to increase corporate control of the food supply.
- **Unknown Impacts:** There is uncertainty about the impacts on human health, the environment, soil, groundwater, and the food chain.
- **Social and Economic Issues:** Activists are concerned that multinational agribusiness companies would start controlling farming, displacing small farmers, and creating dependency on GM seed companies.
- **Market Acceptance:** There are concerns regarding acceptance of GM food in the market.

Genome Editing Technology	Genetically Modified Technology
It is done without introducing foreign genetic material.	It introduces foreign genetic material into the host genome.
It focuses on modifying the existing genome of the organism.	It involves the insertion of genes from external sources like soil bacteria.
Produces precise genetic modifications without foreign DNA involvement.	Produces organisms with genes from other species integrated into the host.
Ex. CRISPR-based modified Gene-edited Mustard.	**Ex. Bt cotton with foreign genes (cry1Ac and cry2Ab) for pest resistance.**

Genome Edited Mustard: Indian scientists have developed the first ever low-pungent mustard based on **CRISPR/Cas9 gene editing, while being non-GM and transgene-free**.

- It is a type of mustard that has been genetically engineered to have certain desired traits like resistance to herbicides, pests, or diseases, or improved nutritional value.
- The use of the **barnase-barstar system** in breeding allows for the development of hybrids using a wider range of mustard varieties, including those of East European origin such as 'Heera' and 'Donskaja.'



Additional information about GM crops:

- The first GM crop was commercialized in **1996.**
- There are now over 200 GM crops grown in more than **25 countries.**
- The most common GM crops are **soybeans, corn, and cotton.**

Regulation of GM Crops in India:

- **Genetic Engineering Appraisal Committee (GEAC)**: It is a **statutory committee** functioning under the **Ministry of Environment, Forest** and **Climate Change** (MoEF&CC).
- GEAC was constituted under the **"Rules for the Manufacture, Use/Import/Export and Storage of Hazardous Microorganisms/Genetically Engineered Organisms or Cells (Rules, 1989)"** framed under **Environment (Protection) Act, 1986.**
  - **Bt Cotton is the only transgenic crop** approved by the Indian government for commercial cultivation. It has **Cry1Ac gene from Bacillus thuringiensis** to produce a protein toxic to Pink Bollworm.
  - There is another variant called **Herbicide Tolerant Bt (HTBt) cotton**, which incorporates resistance to the herbicide glyphosate. This variant has not received regulatory approval.
- **Acts and rules that regulate GM crops in India include:**
  - Environment Protection Act, 1986 (EPA)
  - Biological Diversity Act, 2002
  - Plant Quarantine Order, 2003
  - GM policy under Foreign Trade Policy
  - Food Safety and Standards Act, 2006
  - Drugs and Cosmetics Rule (8th Amendment), 1988

Conclusion: Genetically modified (GM) crops offer potential benefits for future agriculture. They can enhance crop yield, increase resistance to pests and diseases, and improve nutritional content. However, careful regulation, environmental impact assessment, and public acceptance are essential to ensure their safe and responsible use for sustainable agriculture and food security.

Keywords: Pink Bollworm, GMO, Recombinant DNA Technology, Gene Gun, Genome Editing Technology, Genetically Modified Technology, Genetic Engineering Appraisal Committee.

PREVIOUS YEAR QUESTIONS		
1.	How can biotechnology help to improve the living standards of farmers? (15 marks)	2019
2.	How is science interwoven deeply with our lives? What are the striking changes in agriculture triggered by science-based technologies? (10 marks)	2020
3.	How can biotechnology help to improve the living standards of farmers? (15 marks)	2019

CLONING

Context: One of the creators of the world's first cloned mammal, Dolly the sheep, has recently passed away at the age of 79.

About Cloning:

Cloning is a scientific process that involves the creation of **genetically identical copies** of living organisms or cells. This technique has sparked both fascination and controversy, with its potential applications ranging from medical advancements to the conservation of endangered species.

Type of Cloning:

- **Somatic cell nuclear transfer (SCNT):** This is the most common method of cloning. In SCNT, the nucleus of a somatic cell is transferred into an egg cell that has had its nucleus removed. The egg cell is then stimulated to divide, and the resulting embryo is implanted into a surrogate mother.
- **Embryonic stem cell cloning:** This method involves creating embryos from stem cells. Embryonic stem cells are taken from embryos that have been created in a laboratory. The embryos are then divided into smaller groups of cells, and each group is implanted into a surrogate mother.
- **Gene cloning:** This method involves cloning genes. Genes are the instructions for making proteins. Gene cloning can be used to create new proteins or to modify existing proteins.

Cloning has a variety of potential applications:

- **Agriculture:** Cloning can be used to create crops that are resistant to pests, diseases, and herbicides. This can lead to increased crop yields and reduced food prices.
- **Medicine:** Cloning can be used to create organs and tissues for transplantation. This could help to reduce the shortage of organs and tissues for transplantation.
- **Reproductive Cloning:** Cloning animals for conservation purposes, preserving endangered species, and producing genetically identical individuals.
- **Biomedical Research:** Generating animal models with specific genetic traits to study diseases and develop new treatments.
- **Organ Transplantation:** Creating cloned organs and tissues for transplantation, potentially solving the shortage of donor organs.
- **Livestock Improvement:** Producing genetically superior livestock for increased productivity, disease resistance, and improved food production.
- **Species Revival:** Reviving extinct species by cloning using preserved DNA, although this application is still hypothetical and ethically complex.

Ethical Concerns with Cloning:

- **The potential for abuse:** Cloning could be used to create clones of people without their consent. This could be used for unethical purposes, such as creating clones for military or commercial use.
- **The potential for harm to clones:** Clones may be at increased risk of health problems. This is because clones are genetically identical, and any genetic defects in the original organism could be passed on to the clones.
- **The potential for devaluing human life:** Cloning could lead to a devaluation of human life. If clones are seen as less than human, it could lead to discrimination and abuse.
- **Loss of Individuality:** Cloning raises concerns about the loss of individuality and uniqueness, as clones may be perceived as mere replicas rather than distinct individuals.
- **Health Risks:** Cloning can result in various health issues, including genetic abnormalities and compromised immune systems, which can negatively impact the well-being of clones.
- **Emotional and Psychological Impact:** Cloning can lead to complex emotional and psychological consequences for both the clones and the individuals involved in the cloning process, such as feelings of identity confusion and social stigma.
- **Exploitation and Commercialization:** There are concerns about the potential exploitation of clones for commercial purposes, including unethical practices like human cloning for reproductive purposes or exploitation in industries such as entertainment or organ transplantation.

In China: (Arctic Wolf)

- Chinese scientists have successfully cloned an Arctic wolf despite it growing up far away from other wolves.
- The procedure is considered a significant achievement in preserving endangered wildlife and rare species.

Conclusion: Despite ethical concerns, cloning holds potential benefits in improving the quality of life for individuals afflicted by diseases or disabilities, as well as enhancing existing products or creating new ones. However, the decision to utilize cloning is a multifaceted matter. It necessitates weighing various factors, including the potential advantages and risks, alongside ethical considerations.

Key Words: Genetically identical copies, Somatic cell nuclear transfer, Embryonic stem cell cloning, Gene cloning, Organ Transplantation, Ethical Concern.

STEM CELL THERAPY

About Stem Cells

- Stem cells are specialized cells with the **ability to evolve into different cell types** in the body, acting as a **continuous repair system** that replenishes other cells throughout an organism's lifespan.
- There are two main types of stem cells:
  - **Embryonic Stem Cells**: These cells are derived from embryos. They are **pluripotent**, meaning they can turn into more than one type of cell.

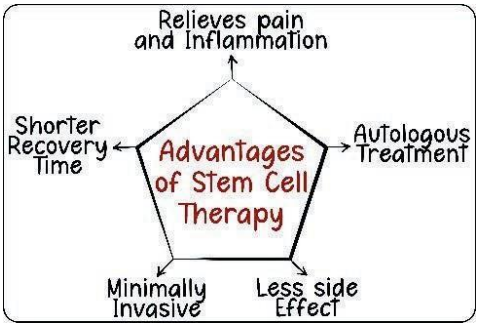
- **Adult Stem Cells:** Found in adult tissues, these cells are limited in their ability to differentiate but are used to replace cells that are lost through **normal wear** and **tear, injury,** or **disease**.

About Stem Cell Therapy:

- It uses stem cells to **repair damaged tissues and organs** and treat various diseases, including blood disorders and certain cancers.
- Defining characteristics of stem cells are:
  - Perpetual **self-renewal**
  - **Ability to differentiate into a specialized adult cell** type
- Stem Cell Transplants are used to treat a variety of diseases such as **Leukemia, Lymphoma, Myeloma, Aplastic anemia, Sickle cell disease etc**. that do not respond to other treatments like chemotherapy and radiation therapy.

Types of Stem Cell Transplants:

- **Autologous stem cell transplant**: The patient's stem cells, taken from bone marrow or blood, are saved before a treatment that destroys blood cells. Post-treatment, these cells are re-infused into the patient to aid recovery.
- **Allogeneic stem cell transplant**: In this type of transplant, stem cells are donated from a matched donor's (sibling, parent, or unrelated person) bone marrow or blood, and given to the patient.



Advantages of Stem Cell Therapy over Other Treatments:

- **Specificity and Precision**: Unlike broad-spectrum treatments like chemotherapy, which can affect both healthy and cancerous cells, stem cell treatments target specific damaged cells.
  - **For example,** Leukaemia treatment with stem cell therapy offers a more tailored approach by replenishing the bone marrow with healthy cells.
- **Reduced Side Effects:** Stem cell therapy, being more targeted, generally results in fewer and less severe side effects.
- **Potential for Treating Previously Incurable Diseases**: Some conditions, like Thalassemia, Alzheimer's or Parkinson's previously necessitated lifelong treatments or had limited therapeutic options. Stem cell therapy opens new horizons for potential cures.
  - **Example:** Thalassemia patients often require regular blood transfusions. Stem cell therapy addresses the root cause and tries to restore the body's ability to produce healthy blood cells.
- **Tissue Regeneration**: Stem cells have the potential to regenerate tissues that are difficult or impossible to heal using traditional methods.
  - **Example:** Stem cells can potentially heal and restore function to severely burned skin or damaged corneas where traditional treatments fail.
- **Drug Development:** Stem cells allow scientists to test new drugs for safety and effectiveness.
  - **Example:** Heart cells from stem cells can streamline drug testing for heart disease, reducing animal testing and enhancing development efficiency.

Side Effects of Stem Cell Transplants:

- **Infection:** The patient is at increased risk of infection after a stem cell transplant. This is because the treatment that destroys the patient's blood-forming cells also destroys their immune system.
- **Graft-versus-host disease (GVHD):** Stem cell transplants carry the risk of GVHD, where the transplanted cells recognize the recipient's body as foreign and attack healthy tissues.
  - Graft-versus-host disease is a condition that occurs when the donor's stem cells attack the patient's body.
  - This can cause a variety of symptoms, including skin rash, diarrhea, and liver damage, Nausea and vomiting, Hair loss, Fatigue, Kidney problems, Heart problems etc.
- **Organ damage:** Conditioning treatments before the transplant, such as chemotherapy or radiation, can cause temporary or permanent damage to organs like the liver, lungs, or heart.
- **Infertility:** Stem cell transplant procedures may lead to infertility or reduced fertility in some patients.
- **Gastrointestinal issues:** Patients may experience diarrhea, nausea, vomiting, or other digestive problems as a result of the transplant and accompanying treatments.

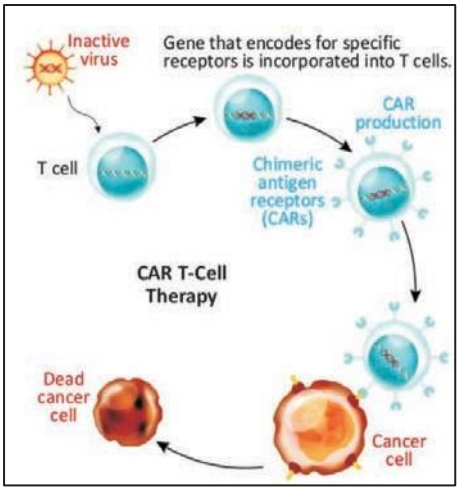
Conclusion: The decision of whether or not to have a stem cell transplant is a complex one. There are a number of factors to consider, including the patient's age, overall health, and the type of disease being treated.

Keywords: Stem Cells, Autologous and Allogeneic stem cell transplant, Tissue Regeneration, etc.

PREVIOUS YEAR QUESTIONS		
1.	Stem cell therapy is gaining popularity in India to treat a wide variety of medical conditions including leukemia, Thalassemia, damaged cornea and several burns. Describe briefly what stem cell therapy is and what advantages it has over other treatments? (10 marks)	2017

CAR – T CELL THERAPY

Context: Recently, ImmunoACT received market authorization for their chimeric antigen receptor (CAR) T-cell therapy called NexCAR19 from the Drugs Controller General of India.

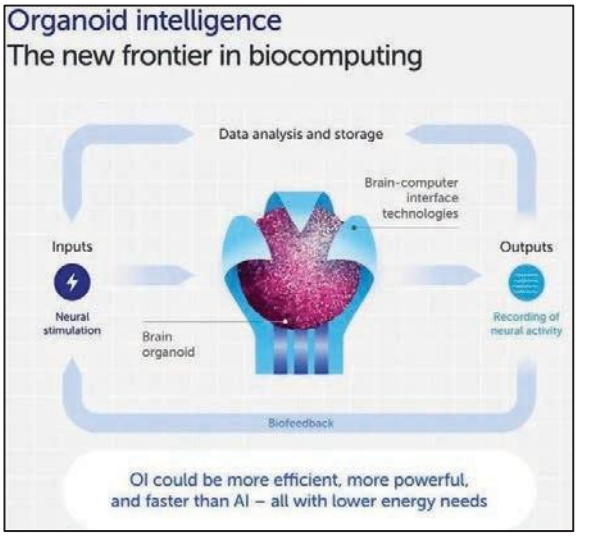


About CAR – T Cell Therapy:

- CAR-T cell therapy is an **immunotherapy technique** that harnesses genetically modified T cells, a type of white blood cell responsible for combating infections, to combat cancer.
- **Living Drugs:** The therapy is also known as 'Living Drugs' as they are **more specific than targeted agents** and directly activate the patient's immune system against cancer.
- **T Cell Collection:** This therapy involves **extracting T cells** from the patient's blood and modifying them to **possess a chimeric antigen receptor (CAR)**.
- **T Cell Engineering:** This engineered CAR protein **binds to a specific protein on the surface of cancer cells**, triggering a signal within the T cell to eliminate the cancerous cells.
- **Administered CAR – T Cell Therapy:** Once the T cells have been engineered, they are infused back into the patient's bloodstream. The T cells then circulate throughout the body and attack cancer cells.

Significance of CAR – T Cell Therapy

- **Improved Immunogenic Surveillance:** Improves immunogenic memory, which provides continuous surveillance to treat local and distant metastatic lesions.
- **Targeted Cell Recognition and Elimination:** The therapy recognizes and eliminates damaged cells and cells infected with harmful pathogens, such as viruses and cancerous cells.
- **Alternative to Chemotherapy:** Reduces the need for aggressive chemotherapy for treating a variety of cancers. This therapy is intended for the treatment of relapsed-refractory B-cell lymphoma and leukemia.
- **Affordability**: Previously, CAR-T cell therapy cost around Rs 3.3 crore in the US. With recent advances in biotechnology, the therapy is expected to be accessible at around Rs 30-35 lakh per patient.



Risks of CAR – T cell therapy:

- **Cytokine Release Syndrome:** Cytokine release syndrome is a serious side effect that can occur when CAR – T cells are infused into the bloodstream.
  - Cytokine release syndrome is caused by the release of cytokines, which are **proteins that help the body fight infection.**
  - Cytokine release syndrome can cause fever, chills, headache, muscle pain, and shortness of breath. In severe cases, cytokine release syndrome can be fatal.
- **Neurotoxicity:** Neurotoxicity is a side effect that can affect the brain and nervous system. Neurotoxicity can cause symptoms such as confusion, seizures, and coma.
- **Graft-versus-host Disease:** Graft-versus-host disease is a side effect that can occur when CAR – T cells attack healthy cells in the body. Graft-versus-host disease can cause symptoms such as fever, rash, diarrhea, and liver damage.

Way Forward/Opportunities for CAR – T Cell Therapy:

- **Cancer Treatment**: The therapy has shown success in treating blood cancers, such as leukemia & lymphoma, even in patients who have not responded to other treatments.
- **Clinical Research:** Ongoing research and clinical trials are expanding the application of CAR-T cell therapy to solid tumors, such as lung, breast, and pancreatic cancers, with encouraging early results.
- **Applicability:** The development of next-generation CAR-T therapies aims to enhance their effectiveness, minimize side effects, and broaden their applicability.
- **Accessibility:** The future of the therapy includes advancements in manufacturing techniques, making it more accessible and affordable for patients globally.

New Developments: Combination therapies, such as combining CAR-T cell therapy with other immunotherapies or targeted therapies, are being explored to further improve treatment outcomes.

Conclusion: CAR-T cell therapy has revolutionized cancer treatment mechanisms by converging cell engineering, gene therapy and synthetic biology. Furthermore, the development of indigenous CAR-T cell therapy in India marks a significant advancement in the country's healthcare landscape. Efforts must be made by researchers and policy planners to reduce the therapy costs to decrease cancer mortality rates in the future.

Keywords: immunotherapy technique, genetically modified, chimeric antigen receptor, Cytokine, Cancer Treatment.

BIO-COMPUTER

Context: Scientists have combined real human brain tissue with electronics to make a new kind of biocomputer.

About Biocomputers:

- A biocomputer is a computer that **utilizes biological components,** such as DNA, proteins, or cells, to carry out computations. Although still in the early stages of development, biocomputers possess the potential to revolutionize the field of computing.
- Biocomputers involve **coupling of lab-grown brain cultures with real-world devices** to harness brain power and investigate human cognition, learning, and neurological disorders.
  - They would be built by merging brain organoids with machine learning.
- **Brain organoids are three-dimensional aggregates of brain cells** formed by extracting human pluripotent stem cells.

Benefits of Biocomputers:

- **Increased Speed:** Biocomputers can perform computations much faster than traditional computers as biological components can perform **computations at the molecular level.**
- **Energy efficient technology:** Biocomputers are much more energy efficient than traditional computers. This is because **biological components do not require electricity to operate.**
- **Increased Scalability:** Biocomputers can be scaled up to much larger sizes than traditional computers as biological components can be replicated easily.
- **Bolstered Security:** Biocomputers are much more secure than traditional computers as biological components are difficult to hack.
- **Selective Cell Treatment Potential:** This technology's primary advantage is its ability to enable doctors to selectively target and treat only damaged or diseased cells.

Challenges of Biocomputers:

- **Complexity:** Biocomputers are much more complex than traditional computers. This makes them difficult to design and build.
- **Unreliability:** Biocomputers are much less reliable than traditional computers. This is because biological components are susceptible to damage.
- **Regulation:** Biocomputers are subject to a number of regulations that traditional computers are not, thus making it difficult to develop and market biocomputers.
- **Data Management Challenges:** The integration of hybrid systems in biocomputers will produce vast amounts of data, necessitating robust Big Data infrastructure and advanced analytical methods for effective storage and analysis.
- **Ethical Considerations:** A dedicated ethics team will be essential to address and navigate the ethical concerns that emerge during the development and application of biocomputers.

Additional Information:

About Neuromorphic Computing:

- It is a process in which computers are designed and engineered to mirror the structure and function of the human brain.

About Organ on Chips:

- Organ on Chips are **microfluidic devices** lined with living human cells for drug development, disease modeling, and personalized medicine.
- They are used to **mimic the environment in human organs**, including blood flow and breathing movements, serving as synthetic environments in which to test new drugs.
- **Applications:**
  - Drug discovery and toxicology,
  - Disease Diagnosis
  - Advancement of personalized medicine

About Brain Computer Interface:

- Elon Musk's neurotechnology company has received FDA approval for human trials of their brain--computer interface.
- **Brain Computer Interface** is a next--generation brain implant with **100-times more brain connections** than currently approved devices.
- This device is implanted in a skull's disk-shaped cutout using a precision surgical robot. The device itself is a coin--sized unit called a **Link**.

Future of Biocomputers: Biocomputers are a promising new technology with the potential to revolutionize computing. Biocomputers are still in the early stages of development, but they have the potential to be used in a wide variety of applications.

- **Medical Diagnosis:** Biocomputers can be used to diagnose diseases by analyzing biological data.
- **Drug Discovery:** Biocomputers can be used to design new drugs by simulating the effects of different compounds on biological systems.
- **Environmental Monitoring:** Biocomputers can be used to monitor environmental conditions by analyzing biological data.
- **Defense:** Biocomputers can be used to develop new defense systems by simulating the effects of biological threats.

Conclusion: Bio-computers have emerged as a promising technology, utilizing biological components for computational tasks. With their potential for high-speed, low-energy processing and unique capabilities, bio-computers hold promise for revolutionizing fields such as medicine, environmental monitoring, and data analysis in the future.

Keywords: Biocomputers, Brain Organoids, Biological Components, Medical Diagnosis, Organ on Chips

VACCINES

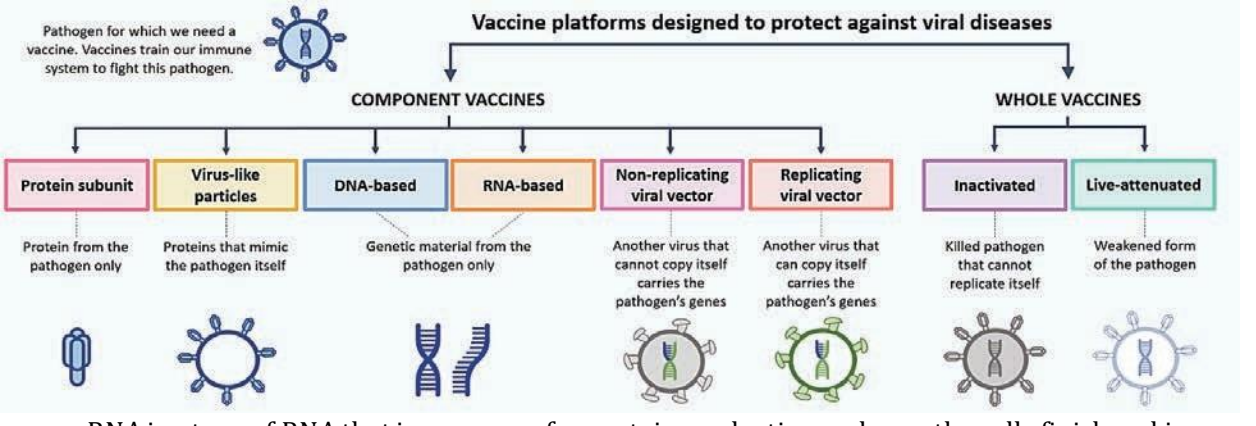
Context: AstraZeneca, maker of Covishield Vaccine, has admitted in court documents that its vaccine, Covishield can cause a rare side effect, a condition called **Thrombosis with Thrombocytopenia Syndrome (TTS)**, which translates to blood clots and low levels of platelets.

About Vaccines

- Vaccines are biological preparations that **stimulate the immune system to recognize and defend against specific pathogens**, such as viruses or bacteria.
- Covishield is a **viral vector platform based vaccine**, which utilizes a modified chimpanzee adenovirus, to deliver the COVID-19 spike protein into human cells.
  - Covishield elicited a **greater number of T cells**, indicating a stronger immune response.
- **Pfizer and Moderna vaccines** are **mRNA based vaccines**, which work by introducing a piece of mRNA that corresponds to a viral protein and eliciting immune response against the protein.
  - India's first **indigenous mRNA vaccine for Omicron, GEMCOVAC-OM,** received emergency use approval from the Drug Controller General of India.

About mRNA vaccine

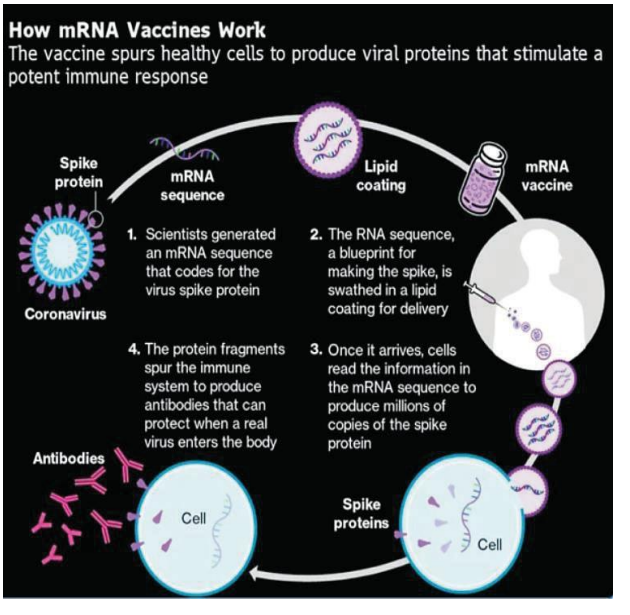
- It is a new type of vaccine that uses a **molecule called messenger RNA (mRNA)** rather than part of an actual bacteria or virus.



- Messenger RNA is a type of RNA that is necessary for protein production and once the cells finish making a protein, they quickly break down the mRNA.
  - mRNA from vaccines does not enter the nucleus and **does not alter DNA**.

Working of mRNA Vaccine:

- All vaccines aim to induce an immune response by **introducing the pathogen in advance**. The critical difference is that most vaccine platforms inject either the virus (killed or inactivated) or a part of it.
- **Introduction of mRNA:** mRNA vaccines work by introducing a piece of mRNA that corresponds to a viral protein, usually a small piece of a protein found on the virus's outer membrane.
  - Individuals who get an mRNA vaccine are **not exposed to the virus,** nor can they become infected with the virus by the vaccine.
- **Immune response to Viral Protein:** By using this mRNA, cells can produce the viral protein. As part of a normal immune response, the immune system recognizes that the protein is foreign and produces antibodies.
- **Antibodies Protecting Against Infections**: If a person is exposed to a virus after receiving mRNA vaccination for it, antibodies can quickly recognize it, attach to it, and mark it for destruction before it can cause serious illness.



Advantages of mRNA Vaccines:

- **Rapid Development:** The production of mRNA vaccines can be accelerated because it does not require the cultivation of live virus or the use of complex manufacturing processes.
- **Flexibility:** The same basic technology can be adapted relatively quickly to target different viruses by designing mRNA sequences for specific proteins.
- **Safety**: mRNA vaccines do not contain live viruses, making them non-infectious and eliminating the risk of causing the disease they are designed to prevent.
- **High Effectiveness:** mRNA vaccines generally have better effectiveness than inactivated vaccines. Ex Pfizer-BioNTech and Moderna vaccines have shown high effectiveness against COVID-19 virus.
- **No Genetic Risk**: mRNA vaccines do not integrate into the recipient's DNA, ensuring no risk of genetic alteration. The mRNA from the vaccine is temporary and degrades naturally within the body

Disadvantages of mRNA Vaccines:

- **Manufacturing Complexity and Cost**: mRNA vaccines require a complex and expensive production process, which involves in vitro transcription and purification steps that are difficult to scale.
- **Cold Chain Storage Requirements**: The storage of mRNA vaccines often requires extremely low temperatures, ranging from about -70°C to -20°C, which can be a significant logistical challenge.

- **Risk of Anaphylaxis:** Although rare, there is a slightly higher risk of anaphylaxis with mRNA vaccines compared to traditional vaccines. This has been observed particularly with the Pfizer/BioNTech COVID-19 vaccine.
- **Long-term Efficacy and Safety Data:** As mRNA technology is relatively new, there is less long-term safety and efficacy data available compared to traditional vaccines that have been in use for decades.

Conclusion: The advantages of the mRNA vaccine approach are numerous and, in addition to being used as a vaccine, mRNA can also be used as a protein supplement or replacement therapy to treat other diseases, driving the necessary research to overcome the current obstacles and limitations with the ultimate goal of developing an ideal form of medicine.

Key Words: COVID-19, Thrombosis with Thrombocytopenia Syndrome (TTS), Covishield, vector platform based vaccine, mRNA Vaccine.

PREVIOUS YEAR QUESTIONS		
1.	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? (15 marks)	2022

XENOTRANSPLANTATION

Context: The first recipient of a modified pig kidney transplant passed away in the US, around two months after the surgery was carried out.

About Xenotransplantation:

- Xenotransplantation is the process of transplanting organs from one species to another, **particularly from animals to humans. It is any procedure that involves the transplantation, implantation or infusion** into a human recipient of either:
  - Live cells, tissues, or organs from a non-human animal source.
  - Human body fluids, cells, tissues or organs that have had **ex-vivo contact** with live non-human animal cells, tissues or organs.
    - **Ex-vivo contact:** It refers to a medical procedure in which an organ, cells, or tissue are **taken from a living body for a treatment or procedure,** and then returned to the living body.

Need for Xenotransplantation:

- **Gap Between Organs Demand and Supply:** Xenotransplantation is seen as **an alternative to the clinical transplantation** of human organs whose demand around the world is increasing.
  - Currently, **over 100,000 individuals** are on the national waiting list for organ transplants, with a majority of them in need of kidneys.
- The recent advancements, including genetic modifications in pigs to render their organs more compatible with humans, have **revitalized hopes of addressing the critical shortage** of donated organs.

Organ Donation Policy

- The Union Health Ministry recently issued revised Guidelines for Organ Donation.
- Revised Guidelines for Organ Donation:
  - Registration for transplant in **any state** across India.
  - **People beyond 65** in need of an organ donation will also be eligible.
  - Patients are allotted a unique ID by NOTTO on registering, which is transferable to multiple hospitals in various states.
  - No **charging of registration fees** from patients.

Legislations Related to Organ Donation

- **Transplantation of Human Organs Act, 1994**
  - It provides various **regulations for the removal of human organs** and its storage.
  - It regulates the **transplantation of human organs for therapeutic purposes** and for the prevention of commercial dealings in human organs.

Benefits of Xenotransplantation:

- **Alleviation of Organ Shortage:** Xenotransplantation can offer a solution to the global shortage of human organs for transplantation.

- **Rapid Availability:** Organs from animals can be available on demand, reducing waiting times and potentially lowering the mortality rates among patients on transplant waiting lists.
- **Advanced Research Opportunities:** This technology aids in biomedical research by providing models for studying human diseases and testing new treatments.
- **Genetic Engineering Possibilities**: Advances in genetic engineering allow for modifications in donor animals to make their organs more compatible with the human immune system, reducing rejection rates.
- **Cost Reduction:** Potentially, xenotransplantation could be less costly compared to human organ transplants, which involve complex logistics and higher procurement costs.
- **Eliminate illegal organ trafficking** and the use of organs from executed prisoners.
- **Eliminates Cultural barrier:** Xenotransplantation eliminates the 'cultural' barriers to donation of organs from deceased humans present in some countries like Japan.

Concerns associated with Xenotransplantation:

- **Immunological Rejection:** Strong immune responses to animal organs can lead to rapid rejection of animal organs due to biological differences.
- **Zoonotic Infections:** There is a risk of transmitting new infectious diseases from animals to humans, potentially leading to severe health issues.
    - In January 2022, the first xenotransplantation of a genetically-modified pig heart was done. However, the patient **passed away after two months due to a range of factor**s, including being tainted with **a latent virus in the pig heart,** which may have contributed to the dysfunction of the transplant.

Why are pigs often used for xenotransplantation?

- **Similarity with Humans:** The pig's anatomical and physiological parameters are similar to that of humans, and the breeding of pigs in farms is widespread and cost-effective.
    - Pig heart valves have been used for replacing damaged valves in humans for over 50 years now.
- **Pig Breeding:** Also, many varieties of pig breeds are farmed, which provides an opportunity for the size of the harvested organs to be matched with the specific needs of the human recipient.

- **Genetic Modifications:** Ethical concerns have been raised over the extent of genetic engineering required to make animal tissues compatible with human bodies.
- **Ethical and Social Concerns**: Various ethical, cultural, and religious concerns have been raised surrounding the moral status of animals and cultural acceptability of using animal parts for human transplants.
- **Regulatory and Legal Issues:** There are challenges in creating adequate regulatory frameworks due to the novel nature of xenotransplantation. There is a need for international cooperation to establish guidelines for patient safety and ethical standards.

Way Forward

- **Promote Xenotransplantation Research:** Governments should support extensive research and ensure rigorous clinical trials, to explore the full potential of xenotransplantation.
- **Encourage Organ Donation:** Adopting systems similar to the **Spanish model of "presumed consent"**, where every individual is considered an organ donor post-mortem unless explicitly opted out during their lifetime.
- **Combat Organ Trafficking:** It's vital to ensure that organ allocation is based solely on medical necessity, not financial or other considerations.
- **Ensure Informed Consent from Donors:** Live donors must provide informed, voluntary consent without coercion, and should be thoroughly educated about the risks and benefits of organ donation.

Conclusion: Lack of availability of suitable organs for timely transplantations has been a leading cause of death and suffering is end stage failure of critical organs cases. Xenotransplantation highlights the growing inter-dependency upon humans as well as other species to meet the needs of new organs to replace failing. This interdependence underscores the complex biological and ethical landscapes that humans navigate in medical advancements.

Keywords: Modified pig kidney, Ex-vivo contact, Organs Demand, Organ Donation Policy, Immunological, Zoonotic, Organ Trafficking.

PREVIOUS YEAR QUESTIONS		
1.	Why is there so much activity in the field of biotechnology in our country? How has this activity benefitted the field of biopharma? (15 marks)	2018

3 NANOTECHNOLOGY

NANOTECHNOLOGY

Introduction: Nanotechnology, also known as nanotech, is a field of technology focused on controlling and manipulating matter at incredibly small scales, specifically at the atomic, molecular, and supramolecular levels. It encompasses the ability to work with particles ranging in size from 1 to 100 nanometers.

Application of Nanotechnology

Nanotechnology, an emerging field, significantly influences nearly every sector of the economy. Research on Nanotechnology has extended to various domains, such as:

- **Agriculture:** Introduction of **nano urea** for fertilizer delivery, nanosensors for precision farming and nano-processing techniques in farming.
  - **Nanocapsules** facilitate the efficient entry of herbicides, chemical fertilizers, and genes into specific plant areas
- **Food Industry:**
  - **Nano-enhanced barriers** are effective in preserving freshness of oxygen-sensitive food.
  - **Nano-encapsulation techniques** can enhance the solubility of essential elements such as vitamins, antioxidants, and healthy omega acids.
  - **Nanobarcodes** play a crucial role in tagging individual products and tracing outbreaks for improved product safety and accountability.
- **Health Sector: Nanoparticles**, with their exceptional precision, have become pivotal in drug delivery systems.
  - **Quantum dots** are used in medical imaging for precise diagnostics.
- **Textiles and Fabrics: Silver nanoparticles** embedded fabrics remain fresh and odor-free even after intense workouts.
  - **Nanoscale Silica or fluorocarbon** coated fabrics repel water and stains, keeping them clean and dry.
- **Electronics and Semiconductor Technology:**
  - **Mobile**: Nanotechnology has created smaller, powerful transistors and sensors for smartphones. Nanomaterials enhance energy storage, benefiting portable electronics devices.
    - **Nano-RAM** promises compact, efficient memory storage in electronic devices.
  - **Semiconductor Sector:** Nanotechnology has helped in miniaturizing electronics for smaller, faster, and more portable devices.
- **Environment:** Nanotechnology has facilitated environmental conservation and is helping in transition to sustainable energy. Nanomaterials like **perovskite** significantly boost solar panel efficiency.
- **Space Sector:** Nanotechnology is instrumental in creating lightweight **solar sails for propulsion**, as demonstrated by **NASA's NanoSail-D2 mission.**
  - Nanotechnology addresses temperature regulation by employing **nano-coatings and phase change materials** to manage spacecraft temperatures in the space environment.

Advantage of Nanotechnology:

- **Enhanced Material Properties:** Nanotechnology allows for the creation of materials with improved strength, flexibility, and conductivity, leading to advancements in various industries such as **electronics, aerospace, and healthcare.**
- **Improved Energy Efficiency:** Nanotech enables the development of energy-efficient devices and systems, leading to reduced energy consumption and environmental impact.
- **Targeted Drug Delivery:** Nanoparticles can be designed to deliver medications directly to specific cells or tissues, increasing treatment efficacy and minimizing side effects.
- **Water and Air Purification:** Nanomaterials can effectively remove pollutants from water and air, contributing to cleaner and safer environments.
- **Miniaturization and Improved Performance:** Nanoscale components enable the development of smaller, faster, and more powerful devices such as computer chips and sensors.
- **Information Technology:** Nanoscale technologies are crucial for the development of high-density data storage, faster data transfer, and the advancement of quantum computing.

Challenges Related to Nanotechnology:

- **Health Concerns:** Nanoparticles can potentially enter the human body through inhalation, ingestion, or skin contact, raising concerns about their long-term effects on health.
- **Environmental Impact:** The release of nanomaterials into the environment can result in formation of a new class of non-biodegradable pollutant and interfere with the functioning of the ecosystems.
- **Ethical Considerations:** The ethical implications of nanotechnology include issues related to privacy, surveillance, and the equitable distribution of benefits and risks.
- **Unknown Risks:** Due to the relatively new nature of nanotechnology, there are still uncertainties surrounding its potential risks, necessitating further research and assessment.
- **Manufacturing Hazards:** The production of nanomaterials may involve the use of toxic substances, posing risks to workers and the environment if not properly managed.
- **Societal Impact:** The widespread adoption of nanotechnology can lead to significant social and economic changes which has an impact on employment, privacy, and societal structures.
- **Lack of Information** on the nature and characteristics of nanomaterials, insufficient methods for detecting and measuring nanomaterials etc.
- **Scarcity of Skilled Manpower**: The sector is niche and has a relatively lesser number of skilled manpower with knowledge of this specialized field.
- **High costs for acquisitions of IPR**, nanotechnology infrastructure etc.

Indigenization of Nanotechnology: The indigenization of technology in the nanotechnology sector represents a transformative shift, fostering self-reliance and innovation within indigenous communities.

- **Government Initiatives:** In 2001, the Department of Science and Technology (DST) launched the **Nano Science and Technology Initiative (NSTI)** to foster research and development in nanotechnology.
- **Research and Development Institutions:** These include the Indian Institute of Science (IISc), the National Centre for Nanoscience and Nanotechnology (NCNN), the National Physical Laboratory (NPL), and the Centre for Nano and Soft Matter Sciences (CeNS), among others.
- **Nanomaterials and Nanodevices: Carbon Nanotube Filters** from Banaras Hindu University, **Typhoid detection kit** using nano sensors.
- **Nanomedicine and Drug Delivery Systems: Nanoparticles, nanocarriers, and nanosensors** are being developed to enhance medical treatments and diagnostics.
  - Research group of University of Delhi developed a patented technology for **enhanced drug delivery system using nanoparticles**.
- **Collaborations and International Partnerships:** Collaborative projects with countries like the United States, Germany, Japan, and Australia have contributed to knowledge exchange and technological advancements.
- **Entrepreneurship and Startups: Nanoshel**, an Indian startup is actively commercializing Nanotechnology products for aerospace, automotive, and electronics industries.
- **Skill Development and Education:** The government has supported the establishment of **Centers of Excellence and Nanotechnology Education and Research Centers** to promote skill development and research.
- **Regulatory Framework:** India has been actively working on formulating a regulatory framework for nanotechnology to address potential environmental, health, and safety concerns associated with the field.
- **Nanotechnology in Agriculture:** Nanofertilizers, nanosensors for crop monitoring, and nanocoatings for pest control are being explored to enhance crop productivity and reduce environmental impact.
- **Nanotechnology for Energy Advancements**: India is leveraging Nanotechnology to enhance solar cells and batteries. Example, Tata Chemicals' nanotech based energy storage system can store **up to 10 times more energy** than traditional counterparts.

Conclusion: Nanotechnology in India holds promising prospects for the future. With advancements in research, development, and applications, it has the potential to revolutionize various sectors such as healthcare, electronics, energy, and materials. India's commitment to this field paves the way for innovation, economic growth, and societal benefits.

Keywords: Nanometers, Nano urea, Nanocapsules, Nanobarcodes, Quantum dots, Fluorocarbon, Semiconductor, NanoSail-D2 mission, Nanomedicine.

PREVIOUS YEAR QUESTIONS		
1.	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. (12.5 marks)	2016

NANOTECHNOLOGY IN AGRICULTURE

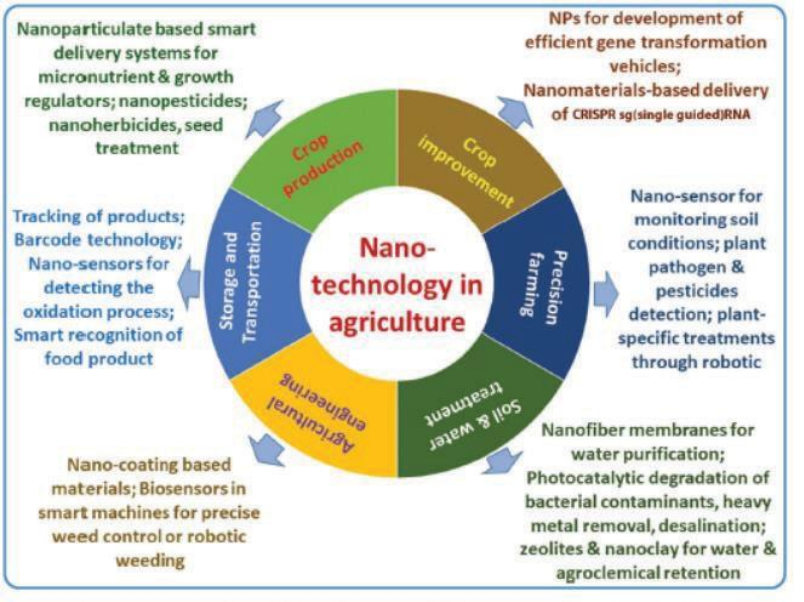
Context: Recently, Fertilizer cooperative Indian Farmers Fertilizer Cooperative Limited (IFFCO), which introduced **nano liquid urea in 2021**, announced that the government has approved the launch of its nano DAP fertilizer (di-ammonium phosphate) in the market.

More on News:

- A 500 ml bottle of nano urea will replace **one bag of 45 kilograms of urea**. It will reduce the transportation costs too thus reducing India's **import bill by around ₹15,000-20,000 crore**.
- The use of Nanotechnology in agriculture enables **efficient disease detection and management, precision farming** through nano-sensors, **enhanced productivity** through nano-fertilizers and pesticides.

Applications of Nanotechnology in Agriculture

- **Nano Fertilizers: Nanocapsules** facilitate the efficient entry of herbicides, chemical fertilizers, and genes into specific plant areas, ensuring a controlled and gradual release of essential substances while **minimizing environmental impact**.
- **Nano Pesticides:** Nanoscale pesticide formulations enhance **solubility, dispersion, target-specific delivery** and efficiency compared to conventional pesticides.
- **Nano-Sensors:** Miniaturized optical, electrochemical and magnetic nano-sensors monitor **soil quality, crop growth environment, plant pathogens, moisture levels** etc. in real-time.
- **Smart Delivery Systems:** Materials like **nanoporous zeolites, cellulose nanofibers, carbon nanotubes** are used for precise delivery of agricultural agents like genes, herbicides, growth hormones etc to enhance the effectiveness.
- **Antimicrobial Nano-coating: Silver nanoparticles** applied as coatings on greenhouse glass, plastic films, and irrigation pipes prevent microbial buildup.
  - This avoids decay and **enhances the durability** of farming infrastructure.



Applications of Nanotechnology in Agriculture Sector

- **Plant Disease Diagnostics: Nano barcodes and nanoprobes** coated with antibodies detect plant pathogens like bacteria and viruses quickly and accurately compared to conventional techniques.
- **Seed germination:** Nano priming of seeds with **zinc, titanium dioxide, and silica nanoparticles** speeds up germination rates and plant growth by penetrating the thick seed coat and enhancing **enzyme metabolism.**
- **Food packaging:** Nanocomposite films with **nano clays and cellulose nanofibers** improve mechanical strength, barrier properties, heat resistance and biodegradability of food packaging compared to conventional **polymer packaging.**
- **Crop protection:** Silica nanoparticles applied on leaves shield the plants from high temperatures and strong UV radiation.
  - **Nano-coatings on fruits** restrict oxygen and moisture penetration to delay ripening and prevent spoilage during storage.

Key Challenges of Nanotechnology in Agriculture

- **Toxicity Issues**: The impacts of nanomaterials on **soil quality, microbial activity and human health** require more evaluation through **life cycle analyses**.

- Nanomaterials reaching the land have the potential to **contaminate soil** and migrate into **surface and ground waters.**

- **Financial Constraints**: The **R&D and specialized manufacturing systems** required to engineer nanoproducts make initial investment prohibitive for small companies.
- **Production Challenges**: Many nanomaterials are currently produced only in small, laboratory-scale quantities. Enhancing methods for scalable, controlled production with consistent qualities is necessary.
- **Regulatory Roadblocks**: Regulatory uncertainty due to lack of **standardized safety data and nano-specific regulations** deters commercialisation.
- **Lack of awareness**: Understanding of nanotechnology remains low among farmers. Effective communication regarding costs versus benefits for different applications is needed.
- **Interdisciplinary Skills Deficit**: There is a scarcity of interdisciplinary expertise that bridges nanoscience, agriculture, and food technology.

Government Initiatives on Nanotechnology in Agriculture

- **Nano Mission**: Nanotechnology research centers like the **Centre for Nano Science and Engineering (CeNSE)** has been launched at IISc Bangalore, which works on **nano-fertilizers and nanotech food packaging**.
- **ICAR Initiatives:** The Indian Council for Agriculture Research established Nanotechnology Centres at IARI and IVRI to develop **nano-biosensors, nano-pesticides, and nanocapsules** for nutrient delivery.
- **Nano Urea and Nano DAP:** IFFCO placed India first in the world in Nano Urea and Nano DAP production.
  - Nano Urea is sprayed not on the ground but on the plants, which leads to a **zero possibility of destruction of natural elements** or earthworms present in the soil.
- **Nano-fertilizers:** IARI developed nanoparticles of **zinc, chitosan, and silica** as nano-fertilizers for improving crop growth and yield.
- **Nano-pesticides:**Tamil Nadu Agriculture University synthesized nanoparticles of herbal extracts as an **eco-friendly, non-toxic nano-pesticide**.

Way Forward

- **Increased Investment in Research and Development:** There is a need to allocate more resources towards R&D to address challenges like scalability, toxicity concerns, and production efficiency.
- **Collaborative Approach:** Foster collaboration between academia, government, and industry to accelerate innovation in nanotechnology for agriculture.
- **Regulatory Framework Development:** Establish clear and standardized regulations for the safe use and commercialization of nanomaterials in agriculture.
- **Awareness and Education Campaigns:** Conduct outreach programs and training workshops to educate farmers, policymakers, and the public about the benefits and risks of nanotechnology in agriculture.
- **Encourage private sector involvement**: Through incentives and partnerships to scale up production and commercialization of nano-enabled agricultural products.
- **Support for Small-Scale Farmers:** Provide financial assistance and technical support to small-scale farmers for adopting nanotechnology-based agricultural practices.
  - Develop **affordable and accessible nano-enabled products** tailored to the needs of smallholder farmers.
- **Monitoring and Evaluation:** Establish monitoring systems to track the environmental and socioeconomic impacts of nanotechnology adoption in agriculture.

Keywords: Nanocapsule, Nano-Sensors, Smart Delivery Systems, Antimicrobial Nano-coating, Nano DAP.

NANOTECHNOLOGY IN HEALTH

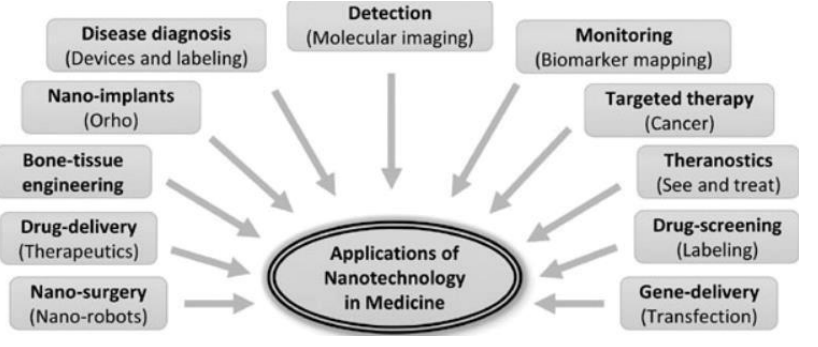
Context: Nanotechnology has revolutionized approaches to diagnosis, treatment, and disease prevention. Nanoparticles, with their exceptional precision, have become pivotal in drug delivery systems, ensuring targeted medication delivery to diseased cells while minimizing potential side effects.

Application of Nanotechnology in Health and Medicine:

- **Diagnostics:** Nanodevices and nanoparticles, like quantum dots and nanocrystals, are used for early detection and diagnosis of diseases.
  - **Cancer Detection: Gold nanoparticles** are used as probes for cancer imaging and diagnostics.

- **Imaging and Diagnostic Tools:** Quantum dots are used in medical imaging for precise diagnostics and earlier diagnosis for therapeutic success rates.

- **Drug Delivery Systems:** Nano-liposomes and other nanocarriers target specific cells or tissues, improving drug efficacy and reducing side effects.
  - **Nanoparticles** encapsulate medication, delivering it **directly to cancer cells** with minimal damage to healthy tissue.
  - **Smart pills** with embedded sensors for real-time monitoring and drug release performs advanced functions like sensing, imaging, and drug delivery.
  - **Nanorobots** are used for targeted drug delivery and surgery at the cellular level.
- **Regenerative Medicine:** Nanotechnology is employed in developing materials for tissue engineering, such as scaffolds that mimic biological tissues, aiding in tissue repair and regeneration.
- **Pharmaceuticals**: Nanoparticles improve the pharmacokinetics of drugs, increasing their solubility, stability, and bioavailability, which allows for lower dosages and reduced toxicity.
- **Nanofibres** are used in wound dressings, surgical textiles, implants, tissue engineering, and artificial organs. They have enhanced healing properties and are "smart bandages" with sensing capabilities.



Challenges of Nanomedicine:

- **Biocompatibility and Safety:** The interaction of nanoparticles with cells and biological systems can sometimes induce toxicity, leading to potential health risks.
- **Regulatory Challenges:** The approval process for nanomedicines can be complex and lengthy due to the unique characteristics of nanoparticles.
- **Targeting Accuracy:** While targeted delivery is a major advantage of nanomedicine, achieving precise targeting to diseased cells without affecting healthy cells remains a significant challenge.
- **Delivery across the blood-brain barrier:** Most nanoparticles have difficulty crossing the blood-brain barrier, limiting central nervous system applications.
- **Bioaccumulation**: Nanoparticles tend to accumulate in organs like the liver, spleen, lungs and brain. However, the long-term effects of such accumulation are not known.
- **Interference with the immune system:** Some nanoparticles suppress the immune system, while others may be toxic to the immune cells. Their effects on the complex immune signaling pathways are still being studied.
- **Cost barriers:** High costs due to complex production requirements and uncertainty about insurance coverage and reimbursement levels restrict access and mainstream use

Conclusion: Nanotechnology will provide promising therapies to cope with various severe diseases, and will also provide tools to solve the various bottlenecks in healthcare sectors. However, different nanomedicines and nanoformulations targeting various diseases must be meticulously designed in order to achieve the safest and most efficacious therapeutic regimen.

4 AWARENESS IN THE FIELD INFORMATION, COMMUNICATION, COMPUTER AND ROBOTICS

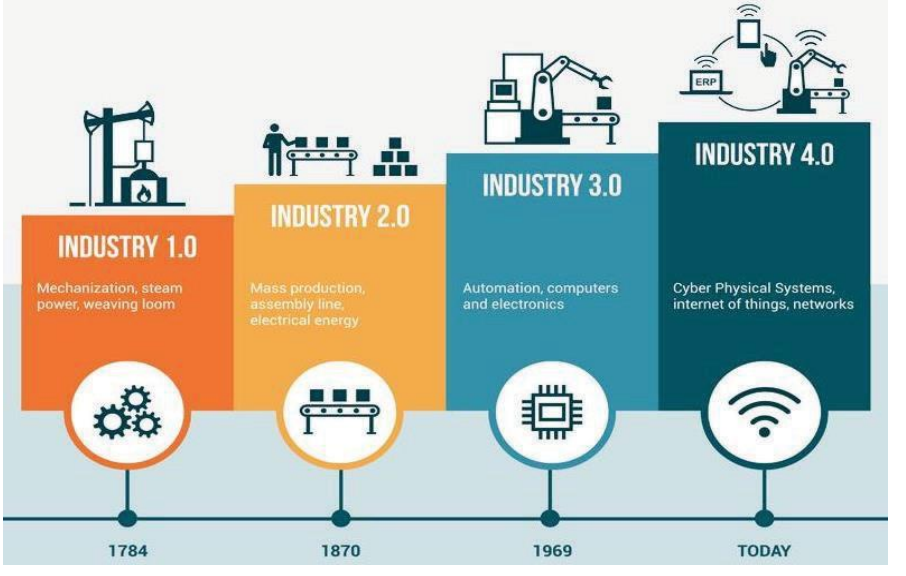
AWARENESS IN THE FIELD OF COMPUTERS AND ROBOTIC TECHNOLOGY

FOURTH INDUSTRIAL REVOLUTION (IR 4.0)

Context: India's first Fourth Industrial Revolution Centre on **healthcare and life sciences** will be set up in **Hyderabad** in partnership with the World Economic Forum, making it the 18th global node.

About Fourth Industrial Revolution:

- The Fourth Industrial Revolution refers to the next phase in the **digitization of the manufacturing sector** driven by disruptive trends, including the rise of data and **connectivity**, **cyber-physical systems**, **human-machine interaction**, and improvements in robotics.
- It is characterized by the use of different technologies to **blur the boundaries between the digital, physical, and biological worlds.**



Features of the Fourth Industrial Revolution (FIR):

- **Technological Convergence**: Fourth IR is characterized by integration of AI, robotics, IoT, and quantum computing, reshaping daily life and business operations.
- **Digitization of the Economy:** FIR is leading to increased reliance on digital technologies across businesses, revolutionizing how they operate and deliver services.
- **Automation of Tasks:** It is characterized by adoption of AI and robotics in automating tasks, which impacts labor markets and productivity.
- **Emergence of New Business Models:** FIR is leading to emergence of digital platforms that disrupt traditional markets with new service delivery methods.
- **Enhanced Connectivity:** Widespread use of the internet and mobile devices, enhancing global communication and interactions.
- **Smart Manufacturing:** It has introduced smart factories with cyber-physical systems that enhance production processes through automation and real-time decision-making.

Benefits of the Fourth Industrial Revolution (FIR):

- **Increased Productivity:** The FIR has the potential to increase productivity by automating tasks and by enabling new ways of working.
- **Improved Decision-Making:** The FIR can help businesses to make better decisions by providing them with access to real-time data and insights.
- **New Products and Services:** It can lead to the development of new products and services that can improve people's lives.
- **Economic Growth:** FIR has led to decreased transportation and communication costs, improved logistics, and reduced trade costs, which are fostering economic growth.
- **Improved Healthcare:** It can be used to develop new treatments and cures for diseases.
- **Sustainable Development:** FIR can be used to develop new technologies that can help to reduce environmental impact.

Challenges of the Fourth Industrial Revolution:

- **Job Displacement:** The FIR is likely to lead to job displacement and labor market disruptions, as tasks that are currently done by humans are automated.
- **Skill Gap and Inequality:** The divide between low-skill/low-pay and high-skill/high-pay jobs may widen, increasing social tensions.
- **Digital Divide:** The Fourth Industrial Revolution is likely to exacerbate the digital divide between those who have access to digital technologies and those who do not.
- **Security Risks:** The Fourth Industrial Revolution is likely to create new security risks as digital technologies become more interconnected.
- **Impact on Society:** The Fourth Industrial Revolution is likely to have a profound impact on society, changing the way we live, work, and communicate.
- **IP and Licensing:** Ambiguities in intellectual property rights hinder the commercialization of innovations.

Way Forward

- **Enhancing Regulatory Frameworks:** Robust policies need to be developed that not only foster innovation but also protect individual privacy and data security.
- **Developing ethical guidelines**: Establish guidelines that ensure technologies are developed and used for the benefit of society.
- **Inclusive Access:** Expand digital literacy programs, particularly for underrepresented and disadvantaged groups for equitable benefit.
- **Cybersecurity:** Robust security protocols are needed to protect against data breaches and cyber threats
- **Investing in upskilling and reskilling:** Government and the industries should focus on bridging this gap.
- **Encouraging Public-Private Partnerships:** Foster collaborations between government, industry, and academia to drive innovation and ensure that technological advancements are aligned with societal needs

Conclusion: The Fourth Industrial Revolution is a complex and rapidly evolving phenomenon. It is still too early to say what the full impact of the revolution will be. However, it is clear that the revolution is having a profound impact on businesses, governments, and societies. It is creating new opportunities for growth and innovation, but it is also raising new challenges.

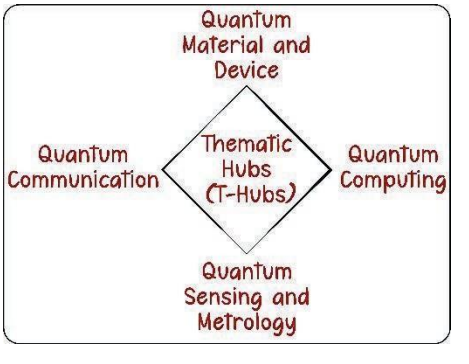
Initiatives taken by India:

- **Farmer Zone**, a cloud-based platform, is being developed by the Department of Biotechnology to provide smart solutions to farmers.
- **Center for the Fourth Industrial Revolution (C4IR)-India**, Mumbai to exchange ideas in partnership with NITI Aayog and WEF.
- **Smart Advanced Manufacturing and Rapid Transformation Hub (SAMARTH)** -Udyog Bharat an Industry 4.0 initiative of the Department of Heavy Industry.
- **New Industrial Policy**: It intends to position India as a global leader in FIR technologies by aligning with emerging tech like AI, blockchain, and drones.
- **Digital Twin technology** for creating similar virtual models of various physical things

Keywords: Digitalisation, digital divide, automation, convergence, digital infrastructure.

QUANTUM TECHNOLOGY

Context: The Union Cabinet recently approved the budget of ₹6,003 crore for **National Quantum Mission (NQM)** that will fund research and development of quantum computing technology in India.



About National Quantum Mission (NQM):

- The mission planned for **2023-2031**, is being implemented by the **Department of Science & Technology (DST)** under the Ministry of Science & Technology.
- It aims to s**eed, nurture, and scale up scientific and industrial R&D** and create a vibrant & innovative ecosystem in Quantum Technology (QT).

- **Salient Features of NQM:**
  - It targets developing intermediate scale quantum computers with **50-1000 physical qubits in eight years** in various platforms like superconducting and photonic technology.
  - **Satellite based secure quantum communications** over a range of **2000 km** within India and with other countries.
  - **Develop magnetometers with high sensitivity** in atomic systems and Atomic Clocks for precision timing, communications and navigation.
  - It will support design and synthesis of quantum materials like **superconductors, novel semiconductor structures & topological materials** for fabrication of quantum devices.
  - **Four 'Thematic Hubs' (T-Hubs)** will be set up in top academic and national R&D institutes in the domains of **quantum computing, communication, sensing and metrology.**
- **Components of National Quantum Mission:**
  - **The National Quantum Coordination Office (NQCO)** is responsible for coordinating the NQM and ensuring that it is aligned with the national interest.
  - **The National Quantum Infrastructure (NQI**) is a network of quantum research centers that will provide the foundation for development of quantum technologies.
  - **The National Quantum Education (NQE) program** is a training program that will prepare the next generation of quantum scientists and engineers.
  - **The National Quantum Initiative (NQI)** is a public-private partnership that will promote the responsible development and use of quantum technologies.

About Quantum Technology:

- Quantum mechanics is a fundamental theory in physics that describes the **behavior of matter and energy at the atomic and subatomic level**. Quantum technology is a rapidly developing field that is based on the principles of quantum mechanics.
- **Key principles of Quantum technology are:**
  - **Qubits:** Just like a **binary bit (0 and 1)** is the basic unit of information in classical computing, a qubit **(a combination state of 0 and 1)** is the basic unit of information in quantum computing.
  - **Superposition:** It is the ability of a quantum particle to be in multiple states at the same time until measured.
  - **Entanglement:** It refers to a situation in which two or more quantum particles are linked in such a way that it is impossible for them to be described independently.

Applications of Quantum Technology:

- **Cryptography:** Quantum technology could be used to develop new encryption methods that are unbreakable by conventional computers.
- **Computing:** Quantum computers could be used to solve problems that are impossible for conventional computers, such as breaking encryption codes and simulating complex molecules.
- **Communication:** Quantum communication could be used to develop new communication networks that are secure and faster than traditional networks.
- **Metrology:** Quantum metrology could be used to develop new sensors that are more accurate and sensitive than traditional sensors.
- **Healthcare:** Quantum technology could be used to develop new medical treatments, such as new drugs and new diagnostic tools.

Quantum Computing utilizes quantum mechanics principles to **tackle problems beyond classical computers' capacity and uses qubits** instead of binary bits as the basic memory units.

- Applications of Quantum computing includes **drug design & development, cybersecurity & cryptography, logistics optimisation, traffic planning, climate change etc.**

Challenges of Quantum Technology:

- **Complex Technology:** Quantum technology is very complex, and it requires a deep understanding of quantum mechanics.
- **Affordability issues:** Quantum technology is very expensive, and it is not yet clear how to make it affordable.
- **Scalability issues:** Quantum technology is difficult to scale up, and it is not yet clear how to build quantum computers that are large enough to solve real-world problems.
- **High Hardware Requirements:** Quantum technologies often require specialized and complex hardware, which can be costly to develop and maintain.

- **Limited Availability of Quantum Resources:** Access to high-quality qubits, quantum algorithms, and quantum software tools is limited, hindering the advancement and widespread adoption of quantum technology.

Conclusion: Quantum technology is a rapidly developing field with the potential to revolutionize a wide range of industries. Quantum technology faces a number of challenges, but it is clear that quantum technology has the potential to change the world.

Government Initiatives in the Field of Quantum Technology

- **Quantum-Enabled Science and Technology (QuEST):** The DST launched the Quantum-Enabled Science and Technology **(QuEST)** initiative to invest INR 80 crores to lay out infrastructure and to facilitate research in the field.
- **Quantum Computer Simulator (QSim) Toolkit:** It provides the first quantum development environment to academicians, industry professionals, students, and the scientific community in India.
- **National Mission on Quantum Technology and Applications (NMQTA):** In the Union Budget of 2020-2021, the Central Government has allocated Rs. 8000 crore for the National Mission on Quantum Technology and Applications **(NMQTA).**

- **Quantum Communication** uses the principles of quantum mechanics to transmit information. It is much more secure and faster than traditional communication.
- **Quantum Metrology** is a type of metrology that uses the principles of quantum mechanics to measure physical quantities. It is much more accurate, sensitive and advanced than traditional metrology.
- **Quantum Healthcare** uses the principles of quantum mechanics to develop new healthcare technologies.

Quantum cryptography

- It is also known as **Quantum encryption or Quantum Key Distribution**, refers to various cybersecurity methods for encrypting and transmitting secure data based on the naturally occurring and immutable laws of quantum mechanics.
- **Advantages of Quantum Cryptography**
  - **Ensuring Communication Security:** It guarantees absolute security, thwarting any compromise without detection by either the sender or the recipient of the message.
  - **Detects eavesdropping :** If a third party attempts to read the encoded data, then the quantum state changes, modifying the expected outcome for the users.
  - **Offers multiple methods for security :** There are numerous quantum cryptography protocols used. Some, like QKD, for example, can combine with classical encryption methods to increase security.

Keywords: Quantum Computing, Quantum health, Metrology, Material Science, Cryptography

CLOUD COMPUTING

Context: Recently, the RBI Governor announced a proposal to establish cloud facilities for storing data of financial institutions in India.

About Cloud Computing

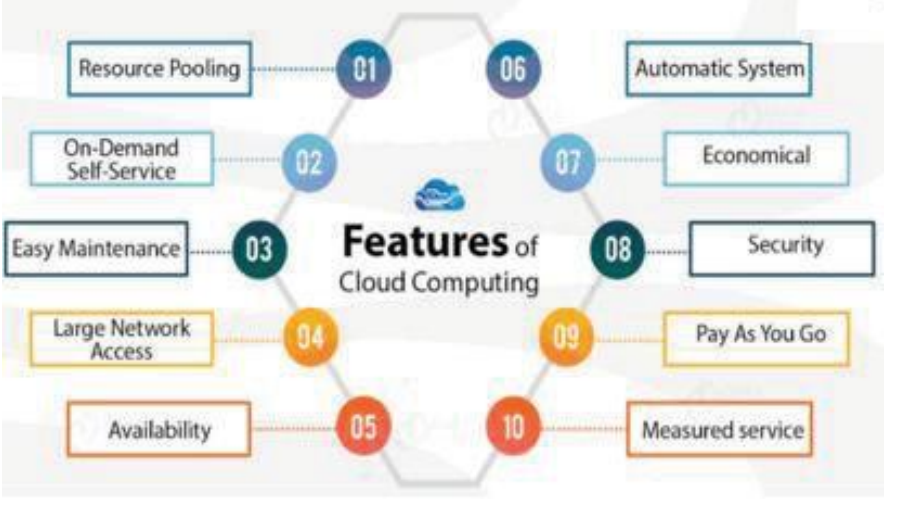
- **Cloud Computing:** It is the use of hosted services, such as **data storage, servers, databases, networking, and software over the internet.** It is **on-demand access** to computing resources via the internet, hosted at a remote data center managed by a **cloud services provider (CSP).**

Benefits of using Cloud Computing:

- **Cost Management:** Using cloud infrastructure can **reduce capital costs,** as organizations don't have to spend on buying and maintaining equipment.
- **Data and Workload Mobility:** Users can **access information stored on cloud from anywhere with any device** with just an internet connection. **Example, Zoom** is a cloud-based software platform for **video and audio conferencing** that records meetings and saves them to the cloud.
- **Business Continuity and Disaster Recovery (BCDR)**: With cloud-based services, organizations can quickly recover their data in the **event of emergencies,** such as natural disasters or power outages.

- **Edge computing** is a distributed computing paradigm that brings computation and data storage closer to the edge of the network, closer to the source of the data. This can improve performance, reduce latency, and increase security.
- **Internet of Things (IoT)** is the network of physical objects that are embedded with sensors, software, and network connectivity to collect and exchange data.
- Examples Use of Edge computing and IoT Together
  - **Self-driving Cars**: Edge computing is used to process data from sensors in self-driving cars and make maneuvering decisions.
  - **Industrial Automation:** Edge computing is used to monitor and control industrial machinery.
  - **Smart Cities:** Edge computing is used to collect data from sensors in smart cities. This data is used to monitor traffic, manage energy usage, and provide other services.

- **On Demand Scalability:** Cloud services provide the ability to scale resources up or down based on demand.
- **Environmental Impact**: Cloud providers often operate **highly efficient data centers**, leading to energy savings compared to traditional on-premises infrastructure.



Challenges Associated with Cloud Computing:

- **Cloud Security**: When relying on the cloud, organizations risk **data breaches, hacking of APIs and interfaces**, compromised credentials and authentication issues.
  - **Example,** as per **Thales Cloud Security Report 2023**, more than **35% of respondents in India** have experienced a data breach in their cloud environment.
- **Cost Unpredictability**: Cloud costs are **frequently interdependent**, with one cloud service utilizing one or more other cloud services, leading to unpredictable **cloud costs.**
- **Rising burden on Existing cloud infrastructure:** According to **Niti Aayog Advisor**, 98% of organizations are using some form of cloud computing, up from 91% in 2020. This increasing demand has led to rising burden on the existing infrastructure of cloud service providers.
- **Privacy Issues**: Organizations often navigate through various **data protection and privacy laws** when storing and processing data in the cloud, due to which businesses may feel a **loss of control over their data** when it's stored on third-party servers.
- **Multi-Cloud Causing Operational Complexity:** The adoption of multi cloud continues to surge globally, with **around 79% of organizations** having more than one cloud provider. This makes managing data in the cloud more **complex than in on-premises environments**.

Way Forward:

- **Integration with Edge Computing**: There is a growing trend toward integrating edge computing with cloud services to enable processing closer to the source of data generation.
- **Advanced Security Measures:** Implementing **zero-trust security architectures** is gaining prominence to mitigate the evolving threat landscape. This involves **continuous verification** of user identity and device security.

- The use of **advanced encryption techniques** and confidential computing can further help in ensuring safety of financial institutions.
- **Artificial Intelligence (AI) and Machine Learning Integration**: Offering more AI and machine learning services would make it easier for organizations to **integrate advanced analytics and AI capabilities** into their applications.
- **Data Governance and Compliance**: There is a need to enhance data governance as **data privacy regulations** become more stringent, to help organizations meet regulatory requirements.

Conclusion: As cloud computing becomes integral to financial operations, blending advanced technologies like edge computing and enhancing security measures becomes crucial. This initiative not only promises improved data handling efficiency and security but also aligns with the global trend towards digital sovereignty.

Keywords: Edge computing, IOT, Real-time data, industrial automation, latency.

PREVIOUS YEAR QUESTIONS		
1.	Discuss the advantages and security implications of cloud hosting of servers vis-a-vis in-house machine-based hosting for government businesses. (12.5 marks)	2015

VIRTUAL PRIVATE NETWORK (VPN)

Context: The Kerala police have started transferring sensitive data through Virtual Private Network (VPN) in a bid to boost cybersecurity.

About Virtual Private Network (VPN)

- Virtual Private Network (VPN), is a **technology that enables secure and private communication over public networks** such as the internet. It creates a private network connection by encrypting the data transmitted between the user's device and the VPN server, ensuring confidentiality and data integrity.
- **Some Types of VPN:**
  - **Remote Access VPN:** Used to securely connect to a private network remotely.
  - **Site-to-Site VPN:** Establishes secure connections between different networks, such as branch offices or multiple data centers.
  - **Mobile VPN:** Secures connectivity while users are on the move.
  - **SSL/TLS VPN:** It operates through a web browser and uses SSL/TLS protocols to secure remote access to web applications, email services, and other resources.

Advantages of VPN Technology:

- **Enhanced Security:** VPNs provide encrypted connections, safeguarding sensitive data from potential threats, such as hackers or eavesdroppers.
- **Remote Work:** VPNs enable secure remote access to company networks, allowing employees to work from anywhere while maintaining data privacy and network integrity.
- **Geo-Restricted Content Access**: VPNs can bypass geographical restrictions and censorship by masking the user's IP address and providing access to blocked content and services.
- **Anonymity and Privacy:** VPNs hide the user's IP address and encrypt internet traffic, ensuring anonymity and privacy online. This helps protect personal information and browsing activity from surveillance and tracking.
- **Torrenting and File Sharing:** VPNs are commonly used for secure and anonymous torrenting and file sharing, as they hide the user's IP address and encrypt the data transferred.
- **Online Gaming:** VPNs can reduce latency and improve gaming performance by connecting to gaming servers in different regions, allowing gamers to access geo-restricted content.

Disadvantages of VPN Technology

- **Slower Internet Speed:** The process of encrypting data and routing it through remote servers can lead to reduced internet speed.
- **Legal and Policy Issues:** Some countries restrict or regulate the use of VPNs, which can pose legal risks to users.
- **Cost:** While there are free VPNs, they often have limitations in speed, data, and security, making paid VPNs a necessary expense for optimal performance.
- **Complexity in Setup and Use**: Setting up a VPN can be complex for average users, and improper configuration can lead to security vulnerabilities.
- **Potential for Misuse:** VPNs can be used to conduct illegal activities due to the anonymity they provide, which can attract scrutiny from law enforcement and regulators.

Conclusion: VPNs provide secure and private communication over public networks. With different types catering to various needs, VPNs find applications in remote work, content access, anonymity, security, and more. Their versatility and ability to protect sensitive data make them an essential tool in today's digital world.

Keywords: Anonymity and Privacy, Online Gaming, Remote Work

DARKNET

Context: A report by a US-based cybersecurity firm claimed that personal details (Aadhaar, names, phone numbers and addresses) of about 815 million Indians have been leaked on the dark web.

About Darknet:

- The Darknet, also known as the **Dark Web**, is a part of the internet that is intentionally hidden and inaccessible through standard search engines.
- It operates on overlay networks and requires specific software, configurations, or authorization to access.

Benefits of the Darknet:

- **Anonymity:** It allows users to maintain a high level of anonymity by using encryption and routing techniques. It becomes difficult to monitor and trace online activities of individuals, crucial for activists, and journalists.
- **Free Expression and Whistleblowing**: It provides a platform for individuals to express themselves freely without fear of censorship.
  - It can also serve as a safe space for whistleblowers to share sensitive information while maintaining their anonymity.
- **Privacy Protection:** It can be utilized to safeguard personal information, including financial data, from potential data breaches or surveillance. It offers a layer of protection against cybercriminals and data tracking.
- **Access to Censored Information:** The dark web provides a platform for individuals in restrictive countries to access and disseminate censored information, helping to bypass government filters and firewalls
- **Secure Communication for Sensitive Professions**: The dark web offers secure communication channels for journalists, activists, and others whose work requires high levels of confidentiality.

Challenges of the Darknet:

- **Illegal Activities:** The Darknet has become notorious for facilitating illegal activities, including drug trafficking, weapons trade, human trafficking, and cybercrime.
- **Cybercrime:** It is a breeding ground for various cybercrimes, including the sale of hacking tools and services, phishing attacks, and financial fraud
- **Lack of Trust:** Due to the anonymity of the Darknet, users often face difficulties in determining the authenticity and reliability of services or sellers, leading to potential scams or fraud.
- **Child Exploitation and Pornography:** The Darknet hosts a disturbing amount of illegal content, including child pornography.
- **Malware and Cyber Threats:** Darknet platforms may contain malware-infected websites or downloadable files, posing risks to users who access such content.
- **Stigma and Public Perception:** The association of the Darknet with illegal activities often results in a negative perception among the general public.

Way Forward:

- **Strengthen Law Enforcement:** There is a need to develop specialized cybercrime units and provide them with the necessary resources and training to combat Darknet-related crimes.
- **Improve Technology and Tools:** Advanced technologies and tools can aid in the identification and tracking of illegal activities on the Darknet.
  - Develop robust algorithms for data analysis and pattern recognition to detect criminal behavior, illicit content, and cyber threats.
- **Public Awareness and Education:** The public should be made aware about the risks and dangers associated with the Darknet using digital literacy programs etc.
- **Collaboration with Technology Companies:** The government agencies and technology companies should collaborate to develop solutions that can monitor and block illegal activities on the Darknet.
- **International Cooperation and Regulation:** Strengthen international cooperation to tackle the cross-border nature of Darknet crimes.
- **Support Research and Innovation:** Support academic and industry research initiatives that explore ways to identify and mitigate the risks associated with the Darknet.

- Foster innovation in cybersecurity and encryption technologies to enhance online safety and privacy.

Conclusion: It is important to recognize that while the Darknet presents certain benefits in terms of anonymity and privacy, its challenges and association with illegal activities cannot be ignored. Addressing the issues related to criminal activities and ensuring a safer online environment should be a priority to harness the potential benefits of the Darknet while mitigating the risks it poses.

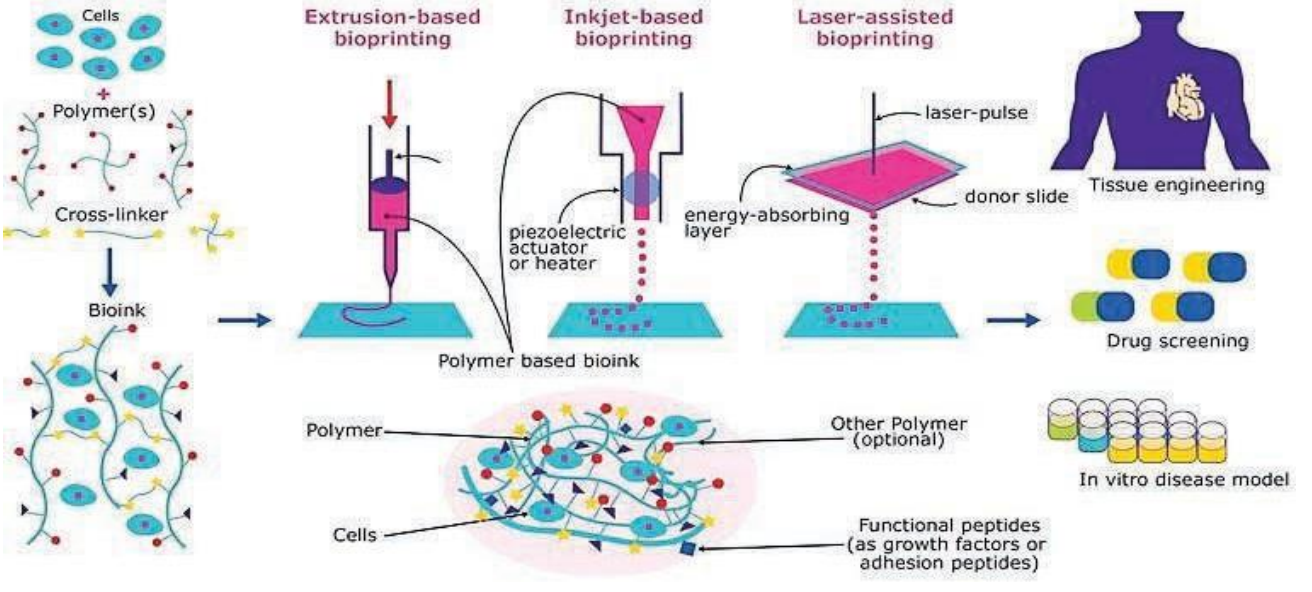
Keywords: Dark Web, illicit activities, Anonymity, Privacy Protection, Lack of Trust.

WORLD'S FIRST 3D-PRINTED NEURAL TISSUE

Context: Recently, **a study has been published** in **'Cell Stem Cell'** that **researchers have created the first functional 3D-printed brain tissue.**

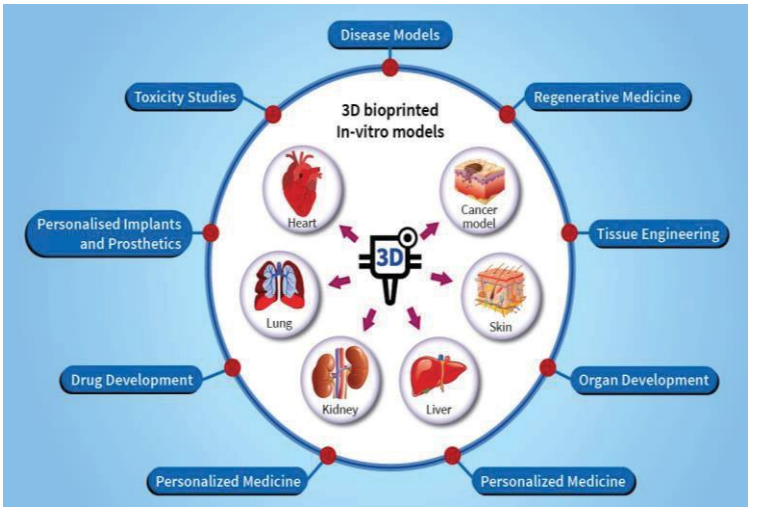
What is 3D-Bioprinting?

- **A Computer-guided Process:** It is a computer-guided process that builds layers of materials, cells, and other components to build living structures.
- **Significance:** It has huge potential for creating tissues that replicate, and in some cases even replace the real deal.



About the First Functional 3D-printed Brain Tissue:

- **A New Significant Tool for Scientists:** It provides neuroscientists with a new tool for studying communication between brain cells and other parts of the human brain.
- **Feature:** It can **develop and form connections** in the same way **as real human brain tissue.**
- **Usability:** Many labs should be able to use it as it **doesn't need special bio-printing equipment.**
- **Significance:**
  - **To Treat Diseases:** It leads to better ways of treating diseases like **Alzheimer's and Parkinson's.Easy to Maintain:** It is easy to keep healthy and can be studied with microscopes and other equipment typically found in most laboratories.**Understanding Complex Working:** Now it is possible to print the tissue by design and neuroscientists can have a defined system to look at how the human brain network operates.



  - **Concern:** It is challenging to print functional human brain tissue and so far most 3D-printed tissues lack proper connections between cells.

- **Neurons** need to be able to mature while keeping the tissue structure intact, and supporting cells are essential for the tissue to function properly.
  - Neurons are **the structural and functional unit** of the nervous system. All neurons comprises three different parts- dendrites, cell body and axon.

Conclusion: The precision of this 3D-printing method **allows control over cell types and arrangements,** unlike miniature lab-grown organs used for brain research called brain organoids.

- It can be used **to look at the molecular mechanisms** underlying brain development, human development, developmental disabilities, neurodegenerative disorders, and more. It will **improve the process to create more specific brain tissues with guideable cells.**

What is 3D Printing:

- It is also known as **additive manufacturing,** is a method of creating a three dimensional object layer-by-layer using a computer created design.
- This is the opposite of **subtractive manufacturing processes**, where a final design is cut from a larger block of material.

What Materials can be used in 3D Printing?

- There are a variety of 3D printing materials, including **thermoplastics** such as **acrylonitrile butadiene styrene (ABS)**, metals (including powders), **resins and ceramics.**

3D Printing Technologies

There are **three broad types of 3D printing technology**

- **Sintering** is a technology where the material is heated, but not to the point of melting, to create high resolution items. Metal powder is used for direct metal laser sintering while thermoplastic powders are used for selective laser sintering.
- **Melting methods** of 3D printing include **powder bed fusion,** electron beam melting and direct energy deposition,
  - These use **lasers, electric arcs or electron beams** to print objects by melting the materials together at high temperatures.
- **Stereolithography** utilises photopolymerization to create parts.
  - This technology uses the correct light source to interact with the material in a selective manner to cure and solidify a cross section of the object in thin layers.
- **Application of 3D printing:**
  - **Aeronautical Manufacturing**: 3D printing is being used to create lightweight, strong parts for aircraft and spacecraft. Example **PS4 engine of PSLV**
  - **Automotive Manufacturing:** It is being used to create prototypes and custom parts for automobiles..
  - **Medical Manufacturing:** 3D printing is used to create custom prosthetics and implants, as well as to print models of organs and tissues for surgical planning
  - **Consumer goods:** 3D printing is being used to create a wide range of consumer products, such as toys, jewelry, and furniture.

Keywords: 3D-Bioprinting and its application,

PREVIOUS YEAR QUESTIONS		
1.	How does 3D printing technology work? List out the advantages and disadvantages of the technology. (5 marks)	2013

4D PRINTING

Context: 4D printing is an advanced manufacturing technique that involves the creation of objects that can self-transform or adapt their shape over time in response to external stimuli such as heat, light, or moisture.

About 4D Printing:

- It **builds upon 3D printing technology** by adding an additional dimension of time, allowing objects to change their form or function after being printed.
- In 4D printing, objects are created using materials that can change their shape, properties, or functionality over time when exposed to specific environmental stimuli, such as heat, humidity, light, or other triggers.

5D printing: It adds two more rotational axes to the traditional linear X, Y, and Z axes used in 3D printing. This expands the range of motion and allows for greater control over the printing process and enables the creation of intricate designs with ease.

Principle for 4D Printing:

- **Material Used: Hydrogel or shape memory polymer**, a programmable ingredient, is capable of altering its physical shape or thermomechanical properties based on user input or autonomous sensing.
- These materials have the **ability to remember and return to their original shape or transform** into a new shape when exposed to specific triggers.
- By integrating these materials into the 3D printing process, objects can be designed to undergo predetermined shape changes in a controlled manner.

Potential applications of 4D printing:

- **Biomedical Field**: It can revolutionize healthcare by enabling the creation of adaptive medical devices, such as implants or prosthetics, that can adjust or grow within the body.
  - It can also be used to develop drug delivery systems that respond to specific physiological conditions.
- **Architecture and Construction**: 4D printing has the potential to create dynamic buildings, adaptive facades, or infrastructure that can respond to changing needs or weather conditions.
- **Aerospace and Defense:** 4D printing can be utilized in the manufacturing of lightweight and shape-changing components for aircraft or spacecraft. This can lead to improved aerodynamics, reduced weight, and enhanced functionality of aerospace systems.
- **Smart Textiles:** 4D printing offers opportunities for the creation of customizable and shape-shifting garments, shoes, or accessories.
- **Consumer Goods:** The applications of 4D printing extend to consumer products, where it can be used to develop self-assembling furniture, toys, or home appliances that adapt to user preferences or spatial constraints.
- **Robotics and Automation:** 4D printing can enhance the capabilities of robots by enabling them to change their shape or perform complex tasks through shape-shifting components.

Advantages of 4D Printing:

- **Adaptability:** Objects printed with 4D technology can adapt to environmental changes, making them useful for applications in diverse fields such as aerospace, construction, and biomedicine.
- **Reduced Shipping and Storage Costs**: Since objects can be printed flat and expanded only when needed, it reduces the cost and space required for shipping and storage.
- **Efficiency in Manufacturing:** It allows for the production of complex objects with minimal waste, enhancing manufacturing efficiency and sustainability.
- **Innovative Solutions**: Offers new solutions in medicine, such as implants that can change shape or properties once inside the body to better interact with their surroundings.

Disadvantages of 4D Printing:

- **High Cost:** The technology and materials required for 4D printing are often expensive, limiting its accessibility and widespread use.
- **Limited Materials:** There are currently limited materials available that can be used for 4D printing, restricting the types of objects and applications.
- **Complexity in Design:** Designing for 4D printing requires advanced knowledge of materials science and engineering, making it a complex and skill-intensive endeavor.
- **Durability Concerns:** There are questions about the long-term durability and stability of 4D printed objects, especially when exposed to varying environmental conditions.

Conclusion: While 4D printing is still in its early stages of development, it holds immense potential for transforming various industries by introducing adaptive and dynamic functionalities. Continued research and advancements in material science, printing techniques, and design methodologies will further unlock the possibilities of 4D printing in the future.

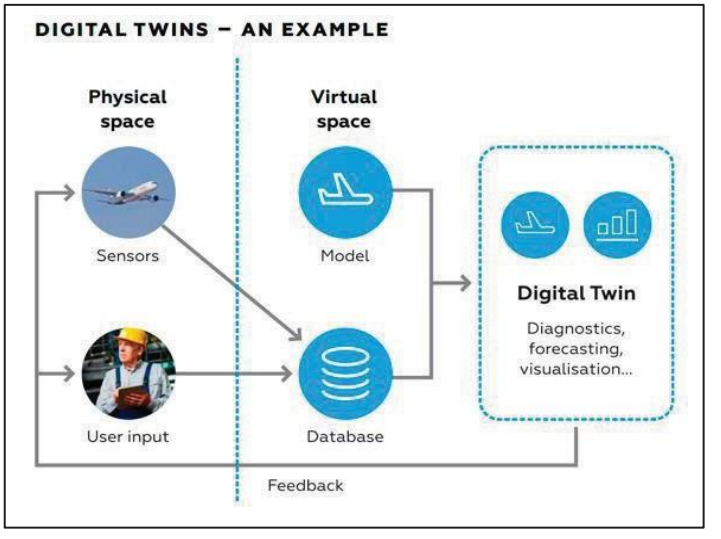
Keywords: Smart materials, Aerospace and Defense, Consumer Goods, Robotics and Automation.

DIGITAL TWIN

Context: Department of Telecommunications (DoT) has unveiled the **'Sangam: Digital Twin'** initiative, which creates virtual replicas of physical assets for real-time monitoring, simulation and analysis

About Sangam: Digital Twin Initiative

- Sangam: It is a **proof-of-concept (PoC)** exercise, distributed in two stages where the first stage focuses on **exploratory activities,** while the second stage involves **practical demonstrations** of specific use cases.
- A digital twin is a **virtual representation of a physical object or system**. It is a real-time data model that reflects the current state of the physical object or system.
- Digital twins can be used to **monitor, analyze, and optimize the performance of physical objects or systems**. They can also be used to predict failures and to simulate different scenarios.



Components of Digital Twin:

- **Data Collection:** Digital twin is based on a real-time data model of the physical object or system. The data can be collected through sensors, cameras, and actuators.
- **Algorithms**: Digital twin uses algorithms to analyze the data and to generate insights. The algorithms can be used to monitor the performance and predict failures of the system.
- **Interface:** It provides an interface that allows users to interact with the model. The interface can be used to evaluate performance, troubleshoot problems, and make changes to the model.

Applications of Digital Twin:

- **Manufacturing:** Monitor and optimize the performance of manufacturing processes along with predicting failures in different scenarios.
- **Logistics Optimization:** Monitor and optimize the performance of transportation networks. They can also predict traffic congestion.
- **Energy Optimization:** Monitor and optimize the performance of energy systems along with predicting power outages.
  - **Example: General Electric** employs digital twin technology across wind farms to predict equipment failures and optimize energy production
- **Healthcare:** Improve patient care by creating personalized digital models of patients for detailed simulations and analyses.
- **Smart Cities:** It facilitates **urban planning and management** by simulating scenarios like traffic, population growth, and emergency responses.
  - Example: **Singapore's Virtual Singapore project** is a prime example of digital twins.
- **Aerospace:** Optimizing the performance of aircraft and forecasting the maintenance of different components, which enhances safety and efficiency.

Challenges of Digital Twin:

- **Data Integrity and Quality:** Accurate digital twins rely heavily on high-quality data. Inaccuracies in data can lead to misleading outputs, making it critical to ensure data accuracy and reliability.
- **Complexity of Algorithms**: The algorithms that process data and generate insights need to be robust and reliable. Inaccurate algorithms can result in erroneous decisions based on the digital twin's outputs.
- **User Interface Design**: It's essential for the interface of digital twin systems to be user-friendly to allow effective use by all stakeholders, regardless of their technical expertise.
- **Scalability**: As organizations look to scale digital twin technology across different operations or integrate more complex simulations, they face challenges related to computational demands and the need for robust infrastructure.
- **Security and Privacy**: With the increase in data breaches, ensuring the cybersecurity of digital twins is paramount..
- **Interoperability**: Digital twins must be able to communicate seamlessly with other systems and protocols, which is often hindered by a lack of standardization across platforms and technologies .

- **Cost and Implementation**: The initial setup cost and complexity of implementing digital twin technology can be prohibitive for some organizations, particularly small & medium enterprises.
- **Technological Maturity**: As a relatively new technology, digital twin development is still maturing, which can lead to issues with reliability and performance .

Conclusion

Digital twins are a promising technology with the potential to revolutionize a wide range of industries. However, digital twins face a number of challenges that need to be addressed before they can become a reality.

Keywords: Digital twin, revolutionize, interoperability, interface, algorithm, scalability.

ONLINE GAMING

Context: The online gaming industry in India has seen a rapid expansion of 28% CAGR between FY20 and FY23. Projections indicate further growth to ₹33,243 crore by FY28, with a sustained 15% CAGR.

About Online Gaming Industry:

- Online gaming refers to **games that can only be played with an internet connection**. This is a part of the **sunrise industry** with a growing demand for game access.
- India is currently the l**argest gaming market in the world, boasting a user base of 568 million gamers** and over 9.5 billion gaming app downloads in 2023.
- **Types of Online Gaming:**
  - **E-sports:** Well organized electronic sports which include professional players).
  - **Fantasy sports:** Choosing real life sports players and winning points based on players' performance.
  - **Skill Based:** Mental skill.
  - **Chance Based:** Based on random activity like roll of a dice) online games.

Factors leading to Growth Online Gaming

- **Penetration of Smartphone**: According to the World Economic Forum (WEF), mobile devices are the primary driver of India's gaming industry. India Currently has some 650 million smartphone users
- **Affordability of Internet**: India is a data-rich market with cheaper mobile data as compared to global averages. Growing internet penetration will benefit India's mobile-first gaming market.
- **Demographic Factor:** Gaming has a higher adoption amongst the younger population in India with the 18-30 age group highly engaged users of gaming.
- **COVID-19 pandemic impact:** The Covid-19 lockdown period accelerated the adoption of online gaming as a form of virtual entertainment and social connection.
- **Recognition for esports as a standalone sub-segment:** It has also been officially recognised by the Indian Olympic Association by establishing the Esports Federation of India as the leading governing body of Esports in the country.
- **Government Support and Regulatory Clarity:** Initiatives like the IT (Intermediary Guidelines and Digital Media Ethics Code) Rules 2021 have provided a regulatory framework for online gaming, addressing concerns about harmful content and addiction.
- **Games with localized content:** Most popular games in India like Teen Patti by Octro, Ludo King by Gametion and others provide options to play games in local languages like Hindi, Gujarati, Marathi etc.
- **Growth in investments:** Various global investment firms have made significant investments in the Indian game sector over the past few years, resultantly creating gaming unicorns like Dream11 and Mob ile Premier League.

Challenges:

- **Regulation:** The online gaming industry is not yet fully regulated in India. This can make it difficult for businesses to operate and can also lead to consumer protection concerns.
- **Fraud:** Online gaming is a target for fraud and scams. This can make it difficult for consumers to trust online gaming businesses.
- **Online Addiction:** Excessive gaming can lead to addiction, negatively impacting mental health, relationships, and productivity.
- **Cybersecurity Risks:** Online gaming platforms may be vulnerable to hacking, identity theft, and data breaches, compromising players' personal information.
- **Social Isolation:** Spending excessive time gaming online can lead to social isolation, as players may prioritize virtual interactions over real-life relationships.

- **Taxation Concerns and Sustainability Challenges:** The imposition of a 28% GST on the total face value of bets has raised concerns about the long-term sustainability of the industry.
- **Health Issues:** Prolonged gaming sessions can contribute to sedentary lifestyles, physical ailments like eye strain, and poor posture.
- **Online Harassment:** Players may experience harassment, bullying, or toxic behavior from other players, leading to a hostile gaming environment.

Steps Taken by Government Online Gaming:

- **Digital Gaming Research Initiative:** The government has started a digital gaming research initiative to support the Indian digital gaming research space and industry.
- **AVGC Promotion Task Force:** The Ministry of Information and Broadcasting has established the Animation, Visual Effects, Gaming and Comic (AVGC) Promotion Task Force.
- **Inter-Ministerial Task Force:** The Ministry of Electronics and Information Technology (MeitY) formed an inter-ministerial task force to propose a national-level legislation for regulating online gaming. The task force submitted its report in October 2022, outlining recommendations for effective regulation.
    - **Nodal Ministry for Regulation:** As per the task force's recommendations, MeitY has been designated as the nodal ministry responsible for regulating online gaming.
    - **Central Regulatory Body:** The task force proposed the establishment of a central regulatory body dedicated to overseeing the online gaming sector.
    - **Prevention of Money Laundering Act (PMLA):** To ensure financial transparency, the task force suggested bringing online gaming under the purview of the Prevention of Money Laundering Act, 2002.

Way forward:

- **Uniformity in Laws:** Proper gaming regulation for all parties involved is urgently needed, otherwise the center should be given the authority to enact rules and regulations using either the residuary powers under article 248 or the power under article 252.
- **Coordination and Cooperation:** To fully realize the potential of the online gaming industry, the State and Union Governments should work together to set appropriate guidelines in conjunction with industry stakeholders.
- **Monitoring**: To standardize regulations and maintain uniformity in the laws across India, there has to be one regulatory authority overseeing the whole online gambling sector.
- **Parent Responsibility:** Parents need to be accountable for their children's gaming habits and time spent online.
- **Safeguarding Children:** Implement an age rating system that restricts minors to go on without their parents' permission. This issue could be solved by using OTP verification on Aadhaar.
- **Awareness:** Gaming businesses should aggressively inform players about possible risks and how to spot circumstances where cheating and abuse are likely to occur.

Conclusion: The government's proactive steps in regulating online gaming demonstrate its commitment to create a secure and transparent environment for players and industry stakeholders. With the establishment of a central regulatory body, clear definitions, and inclusion under relevant legislation, online gaming is poised to thrive while adhering to legal and ethical standards. These measures contribute to the overall growth of the AVGC sector, positioning India as a key player in the global online gaming arena.

Keywords: Virtual reality, augmented reality, online game, E-sports, in-app purchase.

AWARENESS IN THE FIELD OF INFORMATION AND COMMUNICATION TECHNOLOGY

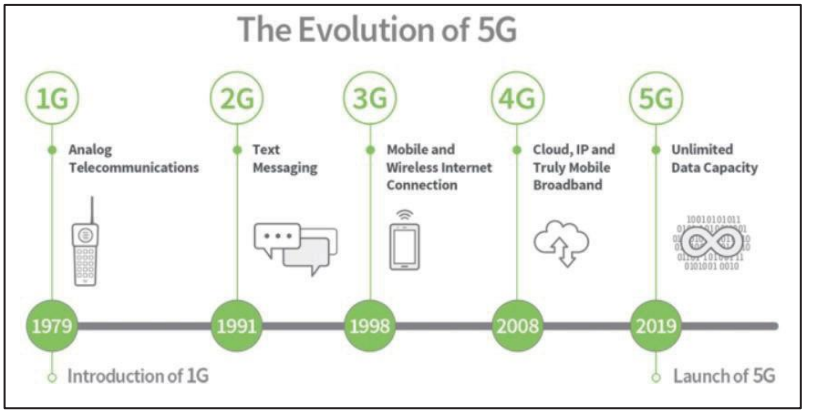
BHARAT 6G ALLIANCE

Context: Recently, the Department of Telecommunication (DoT) launched Bharat 6G Alliance to drive innovation and collaboration in Next-Generation Wireless Technology (6G).

Evolution of Mobile Communication Technology

- Mobile communication technology evolved from offering **voice calls of low quality (1G)** in the 1970s to **5G technology in 2020**, which offers high speed data, low latency and massive connectivity.
- **5th Generation Mobile Network:** It involves the use of millimeter wave (mmWave) or sub-6 GHz frequencies, enabling **massive multiple-input multiple output (MIMO) and beamforming** within a cell.

- **6th Generation Mobile Technology:** It is still under development and is expected to utilize **terahertz (THz) frequencies** or **optical wireless communication (OWC)** to offer significantly higher capacity and lower latency than 5G networks.
- **Key Features of 6G:**
  - **High Data Rates:** It has high data rates of **1 Tbps** and aims to enable **immersive reality, quantum communication**, and applications of artificial intelligence.
  - **Use of Artificial Intelligence**: AI will be used to improve the performance of 6G networks by managing traffic and ensuring data delivery reliability.
  - **MIMO and Network Slicing technology** would be employed for 6G technology too.
  - **Ultra-reliable low latency communication (URLLC):** It is a method of communication that ensures very low latency even in congested networks.



About Bharat 6G Alliance (B6GA)

- B6GA is a collaborative platform consisting of **public and private companies, academia,** research institutions, and Standards development organizations.
- **Aims:** To make **India a global leader in 6G technology** and to ensure that India has access to the latest and most advanced mobile telecommunications technology.
- **Objective:**
  - Promote high-impact open research and development (R&D) initiatives.
  - To facilitate market access for Indian telecom technology products and services.
  - Promote technology ownership and indigenous manufacturing.
  - Create a culture of technology co-innovation.
  - Promote the development of **Intellectual Property (IP)** creation of 6G technology.

Significance of 6G Technology

- **Sustainability:** 6G will promote sustainability by supporting data collection and closed-loop control of numerous appliances by enabling faster and lower cost-per-bit connectivity.
- **Energy-efficient technology:** 6G technology will be much more energy-efficient, turning off components and reducing capacity when demand is low.
- **Innovation and Economic Growth:** 6G technology will fuel innovation and create new opportunities for businesses and industries, driving economic growth, job creation, and technological advancements in various sectors.
- **Autonomous Vehicles:** The improved network capabilities of 6G could enable more reliable and safer autonomous vehicle communications.
- **Secure:** 6G networks will be built to withstand threats such as jamming.

Potential Applications of 6G Technology:

- **Healthcare:** 6G with IoT devices will enable patients to access healthcare services on demand and in an emergency. Example, fully AI-enabled ambulances transmitting critical health parameters to the doctor at hospital.
- **Agriculture:** It would help create an intelligent predictive system using IoT and AI/ML approaches to anticipate yield, irrigation schedule, and crop health information.
- **Education**: It can enable democratization of quality education by allowing students to access high quality educational resources and enabling resource sharing among institutions.
- **Internet of Things (IoT):** The high capacity and low latency of 6G will make the Internet of Things (IoT) more effective, leading to a seamless hyperconnected world.
- **Real-time gaming and virtual reality**: 6G's low latency will make it possible for users to play real-time games and experience virtual reality without any lag.
- **Smart cities:** 6G will be used to connect devices in smart cities, such as traffic lights, streetlights, and security cameras.

Challenges Related to 6G in India

- **Standardization Challenges**: Establishing consensus on standards to ensure interoperability and compatibility across different networks and devices is a critical and complex task.
- **Infrastructure Requirements**: The Bharat 6G project demands significant development in infrastructure to support technologies like terahertz communication and MIMO technology.
- **Funding Challenges**: Substantial investment is needed to drive the research and development stages from ideation to commercialization of 6G technology..
- **Technological Challenges**: The deployment of 6G involves utilizing high-frequency bands like THz, which can provide higher data rates but also face issues such as narrow beam transmission and penetration losses.
- **Security and Privacy issues**: With the increase in connectivity, ensuring robust cybersecurity measures becomes more crucial.
- **Lack of fiber connectivity:** With less than 30 percent of the country's telecom towers now linked by fiber, the networks are ill-equipped to support 6G data speeds.
- **Lack of Digital Inclusion**: It is vital to ensure that 6G technology benefits all sections of the population, including rural areas.

Conclusion: India has the necessary resources to drive the 6G wave globally and leverage this powerful force multiplier to transform itself into a leading global supplier of advanced, relevant, and affordable telecom systems and solutions. India should prioritize research on 6G technologies for the next decade to enhance its implementation and resource allocation, so that India can secure a leading role in global 6G adoption.

Keywords: Network Slicing, Millimeter wave (mmWave) frequencies, MIMO (Multiple-Input Multiple-Output)

FACIAL RECOGNITION TECHNOLOGY

Context: Complaints have been raised about Digit Yatra, a biometric boarding system using **Facial Recognition Technology**, where security personnel and airport staff were **collecting their biometrics for the app, using coercion and deceptive** methods.

About Facial Recognition Technology (FRT)

- Facial recognition technology is a **biometric technology that uses algorithms to identify and authenticate individuals** based on their unique facial features.
- Computer algorithms map **unique facial landmark**s such as shape of cheekbones, contours of lips etc. and convert these into a numerical code, termed a **faceprint**.
- For verification or identification, the system compares faceprint generated with a large existing database of faceprints.

Applications of Facial Recognition Technology (FRT):

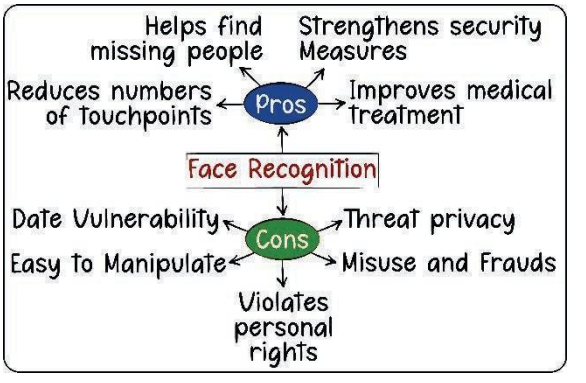
- **Security and Surveillance:** It can enhance security and surveillance systems by identifying individuals in real-time, enabling law enforcement agencies to locate and track suspects.
- **Smart Cities:** It can contribute to the development of smart cities by enabling traffic monitoring, crowd management, and public safety initiatives.
- **Healthcare:** FRT can assist in patient identification, ensuring accurate medical record matching and preventing errors.
- **Identity Verification:** FRT can replace traditional methods like PINs or passwords with biometric authentication, improving user experience and security.
- **Border Control and Travel:** FRT can expedite the processing of travelers at airports and border checkpoints. Example Digi Yatra
- **Retail and Marketing:** Retailers can utilize facial recognition to analyze customer demographics, behavior, and emotions in real-time. This data can help personalize marketing efforts, optimize store layouts, and improve customer experiences.

Artificial Intelligence and Facial Recognition powered Solution for Telecom SIM Subscriber Verification (ASTR)

- The **Department of Telecommunications (DoT)** has developed an artificial intelligence based facial recognition tool known as ASTR.
- It has the capability of **running checks on subscriber databases of telecom operators** to deduce whether it contains multiple connections associated with the same person.

Worldcoin: It is a **cryptocurrency** that uses **iris scans** to verify the identity of its users. Founded by **Sam Altman,** the former CEO of OpenAI, Worldcoin aims to create a global financial network that is accessible to everyone.

Benefits of Facial Recognition Technology (FRT)



- **Faster Processing**: Facial recognition allows for fast and smooth remote identity verification.
  - Eg. **Digi Yatra** - Digital processing of passengers at the airports. Passengers will be automatically processed based on facial recognition system.
- **Improved User Experience:** Facial recognition systems offer a unique, smooth, and hassle free user experience, reducing the wait times.
- **Secure Method**: Like any other biometric method Facial recognition systems are secure and use unique, un-inimitable facial fingerprints.
- **Increased Compliance**: Facial recognition through video identification is the only standard method recognised for remote identity verification for high-risk operations such as opening bank accounts, signing contracts, etc.

Concerns associated with the use of Facial Recognition Technology (FRT)

- **Privacy and Consent:** Lack of control over storage, extent, and informed consent with respect to use of facial data by public and private players, resulting in privacy invasion
- **Data Protection law:** Absence of FRT- specific regulatory set up and legal framework to govern data protection, storage and use exists in the context of personal biometric data.
- **In-accuracy:** Technical errors due to occlusion (a partial or complete obstruction of the image), bad lighting, facial expression, ageing etc. leading to inaccurate identification.
- **Technological challenges:** FRT is prone to digital attacks or the use of physical or digital portraits, 3D-Models, such as masks or deep-fakes etc. to bypass the system.

Way forward

- **Legal framework:** There is an urgent need to regulate the use of FRT systems and a data protection law that would mandate necessary safeguards in the collection and storage of user data.
- **Accountability**: Clear mechanisms and bodies for oversight and accountability need to be established including requirements for audits and transparency reports.
- **Consent:** Structures for consent that take into consideration passive data collection need to be defined for the use of FRT in criminal and non-criminal cases.
- **Capacity building:** To ensure that end users of the technology are fully trained in both the technical and ethical dimensions of FRT, it is imperative that comprehensive training is provided.
- **Eliminate biases**: The FRT systems datasets and software interface needs to be constantly updated to ensure equality and minimize potential biases based on skin color, religion, caste, etc.

Conclusion: The future of facial recognition technology holds even more potential. However, it is crucial to address concerns related to privacy, data security, and potential biases in facial recognition algorithms. Striking a balance between technological advancements and safeguarding individual rights and ethical considerations will be key to the successful and responsible deployment of facial recognition technology in the future.

Keywords: Biometric Technology, Smart Cities, Identity Verification Digi-Yatra and Mass Surveillance.

RADIO FREQUENCY IDENTIFICATION

Context: National Highways Authority of India (NHAI) has launched the 'One Vehicle, One FASTag' initiative that aims to discourage user behavior of using single FASTag for multiple vehicles or linking multiple FASTags to a particular vehicle.

About FASTag and RFID

- FASTag is a device that employs **Radio Frequency Identification (RFID) technology** for making toll payments directly while the vehicle is in motion.
- RFID is a **passive wireless technology** used for tracking or matching items or individuals.
- **Working of RFID Technology:**
  - The system consists of two main components: **Tags and Readers**. Readers emit radio waves and receive signals from RFID tags.
  - RFID tags use **radio waves** to communicate their identity and other information.

- Tags can be read from **several feet away** and **don't require direct line-of-sight** with the reader.
- The technology has been approved since before the 1970s, but has gained popularity recently. Its applications include **global supply chain management, pet microchipping** etc.

Applications of RFID

- **Army Asset Tracking:** Indian army has adopted RFID asset tracking system, to enhance the management and control of assets within the Indian Army, ensuring improved efficiency and accuracy in inventory tracking.
- **Retail and Supply Chain:** Retail stores can use RFID tags to track inventory, prevent theft, and improve customer service.
- **Access Control and Security:** It can be used to identify and authenticate people, vehicles, or objects, and grant or deny access to restricted areas, such as buildings, parking lots, or events.
- **Medical and Hospital:** It can store and update medical records, track the location and availability of medical devices, prevent medical errors, and monitor the condition and vital signs of patients
- **Logistics and Shipping**: It can be used to label and track packages, containers, pallets, or vehicles, and provide information such as origin, destination, contents, and status.
- **Automation of Manufacturing:** RFIDs can be used to identify and track the components, tools, and machines involved in the production, and provide feedback and instructions for optimal performance.
- **Animal Tracking:** RFIDcan be used to monitor and manage the health, welfare, and behavior of animals, both domestic and wild.
- **Other applications**: RFIDs can be used for library management, contactless payment, sports and entertainment etc.

Significance:

- **Enhanced Tracking and Monitoring:** RFID technology revolutionizes the management of specific inventory systems like ammunition by providing real-time tracking and monitoring capabilities.
- **Increased Safety and Efficiency:** RFID enhances safety by reducing human errors and provides automated checks that prevent the issue of expired or faulty stock.
- **Streamlined Processes:** RFID technology optimizes operations within logistical frameworks by streamlining processes at depots and storage facilities.
- **Cost Reduction in Inventory Management:** By implementing RFID systems, organizations can minimize inventory carrying costs through more efficient logistics and resource allocation.
- **Operational Efficiency:** RFID fosters a more efficient operational environment by ensuring that resources are used more judiciously and that inventory levels are maintained accurately.

Challenges in RFID Technology

- **High Initial Costs:** The initial investment required for RFID technology can be substantial, making it less accessible for smaller operations or those with limited budgets.
- **Technical Issues:** RFID systems can encounter technical difficulties such as signal interference from metal and liquids, reader collision, and tag collision.
- **Privacy and Security Concerns:** The capability of RFID to track and store sensitive information raises privacy concerns.
- **Standardization and Compatibility Issues**: The lack of global standardization for RFID frequencies and technologies can lead to compatibility issues across different systems and countries.

Conclusion: RFID holds immense potential for the future. Its applications in various industries, including supply chain management, logistics, and inventory tracking, have shown significant benefits. With its ability to provide real-time data, improve operational efficiency, and enhance security measures, RFID technology is poised to revolutionize how we manage and track assets.

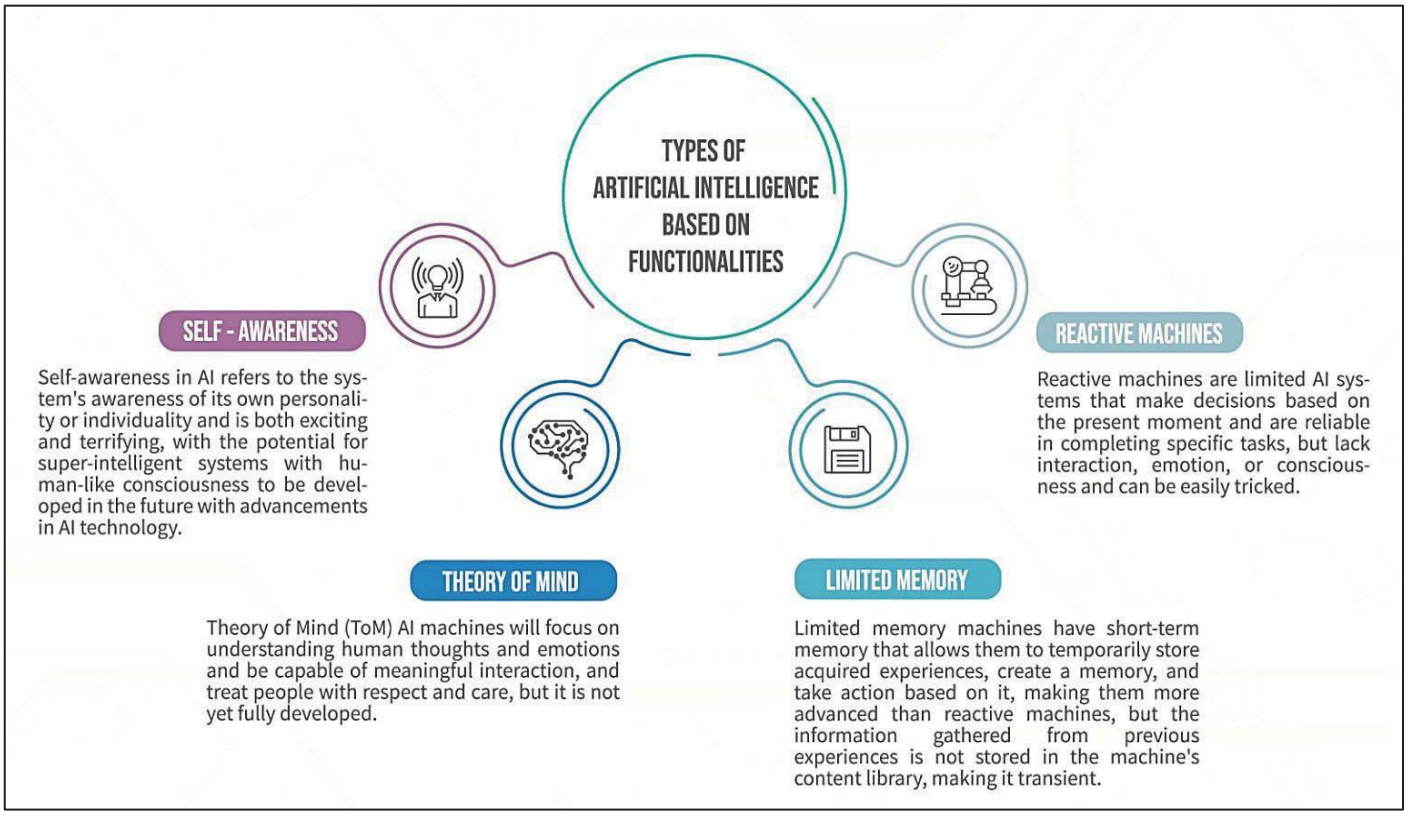
Keywords: line-of-sight, Munitions India Limited, Ordnance Factories Board.

ARTIFICIAL INTELLIGENCE

About Artificial Intelligence (AI)

- Artificial intelligence is the branch of computer science concerned with making computers behave like humans. It refers to the ability of machines to perform cognitive tasks like thinking, perceiving, learning, problem solving and decision making.

- **Types of Artificial Intelligence**
  - **Weak artificial intelligence:** It embodies a system designed to carry out one particular job. **Example:** Amazon's Alexa and Apple's Siri.
  - **Strong Artificial Intelligence:** These systems carry on the tasks considered to be human-like. They are programmed to handle situations in which they may be required to problem solve without having a person intervene. **Example: Self-driving cars**



India's Initiatives for Developing AI:

- **NITI Aayog Contribution:** NITI Aayog has come with the **'National Strategy for Artificial Intelligence' Discussion Paper** that focuses on establishing the International Conference on Tools with Artificial Intelligence (ICTAI) in the country through private sector collaboration.
  - **AIRAWAT (AI Research, Analytics and knowledge Assimilation platform):** NITI Aayog is to set up India's first AI-specific cloud computing infrastructure called AIRAWAT.
- **Global Partnership on Artificial Intelligence (GPAI):** In 2020, India joined with 15 other countries to form the GPAI to establish frameworks for the responsible utilization of emerging technologies.
- **INDIA AI Mission:** Union Cabinet has approved the comprehensive national-level India AI mission for the **period of 5 years**. INDIA AI is a knowledge portal, research organization and ecosystem-building initiative, to unite and promote collaborations with various entities in India's AI ecosystem.

Benefits of AI:

- **Increase in Global GDP:** An increase in global GDP by 14% or $15.7 trillion by 2030 is predicted due to ongoing technological advancements in AI.
- **Boosting annual growth rate:** The discussion paper' **'Towards Responsible#AIForAll'** by Niti Aayog states that there is a potential for large-scale adoption of AI which can boost the country's **annual growth rate by 1.3 per cent,** by 2035.
- **Enhanced Productivity:** There is broad consensus on increasing productivity by adopting AI in producing goods and services. Ex. MIT study shows 14% increase in productivity due to AI.
- **Creation of New Job:** AI may result in automating some routine jobs but will also result in job creation in various **data science, data curation** etc.

- **Innovation:** A recent survey among US professionals reveals that **almost 70% found AI** helping them to be faster, smarter, and more innovative.
- **Effective Policy Implementation:** Pradhan Mantri Fasal Bima Yojana (PMFBY) plans to use Artificial Intelligence technologies to carry out pilot studies for **Optimization of Crop Cutting Experiments (CCEs**) in various States.

Issues associated with Artificial Intelligence:

- **Labour Replacement:** AI can automate repetitive tasks and with generative AI, even creative tasks can be done efficiently and fast, thereby replacing labor.
- **AI Bias:** AI systems can perpetuate existing biases present in training data, leading to discrimination against certain groups.
- **Social Manipulation:** AI-powered algorithms can be used to spread misinformation, influence public opinion, and manipulate social behavior.
- **Rights of AIs**: AIs are still simple and mostly disembodied programs. But, as AIs become more complex and start to have physical, **possibly human shapes**, and more numerous, what rights they should have is debatable.
- **Unintended Consequences**: AI systems can produce unexpected outcomes due to their complexity, which can have negative impacts on society.
- **Disruptive Nature:** AI could be highly disruptive as it is more likely to displace middle-class, white-collared jobs; in comparison, earlier technological advancements displaced people from lower-paid farm jobs to higher-paid factory floor jobs.
- **Multiple Challenges:** AI could create deep challenges for society, including in the labor market, politics, data privacy, crime and warfare; these challenges are difficult to anticipate and plan for.
- **Contrary to Ethical Philosophy:** Immanuel Kant's ethical philosophy emphasizes **autonomy, rationality, and the moral duty of individuals.** Applying Kantian ethics to the use of AI in decision-making within governance could lead to serious concerns.

Way Forward:

- **Reskilling and upskilling:** To match with the age of AI, it will require reskilling and upskilling of the workforce.
- **Integration of AI with Curriculum:** The Central Board of Secondary Education (CBSE) announced its plan to introduce Artificial Intelligence as an elective for students from classes 9 to 12.
- **Stepping up Cyber regulations:** Governments would have to step up their cyber regulations with respect to the new challenges posed by AI.
- **International Collaboration:** Member States should work with international organizations, educational institutions and private and non-governmental entities to provide adequate AI literacy education to the public on all levels in all countries in order to empower people.
- **Focus on online Education:** The PwC report suggests that the greatest economic gains from AI will come from China, with a projected **26% boost to GDP by 2030.**

Conclusion: India's strategic embrace of Artificial Intelligence (AI) promises significant societal and economic enhancements. However, challenges such as labor displacement and AI bias need addressing. Prioritizing workforce reskilling, AI education integration, and robust cyber regulations will ensure India navigates AI advancements responsibly, balancing technological benefits with ethical considerations.

Keywords: Amazon's Alexa, AIRAWAT, INDIA AI Mission, Crop Cutting Experiments (CCEs), AI Bias, human shape, Kantian ethics.

GENERATIVE AI AND LLM

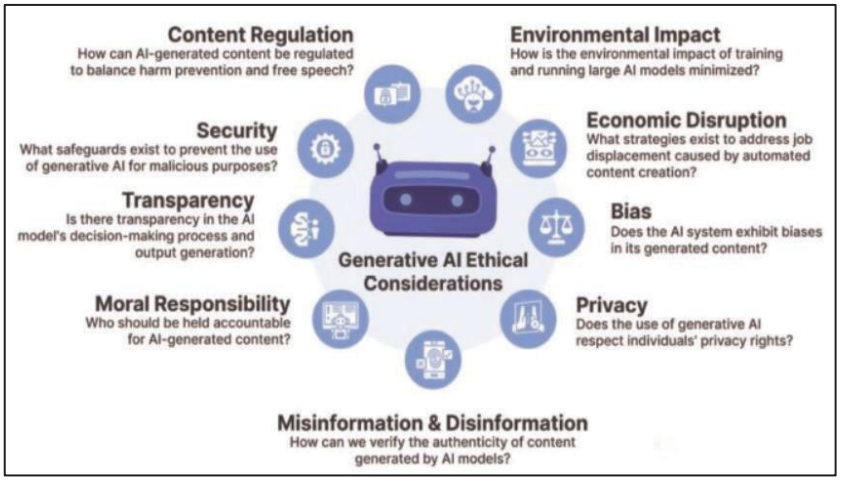
Context: Generative AI tools such as ChatGPT, DALL.E, Gemini and other large language models (LLMs) are enhancing productivity and efficiency across multiple sectors. However they also carry risks such as bias, exclusion and discrimination.

About Generative AI:

- It is a **cutting edge technological advancement** that utilizes machine learning and AI to create new forms of media, such as text, audio, video, and animation.
- It uses advanced machine learning capabilities like **large language models, neural translation,** information understanding, and reinforcement learning to generate new and creative short and long form content, synthetic media, and even deepfakes with simple text, also known as **prompts.**

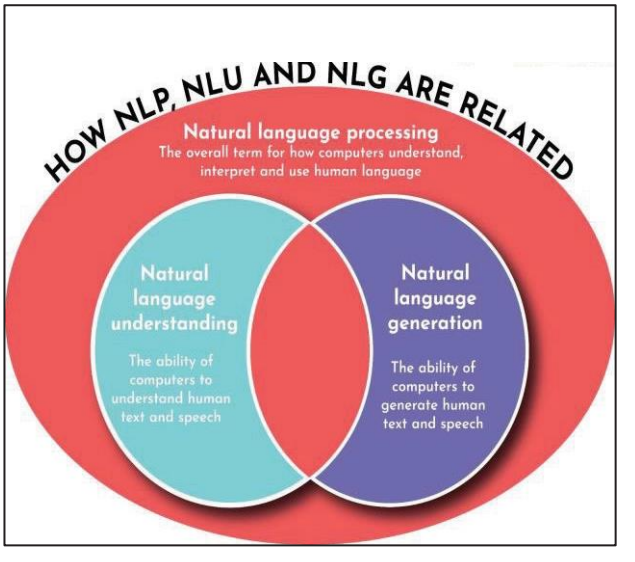
Applications of Generative AI

- **Content Creation: Gen AI models like GPT-4, Gemini can generate text, codes and automate storytelling.**
- **Media Production and Design:** Gen AI models like DALL-E, LUMEN etc. can carry out image synthesis, video generation and video game designing.
- **Healthcare**: Gen AI can aid in predicting molecular structures and generating potential drug compounds, thus accelerating drug discovery process. It also assists in medical image interpretation.
- **Entertainment**: Gen AI can help in music composition and creation of virtual characters in the animation industry.
- **Business and Marketing:** Gen AI assists in content personalization and creating tailored messages. It also allows for the creation of intelligent chatbots and virtual assistants
- **Education:** Generative AI facilitates Automated Tutoring and adaptive learning styles.
- **Simulation and Training:** Generative AI contributes to the development of realistic virtual environments for training purposes, such as flight simulations, medical procedures, and military training.



About Large Language Model (LLM)

- LLM is a type of artificial intelligence model that has been **trained through deep learning algorithms** to **recognize, generate, translate, and/or summarize** vast quantities of written human language and textual data.
- **Foundation Model:** Large language models (LLMs) are **foundation models** that utilize deep learning in **natural language processing (NLP)** and **natural language generation (NLG)** tasks. For the purpose of helping them learn the complexity and linkages of language, large language models are pre-trained on a vast amount of data.



Importance of Large Language Models:

- **Generating Human-like Content:** LLMs trained on internet-scale datasets with hundreds of billions of parameters can now **generate human-like content**.
- **Augmenting human creativity and improving productivity:** LLMs can read, write, code, draw, and create in a credible fashion and **augment human creativity and improve productivity**.
- **Language Translation:** LLMs can be used to translate text between languages. facilitating easy cross-cultural communication and breaking down language barriers.
- **Increased Efficiency:** LLMs can comprehend human language, making them ideal for completing monotonous or labor-intensive tasks.
- **Prompts:** It can build an AI system capable of generating human-level text based on simple prompts without any additional programming required making it possible to create entire articles, even books using only basic input parameters.

Challenges associated with LLMs and AI:

- **Huge Infrastructure Cost:** Significant capital investment, technical expertise, and large-scale infrastructure are necessary to maintain and develop LLMs.
- **Scale of Data Required:** Companies struggle to get access to large enough datasets to train their large language models.
- **Technical Expertise:** Due to their scale, training and deploying large language models are very difficult and require a strong understanding of deep learning workflows, transformers, and distributed software and hardware.

- **Context Window:** Each large language model only has a certain amount of memory, so it can only **accept a certain number of tokens as input**.
- **Reliability and Bias:** Language models' capabilities are limited to the textual training data and thus, **may include false information, race, gender bias, etc.**
- **Skills Shortage:** A lack of talent with expertise in these models makes it difficult to implement and use them effectively.
- **Cultural Biases:** These models primarily focus on English but India's rich linguistic diversity demands a more inclusive approach.
- **Job Losses:** The increasing use of AI has raised concerns about the future of the job market. AI could replace 300 million full-time jobs worldwide, affecting almost 20% of the global workforce.

Way Forward:

- **Consideration of Ethical Implications:** While LLM offers tremendous potential, it is essential to consider the ethical implications and challenges associated with its deployment.
- **Ensuring Transparency and Accountability:** As an AI language model, LLM reflects the biases and limitations in the data it was trained on. It is crucial to mitigate any biases and ensure transparency and accountability in its usage.
- **Responsible Use:** Striking a balance between innovation and responsible deployment is paramount to maximize the benefits while minimizing potential risks.
- **Human-centric Approach:** While LLM can simulate human-like interactions, it is essential to recognize its limitations and ensure that human oversight and judgment are integrated into its applications.
- **Skill Development:** Enterprises must invest in training and development programs to ensure that their teams have the skills to use these models effectively.
- **India specific LLM:** It is an urgent strategic need for India to develop its own LLM tailored to Indian languages.

Conclusion: As Generative AI and Large Language Models (LLMs) like ChatGPT and DALL.E revolutionize multiple sectors, they bring immense potential alongside significant risks such as bias and discrimination. It's crucial to address these challenges through ethical frameworks, transparency, and accountability in AI applications. Moving forward, balancing innovation with responsible use will ensure that AI technologies enhance productivity while respecting societal norms and ensuring equity.

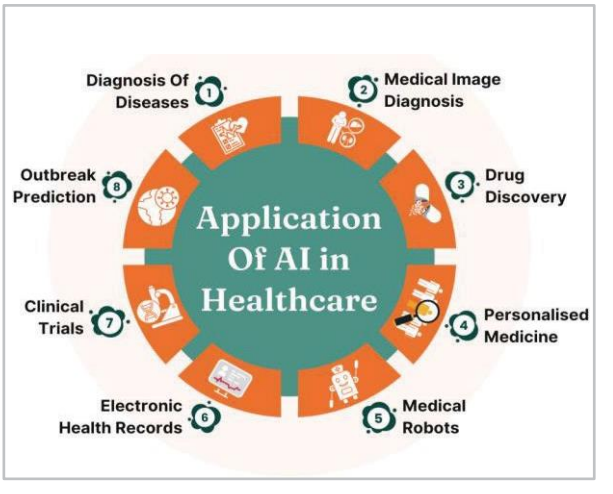
Keywords: Image generation, Music generation, Education, Healthcare.

ROLE OF ARTIFICIAL INTELLIGENCE IN HEALTHCARE

Context: Artificial Intelligence has the potential to revolutionize **India's healthcare model**, making it a global leader in **AI-driven healthcare solutions** and healthcare more accessible and affordable.

AI and Healthcare Sector in India:

- As per the **NASSCOM report**, the market size of the healthcare industry in India was valued at **$372 billion in 2022.**
- As per a **World Economic Forum report, AI expenditure** in India is expected to reach **$11.78 billion by 2025** and add **$1 trillion to India's economy by 2035**.
- **Union Budget 2023-24**: The healthcare sector has been **allocated INR 89,155 crore** to undertake all the **new-age research and innovation**-based healthcare initiatives on a massive scale.



Application of AI in Healthcare:

- **Medical imaging:** AI in MRI and CT imaging allows **deep learning of every organ** of the body under scan.
- **Analysis of Electronic Health Records (EHRs):** Using AI, it is possible to identify patients who are at a **high risk of developing chronic diseases**. **Example, Apollo Hospitals** partnered with **Microsoft** to create an AI-powered **cardiovascular disease risk score**.
- **Reduce out-of-pocket expenditure:** According to the **Economic Survey 2022-23,** almost **half of all health spending** in India is still paid by patients themselves directly at the point of treatment.
  - **Example:** A report by **Accenture** says that AI might save the Indian healthcare sector **$4.4 billion by 2025**.

- **Early Diagnosis of Diseases:** AI algorithms can be utilized in **wearable devices, such as smartwatches or fitness trackers**, to continuously monitor vital signs, collect health data, and identify patterns or anomalies.
- **Promoting Medical Value Travel (MVT):** India has emerged as a global MVT hub, particularly in the fields of **oncology, orthopedics, and robotic surgery**.

AI Healthcare Startups in India:

- **HealthifyMe**: With the help of AI, the app monitors calorie intake and gives dietary recommendations, tips and nutritious recipes.
- **Niramai:** This company launched a patented portable device called Thermalytix which employs AI to accurately detect early-stage breast cancer.

Challenges of Integrating AI in Healthcare:

- **Blind spots in data collection**: Lack of access to reliable data is one of the main problems. To be trained efficiently, AI systems require a **lot of high-quality data.**
- **Biases:** AI models use audio data to diagnose diseases such as Alzheimer's. If these models are not trained with a wide range of accents, their outputs can be biased.
- **Privacy Issues: Sensitive healthcare data** may be jeopardized since AI systems must be educated on enormous volumes of data.
- **Misuse**: Linking health data with other systems will create new avenues for discrimination. **Example, health insurance data** can be leveraged by banks to evaluate eligibility for loans.
- **Ethical Issues-Accountability:** Determining liability in cases of AI-driven medical errors can be challenging. A comprehensive legal framework must define liability and accountability.
- **Cultural Acceptance**: While AI offers remarkable capabilities, the **expertise, intuition, and compassion** of healthcare professionals which make a critical difference remain indispensable.

Government Steps for Integrating AI in Healthcare:

- **Healthlocker**: Digital national health database backed with **cloud-based storage system** which serves as a single source of health data for the nation.
- **Personal Health Records (**PHR): Allow data to be available for citizens and for medical research purposes.
- **Digi Doctors**: A digital directory of doctors along with their name, specialization, qualifications, and number of years of experience.
- **Coverage and claims** digital platform.
- National health analytics platform.
- Unique digital health ID for each citizen.

Way Forward:

- **Boosting investments:** AI integration into healthcare requires critical investments in the workforce, infrastructure, regulatory mechanisms, stakeholders, and business models.
- **Promoting Telemedicine**: Incorporating AI with telemedicine platforms can extend quality healthcare access to rural and underserved areas.
- **Research & Development**: Government must also invest in public and private organizations like NITI Aayog, Tata Institute of Healthcare, Apollo Hospitals, etc. to facilitate the research being done to integrate AI-based solutions into healthcare.
- **Ensuring Data Security**: Digital transformation success is not possible without security thus **safeguarding of patient data** against breaches or data loss and **ensuring robust data security** is the need of the hour.
- **Data Standardisation**: Promoting the standardization of healthcare data formats by **encouraging EHRs and interoperability** between different healthcare systems and providers.

Conclusion:

India stands at a **pivotal moment** in its healthcare journey. By **reimagining its healthcare model**, the country can position itself as the global destination for medical value travel, **a powerhouse in AI-driven healthcare solutions**.

Keywords: Electronic Health Records (EHRs), out-of-pocket expenditure, Medical Value Travel (MVT), HealthifyMe.

PREVIOUS YEAR QUESTIONS		
1.	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? (10 marks)	2023
2.	What are the areas of prohibitive labour that can be sustainably managed by robots? Discuss the initiatives that can propel research in premier research institutes for substantive and gainful innovation. (200 words 12.5 marks)	2015

USE OF AI IN OTHER DOMAINS:

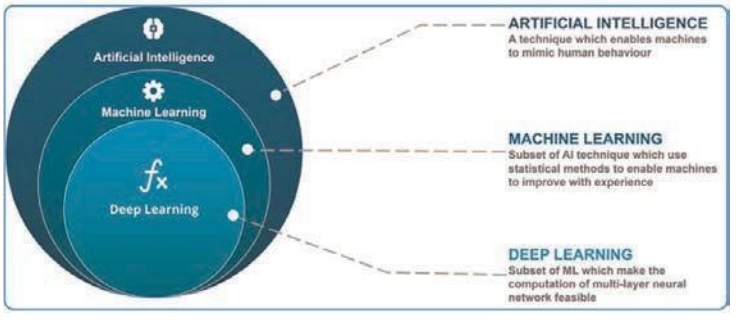
- **Responsible AI in the Military Domain (REAIM)**
  - REAIM summit was held in The Hague, Netherlands, to **raise awareness of the opportunities and challenges** associated with the use of AI in the military domain.
  - **Aim:** To foster cooperation between different stakeholders in order to **develop responsible AI solutions** for the military.
  - **Recommendations of REAIM:**
    - Develop **international norms and standards** for the use of AI in the military.
    - Promote **transparency and accountability** in the development and use of AI systems.
    - Ensure that AI systems are **not biased or discriminatory**.
    - Protect the **privacy and security of data** used to train and operate AI systems.
    - Promote **responsible research and development** of AI in the military domain.
- **Role of AI in Election**
  - **Increased and Effective Voter Engagement:** Integration of AI and social media can boost voter engagement by educating on a candidate's profile and key issues of the region. It will also encourage participation, especially among first-time voters.
  - **Promoting Inclusiveness:** With the help of AI-based Apps like Bhashini, the information can be made available in multiple Indian languages and promote inclusiveness.
  - **Election Transparency and Security:** AI can help in the implementation of transparent advertising policies, rolling out content labels, and restricting misinformation.
  - **Identification of threats: ML algorithms** can help in the identification of election threats that may indicate attempts of interference, thus ensuring the security of EVMs and voter databases.
  - **To Streamline Electoral Processes:** AI can automate various tasks, like voter registration, tallying and can lead to more efficient electoral processes.
  - **Grievance Addressing:** AI-based chatbot can be introduced on the Election Commission's website to monitor and address the grievances.
  - **Cost-Effective:** Generative AI can create campaign materials at a significantly lower cost and with greater efficiency, saving time and resources.

ROLE OF AI IN WEATHER FORECASTING

- **Improve Accuracy:** AI software can make the weather prediction process more effective as one of the key strengths of AI is its ability to work with large sets of data.
- **Improved Efficiency:** Recently, Nvidia, Google DeepMind, and Huawei have introduced machine-learning methods that can predict the weather at least as accurately as conventional methods and much more quickly.
- **Combating Climate Change:** Scientists are using AI techniques for accurate forecasts amidst climate change catastrophes, that help to minimize damage and save lives
- **Continuous Adaptation Process:** AI in weather prediction continuously analyzes data, learning patterns for more precise forecasts without human input or rest.
- **Preparedness:** AI tools like Huawei's Pangu-Weather Model enhance disaster preparedness by predicting natural disasters well in advance, allowing timely precautions that can save lives by enabling meteorologists to study weather patterns in real-time.

Keywords: REAIM, Effective Voter Engagement, Weather Forecasting, Climate Change

DEEP LEARNING

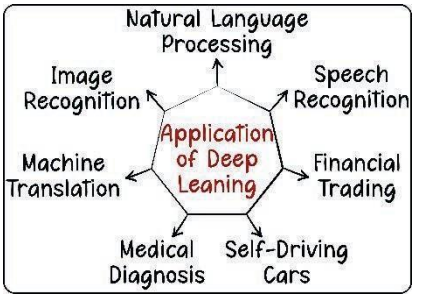


About Deep Learning: Deep learning is a **form of machine learning** that utilizes **artificial neural networks (ANN)** to acquire knowledge from data. Neural networks can decipher complex data patterns like the human brain, which are beyond traditional ML algorithms' capabilities.

Various Types of Neural Networks:

- **Neural Networks**: It is a ML algorithm inspired by the human brain. Neural networks consist of interconnected nodes or neurons that process and pass on input through a learning algorithm.

- **Shallow Neural Networks:** These networks contain only one layer of neurons, making them simpler to train but less adept at recognizing complex data patterns.
- **Deep Neural Networks:** It has multiple neuron layers and can learn intricate data patterns that shallow networks cannot handle.
- **Convolutional Neural Networks (CNNs):** Designed for image recognition, CNNs learn spatial relationships between pixels to accurately identify objects in images.
- **Recurrent Neural Networks (RNNs):** Tailored for sequence modeling, RNNs capture temporal relationships between sequence elements and can predict subsequent elements with high accuracy.



Challenges of Deep Learning:

- **Large Data Requirements:** Deep learning algorithms require large amounts of data to train.
- **High Computational Requirements:** Deep learning algorithms can be computationally resource intensive and expensive to train and run.
- **Overfitting:** Deep learning algorithms can be prone to overfitting, which is when the model learns the training data too well and is unable to generalize to new data.
- **Adaptability:** Deep learning systems sometimes struggle to adapt to changing real-world conditions, which may lead to outdated or irrelevant outcomes.
- **Ethical Considerations**: Deep learning has profound societal effects that can be both beneficial and detrimental. Important issues include privacy, discrimination, and the potential for manipulation, which require careful scrutiny.

Measures for overcoming challenges of Deep Learning:

- **Cost Efficiency**: There is a need to optimize model parameters, utilize cloud platforms, and choose cost-effective hardware to make deep learning affordable and feasible.
- **Enhance Interpretability**: Utilize analysis tools and visualizations, communicate results transparently, and acknowledge limitations.
- **Privacy Measures**: Promote ethical awareness, adhere to responsible AI principles, and engage stakeholders actively. Implement privacy safeguards through policies and legislation.
- **Adaptation to Real-world Change**s: Update models regularly, retrain them, and employ techniques like online and incremental learning to accommodate evolving real-world dynamics.

Conclusion: Deep learning is a powerful tool with the potential to revolutionize many industries. As deep learning technology continues to develop, we can expect to see even more amazing applications of this technology in the years to come.

Keywords: Image recognition, Natural language processing, Speech recognition, Machine translation, Medical diagnosis, Financial trading, Self-driving cars.

DEEP FAKES

Context: In response to various cases of deep fake videos creating misinformation in the society, the government is looking at IT rules to make WhatsApp disclose source ID.

About Deep Fakes

- Deep Fakes are **digital media i.e. video, audio, and images** edited and manipulated using Artificial Intelligence. It is basically hyper realistic digital falsification.
- Deep Fakes raise concerns about **misinformation, privacy violations, and the potential for malicious use in various contexts**, including politics and entertainment.
- Access to commodity cloud computing, public research AI algorithms, and abundant data and availability of vast media have made it easier to create and manipulate media.

Impact of Deepfake Technology:

- **Victims of Deep Fake Pornography**: The primary victims of malicious deepfake technology are women, with over **96% of deepfakes being pornographic videos.** This type of content threatens, intimidates, and psychologically harms individuals.
  - **Ex:** Nearly 4,000 celebrities found to be victims of deep fake pornography
- **Character Assassination**: Deepfakes can portray individuals engaging in antisocial behaviors and saying false things they never did, thus damaging their reputation.
  - **Ex**: Rashmika Mandana deepfake.
- **Erosion of Trust in Media:** Deepfakes contribute to a decline in trust in traditional media. This erosion can lead to a culture of factual relativism, damaging civil society.
- **National Security Threat:** Malicious nation-states can use deepfakes to undermine public safety, create chaos, and sow uncertainty in target countries.
- **Non-State Actors:** Insurgent groups and terrorist organizations can use deepfakes to manipulate and spread inflammatory speeches or provocative actions to incite anti-state sentiments among the public.
- **Liar's Dividend:** The existence of deepfakes can lead to the dismissal of genuine information as fake news.

Solutions to Combat Deepfakes:

- **Enhanced Media Literacy:** Media literacy efforts must be enhanced to cultivate awareness among masses to combat disinformation and deepfakes.
- **Regulations:** Implement meaningful regulations through collaborative discussions involving the technology industry, civil society, and policymakers.
- **Social Media Platform Policies:** Encourage social media platforms to take action against deepfakes. Many platforms have already established policies or acceptable terms of use for deepfakes. **Example:** Labeling content is an effective tool.
- **Technology Solutions:** Develop accessible and user-friendly technology solutions to detect deepfakes, authenticate media, and promote authoritative sources.
- **Individual Responsibility:** Every individual should take responsibility for being critical consumers of online media. Before sharing content on social media, pause and think about its authenticity.
- **Establish a Research and Development Wing:** India can consider establishing a dedicated research and development entity similar to DARPA, which has been at the forefront of deepfake detection technologies.

Conclusion: Deep Fakes pose a significant challenge in today's world, as they can be used to spread disinformation and manipulate digital content. As technology advances, it is crucial for AI-backed tools and detection methods to keep pace with the evolving nature of deep fakes.

What are shallow fakes?

- Shallow fakes or cheap fakes are **pictures, videos and voice clips created without the help of AI technology but by simple editing or by using other simple software tools like Photoshop.**
- **Shallow Fakes** are named so because they **represent a lower quality of image and video editing when compared to the high end creation of Deep Fakes.** Comparatively shallow Fakes can be easily created by using basic online tools and also easily recognisable.
- **Technology used:** They use simple technology and are manually altered or selectively manually altered or selectively edited.
  - **Example:** A conventional edit on a photo, or to change the speech patterns of a video, to mis-caption or mis-contextualize an existing image or video etc.

Keywords: Digital Media, Misinformation, Pornography, Liar's Dividend, Non-State Actors, Shallow fake.

EXTENDED REALITY

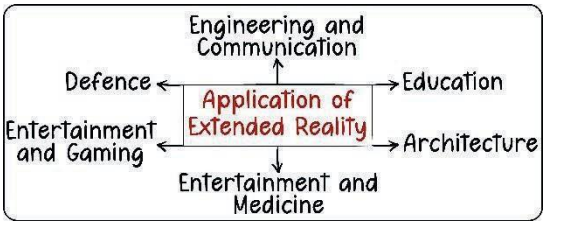
Context: India's Animation, Visual Effects, Gaming & Comics and Extended Reality (AVGC-XR) sector is expected to rise from current **$3 billion to $26 billion by 2030.**

About Extended Reality

- Extended reality (XR) is an umbrella term that encompasses any sort of technology that alters reality by **adding digital elements to the physical or real-world environment** by any extent, blurring the line between the physical and the digital world.
- XR includes **Augmented Reality (AR), Mixed Reality (MR), Virtual Reality (VR),** and any technology, even those that have yet to be developed, situated at any point of the virtuality continuum.
  - **Augmented Reality (AR):** AR is a technology that overlays digital information, such as images, text, or 3D models, onto the real-world environment. Example smartphone games like Pokémon Go, navigation apps and virtual try-on experiences for shopping.
  - **Virtual Reality (VR)**: VR is a technology that creates a completely immersive, computer generated environment. Users are typically isolated from the real world and surrounded by a virtual environment that responds to their actions. Example VR headsets.
  - **Mixed reality (MR)** is the intersection of AR and VR. It's where the physical and digital worlds collide, creating a seamless blend where virtual objects and information interact with the real world in real time. Example Microsoft hololens, Meta Quest.

Feature	Augmented Reality (AR)	Virtual Reality (VR)	Mixed reality (MR)
Definition	Overlays digital content on the real world	Creates a fully immersive virtual environment	Creates a virtual environment combined with the real world.
Interaction with Real World	Enhances real-world environment	Isolates users from the real world	Enhances real world experience.
Devices	Smartphones, tablets, smart glasses, heads-up displays	Dedicated VR headsets (Oculus Rift, HTC Vive)	Microsoft hololens, Heads-up display (HUD), MR glasses
Use Cases	Navigation, retail, healthcare, education	Gaming, simulations, training, virtual experiences	Gaming, remote work, education, healthcare.

Benefits of Extended Reality:



- **Enhanced User Experience:** XR offers an immersive user experience that allows users to interact with virtual objects as if they were real.
- **Improved Training and Education**: It has the potential to revolutionize education and training by providing a realistic and interactive simulation environment. Example Microsoft HoloLens has been used to teach anatomy, chemistry.
- **Increased Efficiency in Manufacturing**: XR can be used to streamline the manufacturing process by allowing designers and engineers to visualize and test products in a virtual environment.
- **Cost-Effective Marketing:** It can be used in marketing to create unique and memorable experiences that engage consumers.
- **Healthcare:** It will allow surgeons to use XR-powered X-ray vision to see under a patient's skin to blood vessels and bones during surgery.

Challenges of Extended Reality

- **High Cost:** XR technology is still in its early stages and is relatively expensive.
- **Data Privacy:** Issues surrounding data privacy and intellectual property emerge with the use of XR
- **Limited Compatibility**: It requires high-end hardware and software, which may not be compatible with all devices.

- **User Discomfort and Social Acceptance:** They are heavy, and uncomfortable to wear for long durations.
- **Ethical Considerations**: XR deployment involves several ethical questions like the possibility of addiction, social isolation, and psychological consequences on users.

Conclusion: As Extended Reality (XR) technologies like AR, VR, and MR evolve, they offer transformative potentials across various industries, enhancing user interaction, education, healthcare, and more. Ensuring responsible development and addressing challenges such as data privacy and ethical considerations will be key to realizing its full potential.

Keywords: AVGC-XR, Augmented Reality (AR), Mixed Reality (MR), Virtual Reality (VR), Meta Quest.

BLOCKCHAIN TECHNOLOGY

About Blockchain Technology

- Blockchain technology is a structure that stores transactional records (also known as block), of the public in several databases, known as the "chain", in a network connected through Peer-to-peer(P2P) nodes.
- This storage is referred to as 'digital ledger'.
- Every transaction in this edger(storage) is authorized by the digital signature of the owner, which authenticates the transaction and saves it from any tampering.
- Blockchain key characteristic features include decentralization, persistence, and anonymity.
- Blockchain technology discards the need for any third-party or central authority for peer-to-peer.

Significance of Blockchain Technology:

- **Decentralized mechanism**: Eliminates need for a third party validation of transactions.
- **Bringing transparency and efficiency**: It ensures transparency, as any asset of value can be represented and tracked.
- **Fraud prevention**: As data stored in several places is not easily accessible.
- **Blockchain Business Value:** WEF anticipates that 10% of global GDP will be stored on blockchain by 2025.
- **Applicability in diverse domains:** Blockchains find application in diverse domains like education, governance, finance & banking, healthcare, cyber security, power sector, etc.

Challenges of Blockchain Technology

- **Scalability:** Blockchain networks can become slow as the number of users and transactions increases, leading to transaction delays and high fees. Ex. Bitcoin's Proof-of-Work (PoW) mechanism can only handle around 7 transactions per second.
- **Energy Consumption:** PoW-based blockchains like Bitcoin require vast amounts of computing power to validate transactions, raising environmental concerns.
- **Interoperability:** Different blockchain networks often have their own unique protocols and standards, making it difficult for them to communicate and interact with each other. Ex. Ethereum and Bitcoin are not directly compatible with each other.
- **Security and Privacy:** Concerns exist around the potential for privacy violations due to the transparency of blockchain transactions.
- **Regulation and Adoption**: Regulatory uncertainty surrounding blockchain technology can hinder its adoption in various industries

Way Forward

- **Addressing Scalability and Energy Consumption:** By shifting to Proof-of-Authority (PoA) mechanism energy consumption could be reduced.
- **Enhancing Interoperability and Collaboration** through standardization, building bridges between different blockchains and collaboration between diverse stakeholders
- **Strengthening Security and Privacy:** Through advanced cryptography and secure coding practices and User education and awareness

Conclusion: Blockchain technology stands to revolutionize numerous industries by enabling decentralized, transparent, and secure transactions. As we look towards 2025, with an estimated 10% of global GDP potentially stored on blockchain, addressing scalability, enhancing interoperability, and improving energy efficiency through innovations like Proof-of-Authority (PoA) are critical for harnessing its full potential.

Proof of Stake (PoS) vs Proof of Work (PoW)

- Proof of work and Proof of Stake are the two major **consensus mechanisms** cryptocurrencies use to verify new transactions, add them to the blockchain, and create new tokens
- PoW is a **distributed consensus system** that relies on computing power to prove that someone has put in the required work to create a valid block proportional to their influence on the network.
- PoS validates cryptocurrency transactions through **randomly selected validators**. Here, owners of the cryptocurrency can stake their coins, which gives them the right to check new blocks of transactions and add them to the blockchain. This is known as the **concept of staking**.

Advantages of Proof of Stake:

- **Energy efficiency:** PoS is much more energy efficient than PoW as PoS does not require miners to use powerful computers to solve complex mathematical problems.
- **Scalability:** PoS is more scalable than PoW, as PoS does not require miners to solve complex mathematical problems, it can process more transactions per second.
- **Security:** PoS is just as secure as PoW. This is because validators are incentivized to behave honestly and to validate blocks correctly.

Disadvantages of Proof of Stake:

- **Centralization:** PoS can lead to centralization of the network. This is because validators who have more stake have a greater chance of being selected to validate blocks.
- **Security:** PoS is not as secure as PoW against **51% attacks**. This is because a 51% attack in PoS only requires control of 51% of the stake, while a 51% attack in PoW requires control of 51% of the mining hashrate.

Keywords: Peer-to-peer(P2P) node, Digital ledger, Anonymity, Decentralized mechanism, Proof-of-Authority (PoA)

VIRTUAL DIGITAL ASSETS-NON- FUNGIBLE TOKEN (NFT)

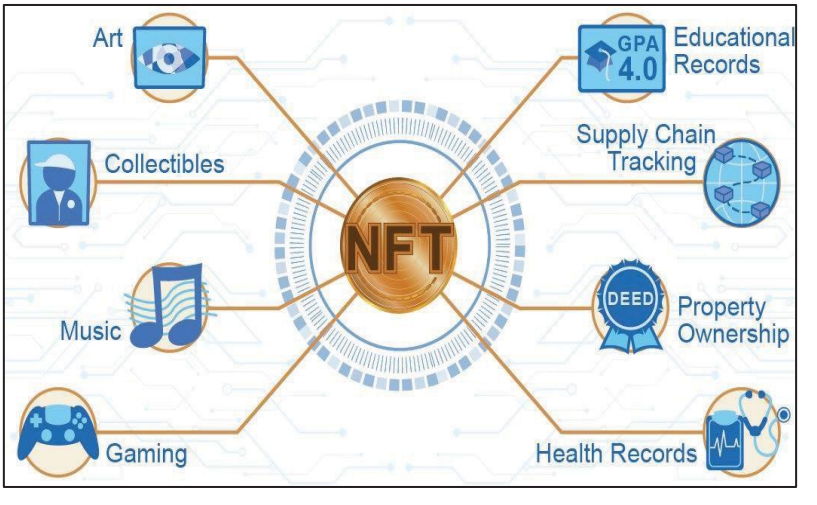
Context: The Ministry of Finance extended the Anti-money Laundering provisions to Virtual Digital Assets (VDA) businesses and service providers. In 2022, the government imposed a **30% tax on income from VDAs.**

About Virtual Digital Assets-Non- Fungible Token (NFT)

- **Virtual digital assets (VDAs)** are digital or electronic representations of value that are not legal tender and are not issued by any central bank or government. VDAs can be used to make payments, purchase goods and services, or to invest.
- **Non-Fungible Token (NFT)** is a **unique digital asset that is stored on a blockchain.** NFTs can represent anything from art to collectibles to in-game items. They are often bought and sold with cryptocurrency, and their value can fluctuate wildly.

Advantages of investing in NFTs:

- **Uniqueness:** Each NFT is distinct, making it different from any other token. This uniqueness adds value to the digital asset.
- **Indivisibility:** NFTs cannot be divided into smaller units. They exist as whole tokens, contributing to their scarcity.
- **Ownership and Authenticity:** NFTs serve as digital certificates of ownership, proving that the holder is the legitimate owner of the associated digital content.
- **Smart Contracts**: Many NFTs utilize smart contracts, self-executing contracts with the terms of the agreement directly written into code.
- **Value of NFTs:** NFTs are valuable because they are unique and cannot be counterfeited. They also represent ownership of a digital asset.
- **Purchasing Platform for NFT:** Some of the most popular platforms include OpenSea, Rarible, and Foundation, where NFT are purchased with cryptocurrency.



- **Creative Monetization:** NFTs allow artists, creators, and content creators to monetize their work directly, bypassing traditional intermediaries.
- **Interoperability and Cross-platform Integration:** NFTs can be integrated into various platforms and ecosystems, creating new opportunities for seamless asset exchange.
- **Enhanced Collectibility and Scarcity:** NFTs can create a sense of exclusivity and scarcity, appealing to collectors and enthusiasts, and potentially increasing the value of digital assets.

Challenges Associated With NFTs:

- **Complexity:** The technology and tooling behind NFTs are still nascent.
- **Legal and Regulatory Challenges:** NFT has no recognized legal definition anywhere in the world.
- **High Consumption of Energy**: They have a significant environmental impact, as they consume a lot of energy and generate a lot of emissions.
- **Prone to Speculation:** They are subject to market volatility and speculation, as the prices and demand of NFTs can fluctuate rapidly and unpredictably.
- **Counterfeit and Fraudulent NFTs**: There have been instances of fraudulent NFTs, which undermines trust in the NFT ecosystem and raises concerns about counterfeit NFTs.

Popular Examples of Non Fungible Tokens (NFTs)

- **Digital Art:** Artists can tokenize their digital artwork, allowing collectors to buy and own unique pieces.
- **Music and Videos:** Musicians and content creators can release limited edition NFTs, providing exclusive access or ownership to their fans.
- **Virtual Real Estate**: Some virtual worlds use NFTs to represent ownership of digital land or virtual items within the virtual space.

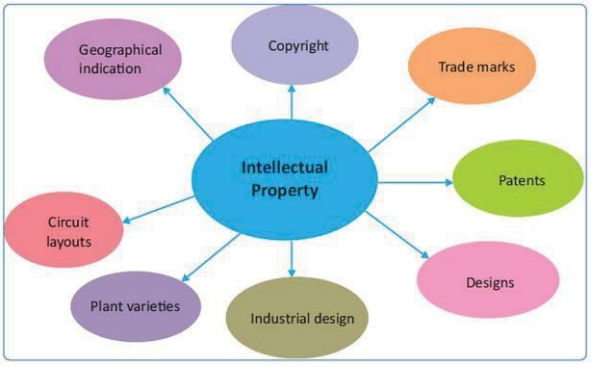
Conclusion: Non-fungible tokens (NFTs) have a promising future as they revolutionize ownership and value representation, enabling digital asset ownership, authenticity verification, and new opportunities in various industries, including art, gaming, and collectibles.

Keywords: Security Risks, AML and KYC Compliance.

5 ISSUES RELATING TO INTELLECTUAL PROPERTY RIGHTS

INDIA'S PATENT CHASE

Context: In 2023, global patent filings saw significant activity, driven particularly by India and China. Despite a slight decline in overall international filings due to economic uncertainties, India recorded the largest increase in Patent Cooperation Treaty (PCT) applications, with a growth of 44.6%, reflecting its expanding innovation ecosystem.



About Intellectual Property Rights (IPRs):

- IPRs protect creations of the mind, including inventions, literary and artistic works, designs, symbols, names, and images used in commerce.
- **Exclusive Rights:** These rights grant creators exclusive use of their creations for a specified period. **For example**, copyrights in India generally last for the lifetime of the author plus 60 years after their death, providing long-term protection and ensuring that creators can benefit from their work.

Status of IPR in India:

- India ranks **42nd in the International IP Index** for 2024, out of 55 countries evaluated. U.S topped the index.
- The IPR application filing has increased from **568049 in 2021-22 to 601789 in 2022-23.**
- Patent application filing increased by **24.64%, from 66440 in 2021-22 to 80211 in 2022-23**, showing an overall increase of 5.94%.
- Reduction in the time of patent examination from **72 months in 2016 to 5-23 months** currently.

About Indian Patent Regime:

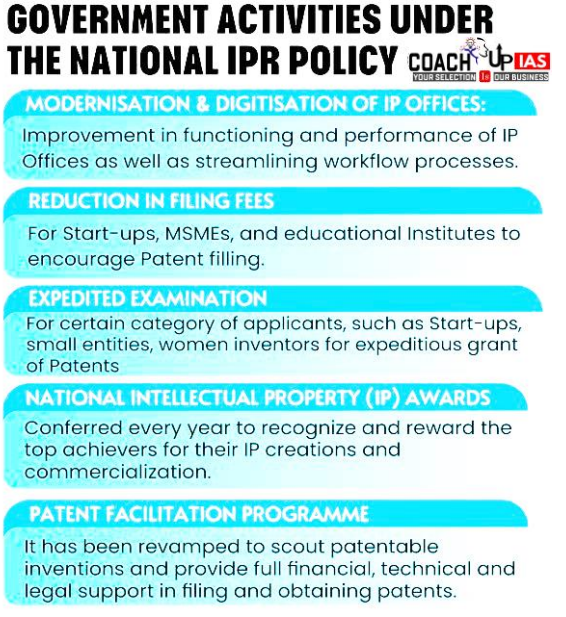
- **Patent**: It constitutes an exclusive set of rights granted for an invention, whether it be a product or process that introduces a novel approach to accomplishing a task or presents an innovative technical resolution to a challenge.
- **Indian Patent Act of 1970:** This act governs Indian patents. Under the act, patents are granted if the invention fulfills the following criteria:
  - It should be **novel**.
  - It should have inventive step/s or it **must be non-obvious.**
  - It should be **capable of Industrial application**.
  - It should **not attract** the provisions of **sections 3 and 4** of the Patents Act 1970.
- **IPR-Related Conventions:** India is also a signatory to several IPR related conventions, including the **Berne Convention, Budapest Treaty, Paris Convention** for the Protection of Industrial Property, and Patent Cooperation Treaty (PCT), all of which govern various patent-related matters

Need For Intellectual Property Rights:

- **Incentivizing Innovation:** IPRs encourage innovation by granting creators exclusive rights, fostering a conducive environment for research, development, and inventive endeavors.
- **Economic Growth and Competitiveness:** Protection of intellectual property incentivizes investment, stimulates economic growth, and enhances a nation's competitive edge in the global marketplace.
- **Fostering Creativity and Cultural Development**: IPRs safeguard creative works, promoting artistic expression, cultural preservation, and the development of diverse intellectual pursuits.
- **Technological Advancement:** Patents and copyrights drive technological progress by providing inventors and creators with a framework for protecting their contributions, fostering advancements in various fields.
- **Attracting Investments:** A robust IPR framework attracts investments by assuring investors that their intellectual assets will be protected, leading to increased funding for research and development initiatives.

Challenges Associated with Patent Filing in India:

- **Quantity vs Quality**: The prevalence of **low-quality patents** perpetuates a cycle under which patentees are incentivized to continue filing low-quality patents. This trend, termed the **"patent paradox".**
- **Lack of Efficiency in Granting Patent:** India lacks the ability to grant patents efficiently. Lack of skilled manpower and huge backlog creates delay in granting patents.
- **Decline in Venture Capital Funding**: **Persistent uncertainty** remains a burden on the worldwide innovation ecosystem, leading to a decline in VC funding across various regions.
- **IP protection and Enforcement**: According to the 2023 USTR Special 301 Report, India remains on the Priority Watch List due to significant challenges in IP protection and enforcement. These challenges include high rates of online piracy, an extensive backlog in trademark oppositions, and insufficient legal means to protect trade secrets.
- **Gender Disparity**: According to the 2023 USTR Special 301 Report, India remains on the Priority Watch List due to significant challenges in IP protection and enforcement. These challenges include high rates of online piracy, an extensive backlog in trademark oppositions, and insufficient legal means to protect trade secrets.



Way Forward:

- **Lessons from Chinese Patent Approach**: The focus should now shift towards ensuring that each patent granted represents a **genuine and significant innovation**.
- **Analysis of Patent Quality**: India should carry out a **post-facto analysis** of patent quality, possibly under the aegis of the **Office of Principal Scientific Adviser**.
- **Raising Awareness:** To further boost domestic patent filings, **partnerships among various stakeholders** would be crucial in creating and raising awareness about intellectual property.
    - **Example, the National IP Awareness Mission (NIPAM)** aims to provide awareness on intellectual property and its rights to 1 million students.
- **Introduce Regulation to Protect AI:** It was noted that neither the **Indian Patents Act, 1970 nor the Copyright Act, 1957** are well equipped to facilitate **inventorship, authorship, and ownership by Artificial Intelligence.**

Keywords: Copyright, IP Index Patent, Innovation, NIPAM, Indian Patents Act, 1970.

PREVIOUS YEAR QUESTIONS		
1.	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. (12.5 marks)	2014
2.	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 judgment in rejecting Novartis' patent application for 'Glivec'. Discuss briefly the pros and cons of the decision. (10 marks)	2013

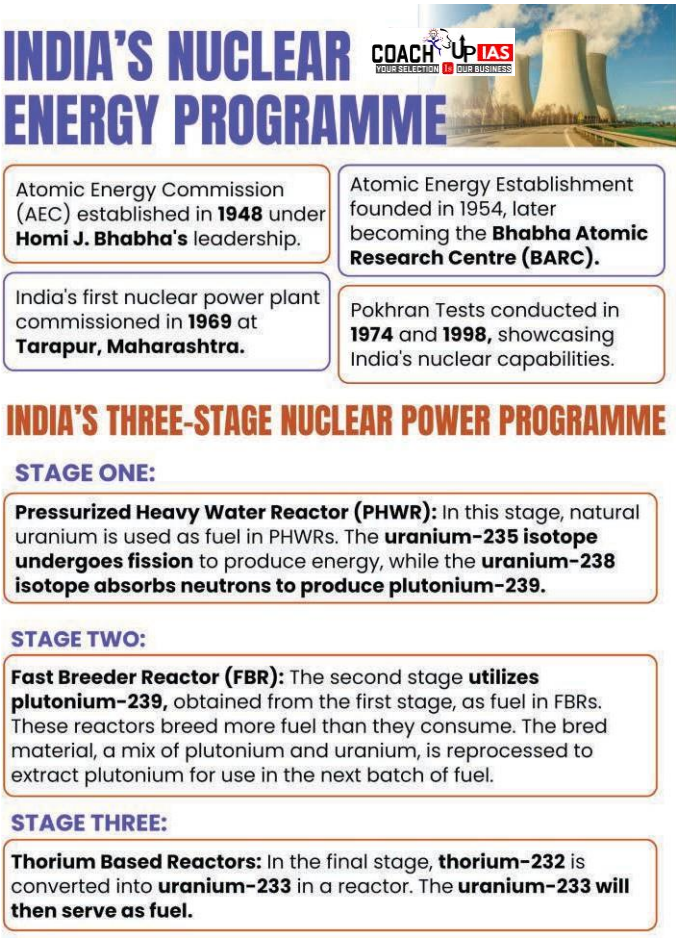
6 ALTERNATIVE ENERGY TECHNOLOGY

NUCLEAR ENERGY

Nuclear Energy: Nuclear energy is the energy released during nuclear reactions, particularly through processes like nuclear fission and nuclear fusion. These reactions release a tremendous amount of energy from the atomic nucleus.

STATUS OF NUCLEAR POWER IN INDIA

- **Fifth Largest Source:** Nuclear power is the fifth-largest source of electricity in India, following gas, coal, hydroelectricity, and wind power.
- **Capacity:** As of 2024, India operates 23 nuclear reactors spread across 8 nuclear power stations, with an installed capacity of approximately 7,480 MW.
- **Share of Nuclear Energy:** The share of nuclear power in total electricity generation was 1.6% for the fiscal year 2022-23.
- **Future Plans:** India aims to triple its nuclear power generation capacity by 2030 as part of its commitment to achieving Net Zero emissions by 2070. Recent additions include two indigenously designed 700 MW Pressurized Heavy Water Reactors at Kakrapar, with plans for 18 more reactors to be added by 2031.



Advantages of Nuclear Energy:

- **Low Greenhouse Gas Emissions:** Nuclear power generation produces low levels of greenhouse gas emissions compared to fossil fuels.
- **High Energy Density:** It has a high energy density, meaning a small amount of nuclear fuel can produce a large amount of energy
- **Base Load Power Source:** Nuclear power provides a steady and reliable source of electricity, suitable for meeting the base load demand
- **Energy Security:** Nuclear energy contributes to energy security by diversifying the energy mix. It reduces dependence on fossil fuel imports and helps stabilize energy prices.
- **Low Land Footprint:** Nuclear power plants require relatively small land areas compared to some renewable energy sources.
- **Decades-Long Fuel Supply:** Uranium, primary fuel for nuclear reactors, is abundant and has the potential for extended use through advanced reactor technologies and efficient fuel recycling.

Disadvantages of Nuclear Energy:

- **Radioactive Waste**: Production of radioactive waste and disposal of high-level radioactive waste pose long-term environmental and safety concerns.
- **Nuclear Accidents:** Events like the Chernobyl disaster in 1986 and the Fukushima Daiichi nuclear disaster in 2011 highlight the potential risks associated with nuclear power plants.
- **Nuclear Proliferation Risk:** Dual-use nature of nuclear technology makes it challenging to ensure that nuclear materials are used only for peaceful purposes and not for nuclear weapons proliferation.
- **High Initial Costs:** Construction of nuclear power plants involves high initial capital costs. Additionally, the time required for planning, permitting, and constructing nuclear facilities can be lengthy.
- **Limited Fuel Availability**: While uranium is currently abundant, there are concerns about its long-term availability.

- **Nuclear Decommissioning:** Decommissioning nuclear power plants at the end of their operational life is a complex and costly process.

Measures taken to enhance generation from nuclear power plants:

- **Conclusion of fuel supply contracts** with several countries under IAEA Safeguards and augmentation of fuel supplies from domestic sources.
- Resolution of issues related to Civil Liability for Nuclear Damage (CLND) Act (2010) & Creation of Indian Nuclear Insurance Pool.
- Amendment of the Atomic Energy Act (1962) 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.

RECENT DEVELOPMENT IN INDIA'S NUCLEAR PROGRAM

- **Kakrapar Atomic Power Project:** The fourth unit of the KAPP-4 in Gujarat, with **700 MWe** capacity, started **controlled fission chain reaction and achieved criticality** i.e., each fission event releases a sufficient number of neutrons to sustain an ongoing series of reactions.
  - It is the biggest indigenously developed variant of the **Pressurised Heavy Water Reactor (PHWR)**.
  - PHWRs use natural uranium as fuel and heavy water as moderator.
- **Kalpakkam Power Plant:** Recently, the Prime Minister witnessed the start of core loading for India's indigenous 500 Mwe **Prototype Fast Breeder Reactor (PFBR)** in the nuclear plant at **Kalpakkam, Chennai.**
  - This signifies the beginning of stage II in India's three-stage nuclear power strategy.
  - PFBR is a nuclear reactor that produces more nuclear fuel than it consumes, making it a key component of India's three-stage nuclear power program.
  - Stage II, featuring the PFBR, is crucial for transitioning towards using thorium fuel, leveraging India's large thorium reserves.

About Fast Breeder Reactors:
It is a type of nuclear reactor that uses fast neutrons to cause the fission of uranium-238 (unlike conventional nuclear reactors that use slow neutrons). The term "breeder" refers to the ability of these reactors to produce more fissile material than they consume.

Benefits of Fast Breeder:

- **Enhanced Fuel Efficiency:** FBRs are capable of generating more fuel than they consume, utilizing uranium-238 or thorium, which are abundantly available, to extend fuel life and efficiency
- **Minimized Nuclear Waste:** FBRs significantly reduce the volume of long-lived radioactive waste produced, thereby decreasing the need for extensive waste storage facilities.
- **Energy Security:** Due to their ability to breed fuel internally, FBRs require less frequent refueling, which reduces dependency on external fuel supplies and simplifies logistics.
- **Technological Self-Reliance:** The development of PFBR is fully indigenous, promoting local industry involvement and aligning with India's self-reliance initiative.
- **Enhanced Safety Measures**: Despite their complex technology, FBRs incorporate multiple safety systems, including automatic shutdown features to handle emergencies effectively

Conclusion: The nuclear energy programme in India is a complex and challenging endeavor. However, the programme has the potential to make a significant contribution to India's energy security and economic development.

Keywords: Nuclear fission and Nuclear fusion, Greenhouse Gas, Energy Density, Civil Liability for Nuclear Damage (CLND) Act, PFBR, Three-stage nuclear power strategy.

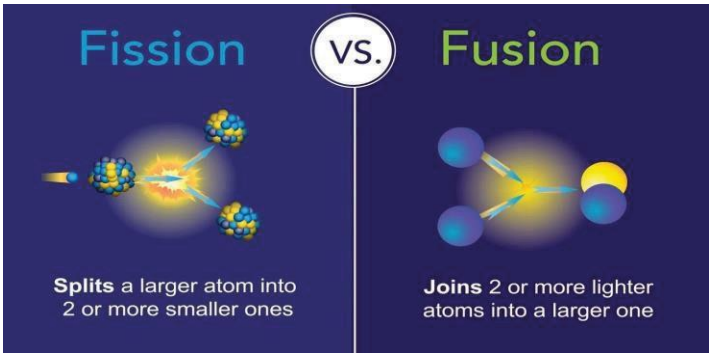
PREVIOUS YEAR QUESTIONS		
1.	With growing energy needs should India keep on expanding its nuclear energy programme? Discuss the facts and fears associated with nuclear energy? (15 marks)	2018
2.	Give an account of the growth and development of nuclear science and technology in India. What is the advantage of the fast breeder reactor programme in India? (15 marks)	2017

NUCLEAR FUSION

Introduction: Nuclear fusion is the process of **combining two light atomic nuclei to form a heavier nucleus**, releasing a large amount of energy. This is usually accompanied by the release of large quantities of energy.

Process of Nuclear Fusion:

- The process of nuclear fusion begins with two nuclei coming close enough together that the strong nuclear force can overcome the repulsive force of the protons in their nuclei. When this happens, the **nuclei fuse together to form a new nucleus**.
- The mass of the **new nucleus is less than the sum of the masses of the original nuclei.** This difference in mass is converted into energy, according to Einstein's famous equation **$E = mc^2$.**
- Nuclear fusion **powers the sun** and other stars.



Benefits of Fusion Energy:

- **Abundant Energy:** Fusion energy has the potential to provide virtually limitless energy by harnessing the fusion of light atomic nuclei, such as hydrogen.
- **Environmental Friendliness:** It produces no greenhouse gas emissions or long-lived radioactive waste, making it a clean and sustainable alternative to fossil fuels and fission-based power.
- **Inherent Safety:** Fusion reactors have inherent safety features, as the fusion process is **self-limiting** and the fuel supply can be easily stopped.
- **Resource Availability:** Fusion fuel, such as deuterium and lithium, is widely available in the Earth's oceans and accessible in large quantities.

Challenges of Fusion Energy:

- **Temperature and Containment:** Achieving nuclear fusion involves sustaining plasma state at millions of degrees Celsius, which is a major challenge.
- **Plasma Stability:** Maintaining stable plasma conditions is crucial for sustained fusion reactions. Plasma instabilities, such as disruptions and turbulence, can disrupt the fusion process.
- **Energy Balance:** Achieving net energy gain from fusion is challenging; the energy input to start and sustain fusion must be less than the energy produced by the reactions.
- **Materials and Component Lifespan:** Developing materials that withstand the extreme temperatures, radiation, and neutron bombardment in fusion reactors while maintaining structural integrity is a significant challenge.
- **Cost and Scalability:** Developing cost-effective fusion technologies and scaling them up for commercial power production is a major challenge.
- **Waste Management:** Although fusion reactions generate less long-lived radioactive waste than fission, managing and safely disposing of any fusion reactor waste is still crucial.

Conclusion: Fusion energy is a promising new source of energy with the potential to provide a clean, safe, and abundant source of energy for the world. However, there are still a number of challenges that need to be overcome before fusion reactors can be commercially viable. With continued research and development, it is possible that fusion energy will be a reality in the not-too-distant future.

Additional Information:

- **South Korea:** A nuclear fusion reaction has lasted for 30 seconds at temperatures in excess of 100 million°C.
- **China:** China's **"artificial sun",** based on fusion reaction, broke all records by generating extremely hot plasma for seven minutes.
- **India and International Thermonuclear Experimental Reactor (ITER):** Recognizing the significance of ITER in the development of fusion energy, India expressed its desire to join the project as an equal partner, alongside the existing six partners.

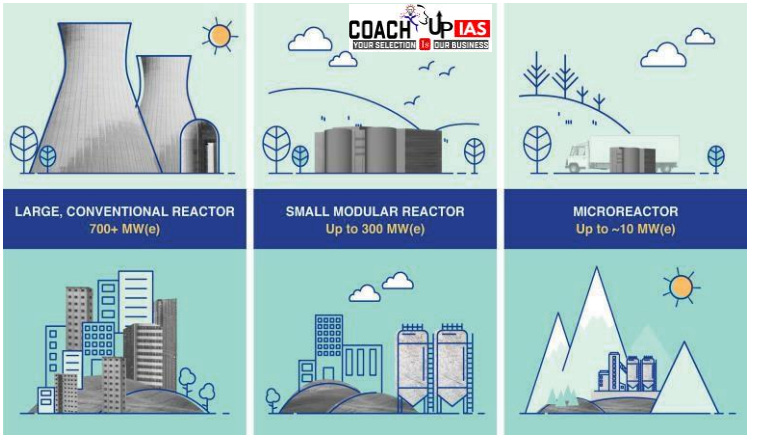
Keywords: Fusion, Fission, Plasma Stability, Artificial Sun.

SMALL MODULAR REACTORS (SMRS)

Introduction: Small modular reactors (SMRs) are advanced nuclear reactors with power generation capacity ranging from **less than 30 MWe to 300+ MWe** and are capable of generating substantial low-carbon electricity.

Characteristics of SMRs:

- SMRs are designed to be factory-built and **assembled on-site,** offering easier deployment and scalability.
- SMRs **utilize passive safety features** and advanced technologies to enhance safety and minimize risks.
- These reactors can **operate for longer periods without refueling** and have lower operational and maintenance costs.



Advantages of SMRs:

- **Flexibility and Scalability:** SMRs can be deployed in diverse locations, including remote areas or places with limited infrastructure.
- **Enhanced Safety:** SMRs employ passive cooling systems, reliance on natural forces like **gravity and convection,** and simplified designs to enhance their safety features.
- **Affordability:** SMRs can benefit developing countries with limited capital resources, as they require lower initial investments compared to large reactors.
- **Grid Resilience:** SMRs can contribute to grid stability & resilience by providing distributed power generation. They can be combined with renewable energy sources to create hybrid energy systems.

Implications and Challenges:

- **Regulatory Framework:** Developing specific regulations and licensing frameworks for SMRs is crucial for ensuring safety, managing waste, and addressing security concerns.
- **Licensing challenges:** Newly developed SMR technologies may find it difficult to accommodate in the existing licensing process.
- **Public Acceptance:** Public perception of nuclear energy, safety concerns, and waste management issues may affect the acceptance and deployment of SMRs.
- **Storage and Disposal:** Even SMRs produce radioactive waste from spent fuel and require spent fuel storage & disposal facilities
- **Technology Development:** Continued research and development are necessary to improve SMR designs, efficiency, and safety features.

Conclusion: SMRs have the potential to provide a number of benefits, including reduced cost, shorter construction time, flexibility, safety, and sustainability. However, there are also a number of challenges associated with SMRs, including regulation, public acceptance, and development risk.

Keywords: Scalability, Modular reactor, non-proliferation, grid resilience.

NATIONAL GREEN HYDROGEN MISSION

Context: India's first multi-purpose green hydrogen pilot project at Nathpa Jhakri Hydro Power Station, Himachal Pradesh was recently inaugurated, in alignment with National Green Hydrogen Mission.

About National Green Hydrogen Mission (NGHM):

- It is a government-led initiative to promote the production and use of green hydrogen in India.
- **Green hydrogen** is produced by using renewable energy sources, such as solar and wind, to split water into hydrogen and oxygen.

Objectives:

- Developing **green hydrogen production capacity of at least 5 MMT (Million Metric Tonne)** per annum, alongside adding renewable energy capacity of about 125 GW in India by 2030.
- It aims to get over **Rs 8 lakh crore of total investments** and generate six lakh jobs.

- Lead to a cumulative **reduction in fossil fuel imports by over Rs 1 lakh crore** and an abatement of nearly 50 MT of annual greenhouse gas emissions.

SUB-COMPONENTS OF THE MISSION

- **Strategic Interventions for Green Hydrogen Transition Programme (SIGHT):** Under it incentives are to be provided for targeting domestic manufacturing of electrolysers and for production of Green Hydrogen.
- **Green Hydrogen Hubs:** States and regions capable of supporting large scale production and/or utilization of hydrogen will be identified and developed as Green Hydrogen Hubs.
- **Strategic Hydrogen Innovation Partnership (SHIP)**: Public-Private Partnership framework for R&D will be facilitated under the Mission.
- **Skill Development:** A skill development programme for the workforce in the sector will also be undertaken under the Mission.

Type	Grey Hydrogen	Blue Hydrogen	Green Hydrogen	Brown Hydrogen	Yellow Hydrogen
Process	Steam Reforming	Steam Reforming with Carbon Capture	Electrolysis	Gasification	Electrolysis
Source	Natural Gas	Natural Gas	Renewable Energy	Coal	Solar Energy

Benefits of NGHM:

- **Decarbonization of Economy:** Green hydrogen is an emissions-free fuel that can decarbonize a wide range of industries, such as transportation, manufacturing, and power generation.
- **Economic Growth:** The NGHM has the potential to create a new clean energy industry in India, which could lead to job creation and economic growth.
- **Energy security:** Green hydrogen can help to reduce India's dependence on imported fossil fuels.
- **Foreign investment:** The NGHM could attract foreign investment in the clean energy sector.

Challenges of NGHM:

- **High Cost of Production:** The cost of producing green hydrogen is still relatively high, which could limit its adoption.
- **Lack of Infrastructure:** There is currently a lack of infrastructure for the production, storage, and transportation of green hydrogen.
- **Lack of Demand:** There is currently limited demand for green hydrogen, which could slow the development of the market.
- **Scale-up:** Scaling up green hydrogen production to meet the demand requires substantial investment and technological advancements.
- **Renewable Energy Integration:** Availability of renewable energy sources at the required scale and consistency is crucial for green hydrogen production.
- **Policy and Regulations:** Establishing supportive policies, regulations, and incentives to encourage the adoption and development of green hydrogen technologies.

Ways to Overcome the Challenges:

- **Technology Development:** Invest in research and development to advance green hydrogen production technologies, such as electrolysis powered by renewable energy sources.
- **Infrastructure Development:** Establish a robust infrastructure for the production, storage, and distribution of green hydrogen, including the development of hydrogen refueling stations.
- **Policy Support:** Implement supportive policies, including incentives, subsidies, and tax breaks, to encourage investment in green hydrogen projects and create a favorable market environment.
- **Skill Development:** Focus on training and skill development programs to create a skilled workforce capable of operating and maintaining green hydrogen infrastructure.
- **Financial Support:** Provide financial support through grants, loans, and public-private partnerships to attract investments in the green hydrogen sector and accelerate its deployment.

Conclusion:

The NGHM is a major step forward in India's efforts to decarbonize its economy. The mission has the potential to create a new clean energy industry in India and help the country achieve its climate goals.

Keyword: Grey Hydrogen, Clean Energy, Policy Support.

FLEX FUEL VEHICLES

Context: India is slowly embracing flex-fuel vehicles (FFVs) after successful implementation of its Ethanol Blended Petrol programme, as part of its commitment to sustainable energy.

About Flex Fuel Vehicles (FFVs): They are specially designed vehicles capable of operating on different fuel types. They can run on various blends of gasoline and biofuels like ethanol or methanol, and in some cases, even entirely on these biofuels.

Fuel Compatibility:

- **Ethanol Blends:** FFVs are capable of using E85, a blend containing 85% ethanol and 15% gasoline, as well as other ethanol blends like E15.
- **Methanol Blends:** Some FFVs are also designed to operate on M85, which consists of 85% methanol and 15% gasoline, along with other methanol blends.

Advantages of Flex-Fuel Vehicles:

- **Reduced emissions**: Ethanol burns cleaner than gasoline, which can help to reduce air pollution.
- **Economical**: Ethanol is typically less expensive than gasoline, which can save money on fuel costs.
- **Domestic Production:** Ethanol can be produced domestically, reducing reliance on imported petroleum and enhancing energy security.
- **Market Demand:** The availability of FFVs and ethanol fuel options promotes a market for renewable fuels, supporting the growth of the biofuel industry.
- **Flexibility:** Flex-fuel vehicles can run on any blend of gasoline and ethanol, which gives more flexibility when filling up your tank.

Disadvantages of Flex-Fuel Vehicles:

- **Limited Fuel Efficiency:** Flex-fuel vehicles typically have lower fuel efficiency compared to vehicles running on a single fuel type, such as gasoline.
- **Reduced Performance:** FFVs may experience reduced performance when running on alternative fuel blends, such as E85 ethanol.
- **Fuel Availability:** Limited availability of ethanol or methanol fuel stations can be a significant challenge.

Ethanol Blending Program

- It is a government-led initiative to promote the use of ethanol in India. Launched in 2003, **it aimed at achieving a 5% blend of ethanol with petrol.**
- The program has been successful and the target has been revised to **20% blending of ethanol with petrol by 2025.**

- **Material Compatibility:** Ethanol can be corrosive to certain materials used in fuel systems, requiring modifications or upgrades.
- **Infrastructure Limitations:** The infrastructure for alternative fuel distribution, such as ethanol refueling stations, may be less widespread, limiting options for consumers.
- **Environmental Impact:** The production and transportation of alternative fuels may still lead to environmental issues, such as land use change, deforestation, and carbon emissions.

Conclusion: FFVs hold significant promise in promoting a transition towards cleaner energy sources in the transportation sector. By providing consumers with the flexibility to use alternative fuels, FFVs offer a practical solution to reduce carbon emissions and enhance energy security.

Keywords: Gasoline, biofuels, Ethanol Blended Petrol programme, Methanol

LITHIUM-ION BATTERY

Context: India is set to finalize an agreement to acquire five lithium blocks for exploration and development in Argentina.

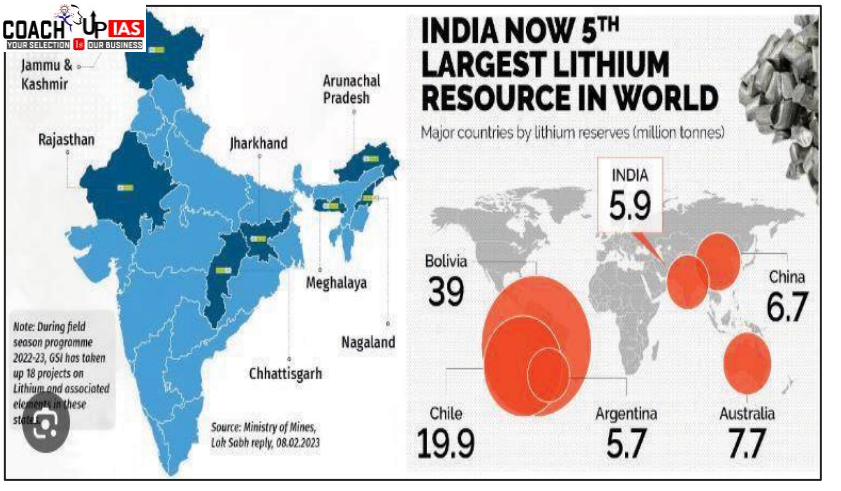
About Lithium:

- **About**: It is a soft, silvery metal having the lowest density of all metals. It reacts vigorously with water.
- **Applications:**
  - Manufacturing lithium-ion batteries used in smartphones, laptops, electric vehicles (EVs) and energy storage systems.
  - Lithium is employed in certain medical treatments, ceramics, and as a component in aerospace technology.

About Lithium-ion battery:

- It is a type of **rechargeable battery** in which lithium ions move from the negative electrode to the positive electrode during discharge and back during charge.

- **Application of Lithium-ion Batteries:** It is used in a wide variety of devices, including laptops, cell phones, and electric vehicles.



Features/Benefits of Lithium-ion batteries:

- **High Energy Density:** Lithium-ion batteries offer a high energy density, providing more energy storage capacity per unit weight and volume compared to other rechargeable battery technologies.
- **Longer Lifespan:** They have a longer lifespan, allowing for more charge and discharge cycles before performance degradation.
- **Fast Charging:** Lithium-ion batteries can be charged at a faster rate compared to other battery types.
- **Lightweight:** They are lightweight, making them ideal for portable electronic devices and electric vehicles.
- **Low Self-Discharge:** Lithium-ion batteries have a low self-discharge rate, meaning they retain their charge for longer periods when not in use.
- **Wide Range of Applications:** They are used in various applications, including consumer electronics, electric vehicles, renewable energy systems, and grid storage, due to their performance and versatility.

Disadvantages of Lithium-ion Batteries:

- **Limited Energy Density:** Lithium-ion batteries have a finite energy density, which means they store less energy compared to other battery types.
- **High Cost:** The manufacturing process and materials required for lithium-ion batteries can make them expensive, limiting their affordability for some applications.
- **Aging and Degradation:** Over time, lithium-ion batteries experience capacity loss and degradation, leading to reduced performance and shorter lifespan.
- **Environmental Concerns:** The extraction and disposal of lithium-ion batteries can have environmental impacts, including the release of toxic materials if not properly handled.
- **Safety Risks:** While rare, lithium-ion batteries have the potential for thermal runaway, leading to overheating, fire, or explosion if mishandled or damaged.

Conclusion: The discovery of lithium deposits in India is a major development with the potential to transform the country's energy landscape. With careful planning and execution, India can become a major player in the global lithium market and reap the economic benefits of this important resource.

Keywords: Argentina, Rechargeable battery, High Energy Density, Lifespan

PREVIOUS YEAR QUESTIONS		
1.	Describe the benefits of deriving electric energy from sunlight in contrast to conventional energy generation. What are the initiatives offered by our government for this purpose? (250 words, 15 marks)	2020

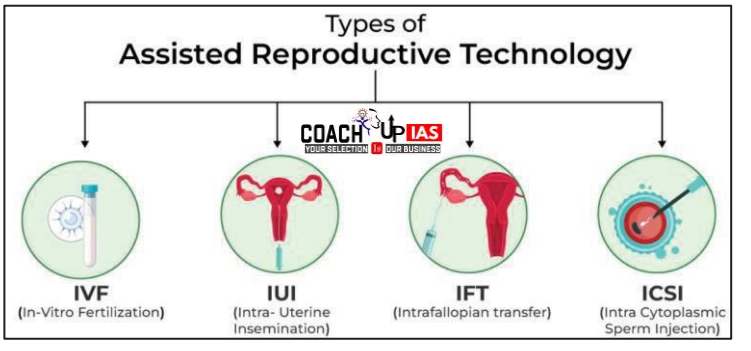
7 HEALTH

ASSISTED REPRODUCTIVE TECHNOLOGY

Context: The Ministry of Health and Family Welfare has requested data from all States and UTs on single and unmarried women utilizing Assisted Reproductive Technology (ART) to **assess the ART Act, 2021 implementation**.

About Assisted Reproductive Technology (ART) Services:

- ART includes **techniques for obtaining a pregnancy** by handling the **sperm** or the **oocyte** (immature egg cell) **outside the human body** and **transferring the gamete or the embryo into the reproductive system of a woman.**
- **Types of ART Services:**
  - **In vitro fertilization:** Fertilization **occurs outside the body** and the fertilized egg is then transferred to the uterus.
  - **Intrafallopian Transfer (IFT):** Similar to IVF where fertilization takes place outside the body but the embryo is then inserted into the fallopian tube and not the uterus.
  - **Intrauterine Insemination:** Introduction of sperms into the female's uterus to achieve pregnancy without sexual intercourse.
  - **Intracytoplasmic Sperm Injection (ICSI)**: It is used for couples where the male is infertile. Single sperm is introduced into a mature egg

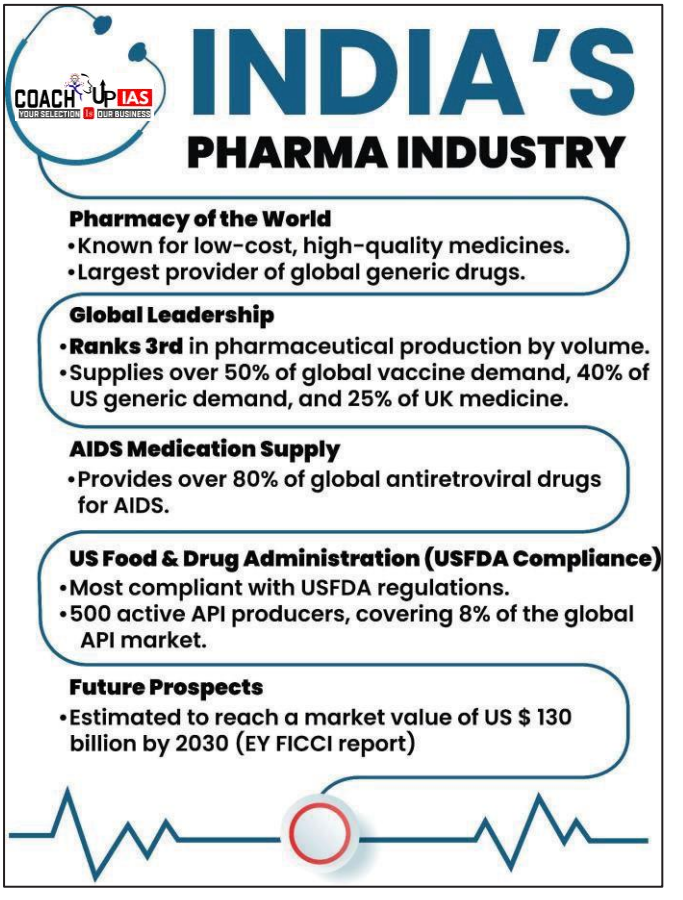


Features of Assisted Reproductive Technology (Regulation) Act, 2021:

- **Provision of ART Services:** It will be provided through **ART clinics**, which offer ART treatments and procedures, and **ART banks**, which collect, screen and store gametes.
- **Registration of ART Clinics and Banks:** Under the act, a **National Registry** is to be maintained which acts as a central database with details of all ART clinics and banks in the country.
- **National and State Boards:** The National and State Boards constituted under the **Surrogacy Act 2021** will also act as the National and State Boards for the regulation of ART services.
- **Registration of Clinics:** The central government will appoint authorities called the **Appropriate Assisted Reproductive Technology and Surrogacy Authority** which will regulate the registration of clinics for both surrogacy and ART services.
  - The Authorities will be constituted at national and state level.
- **Eligibility Criteria for Commissioning Parties:** ART services may be commissioned by Single women or married couples where the **woman is between 21 and 50 years of age**, and the man is between **21 and 55 years** and the married couples must be infertile.
  - **Foreigners** are **not prohibited** from availing ART services.
- **Eligibility Criteria for Donors**: A bank may obtain semen from males between **21 and 55 years of age**, and eggs from females between **23 and 35 years of age**.
  - A woman may donate eggs only **once in her life** and not more **than seven eggs** may be retrieved from her.
  - A bank must **not supply gametes of a single donor to more than one commissioning party** (i.e. couples or single women seeking services).
- **Conditions for Offering Services:** ART procedures must be conducted only with the written consent of the commissioning parties and the donor**.**
- **Rights of a Child born through ART:** A child born through ART will be deemed to be a biological child of the commissioning couple and will be entitled to the rights and privileges available to a natural child of the commissioning couple.
  - A donor will **not have any parental rights** over the child.
- **Regulating Surrogacy:** The Act brings into its ambit the **treatment of surrogacy** and hence ensures protection of the rights of surrogate mothers.

Challenges with ART Act 2021:

- **Concerns of Privacy Violation:** The requirement of ART clinics and banks to share personal information of the donors and the commissioning parties with the National Registry risk the violation of their privacy rights.
- **Lack of Consent for Donors:** Commissioning parties may withdraw consent before the embryo or gamete is transferred to the woman's uterus. However, donors have not been given similar rights to withdraw their consent.
- **Issue of Qualification of Professionals:** The Act does not address the issue of qualification, experience, and the desired skills of the professionals working in ART clinics and banks.
- **No Regulation of Adoption:** Adoption is generally pursued by couples after unsuccessful fertility treatment. However, adoption remains unregulated in India.
- **Challenges in Implementation:** Health being a **state subject**, registering ART clinics and banks across different states is complex due to the need for state-specific health regulations.
- **Concerns with International Surrogacy Contracts:** Legal complications from the signing of surrogacy contracts between international couples and local women offering surrogacy services.



Way Forward

- **Protecting Privacy Rights:** The personal data of patients and commissioning couples should be converted to a form so as to maintain their confidentiality.
- **Addressing International Surrogacy Contracts:** Many international couples from developed countries seek surrogacy services in a developing country like India, making it critical to address.
- **Provision for Regulating Adoption:** Regulation of adoption should be addressed alongside ART and surrogacy.

Conclusion: As India implements the ART Act, 2021, it faces the dual task of leveraging advancements in reproductive technologies while addressing significant legal and ethical concerns. This delicate balance will ensure that ART services enhance societal values without compromising individual rights.

Keywords: In vitro fertilization, Intrafallopian Transfer, Surrogacy, ART clinics and banks

COUNTERFEIT DRUGS

Context: Central Drugs Standard Control Organisation (CDSCO) revoked state authorities' ability to issue NOCs for manufacturing unapproved, banned, or new drugs for export. This decision follows international scrutiny over concerns of substandard drugs supplied by India.

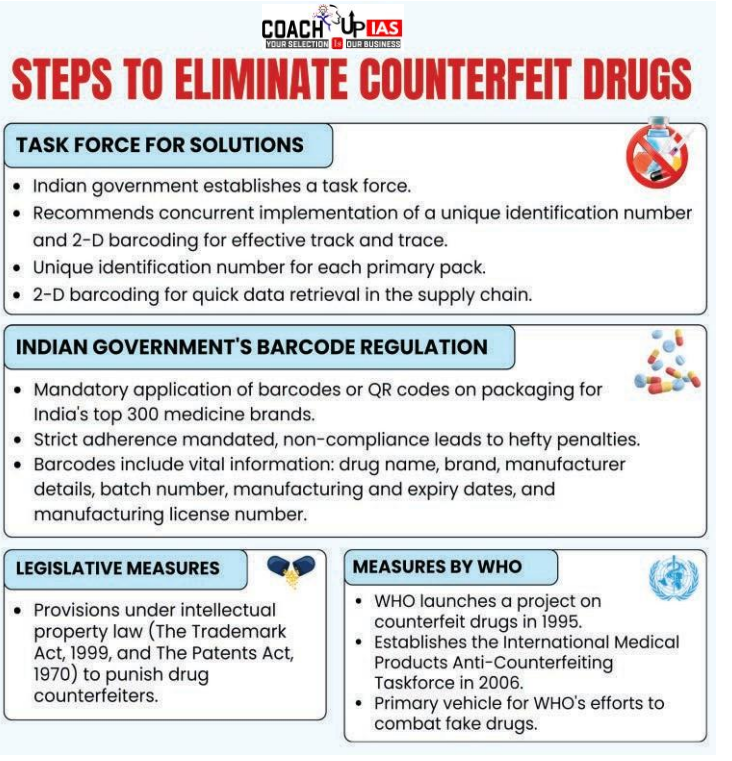
About Counterfeit Drugs:

- **Counterfeit Drugs:** Drugs **manufactured or packaged fraudulently** are referred to as counterfeit/fake/spurious/falsified drugs because they either **lack active ingredients** or have incorrect dosages.
- **Global Issue**: The **World Health Organization** states the frightening figure in which almost **10.5% of the medications worldwide** are either subpar or fake.
- **Cases of Counterfeit Drugs:**
  - Kolkata Seizure: Counterfeit medicines worth approximately ₹2 crores from leading manufacturers were seized from unlicensed premises in Kolkata.
  - Cough Syrup Incident: In 2022, the WHO flagged four cough syrup brands from India, linked to the deaths of 66 children in Gambia.

- Recent Measures: In 2023, the Drugs Control General of India mandated barcodes or QR codes on the packaging of the top 300 medicine brands to curb the spread of counterfeit drugs.

Challenges Associated with Counterfeit Drugs:

- **Manufacturing Complexity**: The scale of manufacturing and complexity of supply chain involving multiple parties from suppliers to resellers, make it difficult to monitor ingredient quality throughout the value chain
- **Lack of Testing Facilities and Monitoring Personnel:** India has limited drug testing capabilities, with only **47 facilities and 6 central labs** under the National Good Laboratory Practice program.
- **Supply Chain Disruptions**: During the COVID-19 induced supply chain disruptions, incidents of substandard and falsified medical products **increased by almost 47% from 2020 to 2021**.
- **Dented Image**: India is known as the **'pharmacy of the world',** but that image has been dented by the death of around **18 children in Uzbekistan** last year after they consumed an **Indian-manufactured cough syrup.**
- **Public Health Concerns**: Substandard products across the pharma industry have a high potential for **life-threatening damage**.
- **Counterfeits Affecting Pharma Growth:** Counterfeit drugs and their circulation tend to prove detrimental to the growth of the pharma industry.



Way Forward:

- **India as World's Pharmacy**: To maintain India's status as the "Pharmacy of the World," stakeholders must tackle counterfeit drugs and protect its significant contributions to exports and GDP (8% of merchandise export and 2% of GDP).
- **Utilizing Technologies to Prevent Drug Counterfeiting**: Technology must be adopted at **all levels of the value chain** to monitor material and ingredients used at every step. **Ex use of barcodes, RFIDs and holograms.**
- **Utilizing Blockchain Technology**: Blockchain technology uses a **decentralized peer-to-peer** architecture for transaction processing with little potential for record-tampering.
- **Awareness Campaigns**: There should be a **country-wide campaign** to make masses aware of the **risks and the precautionary steps** that they must take to verify the authenticity of medicines that they would procure.

Conclusion: To safeguard its reputation as the "Pharmacy of the World" and combat the serious issue of counterfeit drugs, India must enhance its pharmaceutical regulation and monitoring capabilities. Strengthening manufacturing oversight, expanding drug testing facilities, and deploying advanced technologies like blockchain and RFID for tracking are essential.

Keywords: Active ingredients, CDSCO, Pharmacy of the World, Holograms, RFID

PREVIOUS YEAR QUESTIONS		
1.	What do you understand by Fixed Dose drug Combinations (FDCs)? Discuss their merits and demerits. (10 marks)	2013

ANTIMICROBIAL RESISTANCE (AMR)

Context: In a webinar organized by the Centre for Science and Environment (CSE), the issue of increasing resistance to antibiotics was discussed.

About Antimicrobial Resistance (AMR)

It occurs **when bacteria, viruses, fungi and parasites** change over time and no longer respond to medicines making infections harder to treat and increasing the risk of disease spread.

As a result of **drug resistance**, antibiotics and other antimicrobial **medicines become ineffective and infections become increasingly** difficult or impossible to treat.

Global Severity of AMR:	Severity of AMR in India:
• WHO has declared AMR as one of the **top 10 global public health threats.** • According to Lancet, AMR was responsible for **4.95 million deaths per year worldwide in 2019.** • AMR may cause a global **annual GDP loss of $3.4 trillion by 2030.** • AMR may **push 24 million people into extreme poverty.**	• **AMR Capital of World:** India has the highest **infectious disease burden in the world,** including infections due to multi-resistant pathogens. • As per Health Ministry**,** the reported AMR cases spiked more than **4.5 times between 2017 to 2022**. • India is also the **world's largest consumer of antibiotics** in terms of total volume. • **As per ICMR study, E. coli was the most common bacteria**, accounting for 33% of AMR cases in 2022.

Causes of Antimicrobial Resistance (AMR) in India:

- **Overuse of Antibiotics:** As per The Lancet Regional Health-Southeast Asia, the total defined daily dose (DDD) -- the assumed average maintenance dose per day for a drug in adults -- consumed in 2019 was 5,071 million (10.4 DDD/1,000/day)
- **Over the Counter Sale of Drugs:** Antibiotics are easily available in India without a prescription, leading to their inappropriate use.
- **Emergence of New Strains:** A total of **378 new microbial species** were discovered in India between **2008 and 2019**, in places ranging from glaciers to mobile phone screens.
- **Poultry and Veterinary Use of Antibiotics:** Antibiotics are disproportionately used in the poultry and veterinary industry in India to prevent and treat infections. Ex **Colistin**.
- **Wastewater Contamination:** Antibiotic residues in wastewater and wastewater treatment plants serve as **"potential hotspots"** for the development of AMR, as they seep into groundwater.

Steps Taken by India to Prevent AMR:

- **India's National Action Plan on AMR (NAP-AMR) for 2017-2021**: It addresses six critical issues:
  - **Creating awareness** and understanding of AMR.
  - **Strengthening knowledge and evidence** through surveillance.
  - **Reducing the incidence** of infection through effective infection prevention and control.
  - **Optimizing the use of antimicrobial agents** in health, animals and food.
  - **Promoting investments** for AMR activities, research and innovations.
  - **Strengthening India's leadership** on AMR.
- **Delhi Declaration on AMR:** An inter-ministerial consensus was signed at the launch of NAP-AMR, pledging their whole-hearted support in AMR containment.
- **AMR surveillance and research network (AMRSN):** ICMR has established AMRSN comprising 30 tertiary care hospitals**,** both private and government, to generate evidence and capture trends and patterns of drug resistant infections in the country.
- **Red Line Awareness Campaign on AMR:** It urges people not to use medicines marked with a red vertical line, including antibiotics, without a doctor's prescription.

Way Forward:

- **One Health Approach:** AMR requires a united multisectoral approach, which can be achieved through the One Health approach. It brings **together multiple sectors and stakeholders** to work together to attain better public health outcomes.

- **3C approach to R&D:** Coordination, collaboration and communication (3C) are important to ensure resources are used efficiently, and stakeholders are aware of progress in the development of new antibiotics.
- **Improve WASH (water, sanitation, hygiene) services:** Poor waste management and WASH services in metro cities leads to outbreaks of infectious diseases, which spread through the fecal-oral route.
- **Reforming R&D ecosystem:** Including greater public financing, coordinated response from national governments, balanced public-private partnerships in antibiotic R&D.
- **Other Steps to be taken:**
  - **Rational use of Antibiotics** in both humans and animals
  - **Multisectoral Engagement** for tracking and collection of AMR data from human health, animal health and the environment.
  - **Strong surveillance** to monitor antibiotic residues and transmission of AMR bacteria from healthcare facilities, pharmaceutical effluents, etc.
  - **Promotion of more research and technological innovation** to optimize the use of antibiotics.

Conclusion: As the global threat of antimicrobial resistance (AMR) escalates, India's multi-faceted approach underscores the urgency of a united response. Emphasizing coordinated international efforts, enhanced surveillance, and the promotion of antibiotic stewardship, we must bolster our commitment to safeguarding public health against this looming crisis.

Global Efforts in Prevention of AMR:

- **WHO Global Action Plan on Antimicrobial Resistance:** To tackle the growing problem of antimicrobial resistance, which is a major threat to global health.
- **Global Antimicrobial Resistance and Use Surveillance System (GLASS):** For the standardized collection, analysis and sharing of data on AMR and antimicrobial use (AMU) at a national, regional and global level.
- **WHO Essential Medicines List categorizing Antimicrobial in three groups:**
  - **ACCESS**: First & second choice antibiotics for the treatment of common infectious diseases
  - **WATCH**: Antibiotics with higher resistance potential whose use as first and second choice treatment should be limited to a small number of syndromes;
  - **RESERVE –** antibiotics to be used mainly as **'last resort'** treatment options.
- **Muscat Ministerial Manifesto on AMR:** It was signed by health ministers from around the world in **2017**, committing to take action to address the growing threat of AMR. Its targets were**:**
  - Reducing total amount of antimicrobials used in agrifood systems by at **least 30-50% by 2030.**
  - **Preserving critically important antimicrobials** for human medicine and ending the use of medically important antimicrobials for growth promotion in animals.

Keywords: Over the Counter Sale, Delhi Declaration on AMR, WASH, Muscat Manifesto, GLASS, One Health

PREVIOUS YEAR QUESTIONS		
1.	Can overuse and free availability of antibiotics without Doctor's prescription, be 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. (12.5 marks)	2014

WHO'S PANDEMIC TREATY

Context: The Pandemic Treaty, negotiated by the **WHO and its 194 member states,** aims to enhance global pandemic prevention, preparedness, and response.

WHO's Initiative Toward Global Health Order:

- The World Health Organization (WHO) is leading **two major international initiatives** to address the threat of future pandemics.
  - **Revising International Health Regulations (IHRs)**: The first initiative involves revising the IHRs to improve global health alerts' speed and efficiency.
  - **Pandemic Treaty:** The second initiative involves negotiating a new Pandemic Treaty to provide a more efficient and equitable response to pandemics in the future.
- These initiatives aim **to learn from the experiences of the Covid-19** pandemic and enhance global capabilities to respond to new microbial threats.

Provisions of Pandemic Treaty:

- **Early Warning and Detection:** The treaty requires countries to improve early warning systems for pandemic through improved surveillance, data collection, and international data sharing.
- **Risk Assessment and Management:** The treaty obligates countries to assess pandemic risks and establish management strategies like response planning, medical stockpiling, & healthcare training.
- **International Cooperation:** The treaty mandates international cooperation to manage pandemics by sharing information, aiding countries in need, and jointly developing vaccines and treatments.

Benefits of the Pandemic Treaty:

- **Increased coordination:** The treaty aims to enhance coordination among countries during a pandemic, ensuring shared information, resources, and expertise.
- **Improved early warning:** The treaty would help to improve early warning systems for pandemics. This would allow countries to take action sooner to prevent the spread of a pandemic.
- **Increased access to vaccines and treatments:** The treaty would help to increase access to vaccines and treatments for pandemics. This would help to save lives and protect livelihoods.

Challenges Faced by Pandemic Treaty:

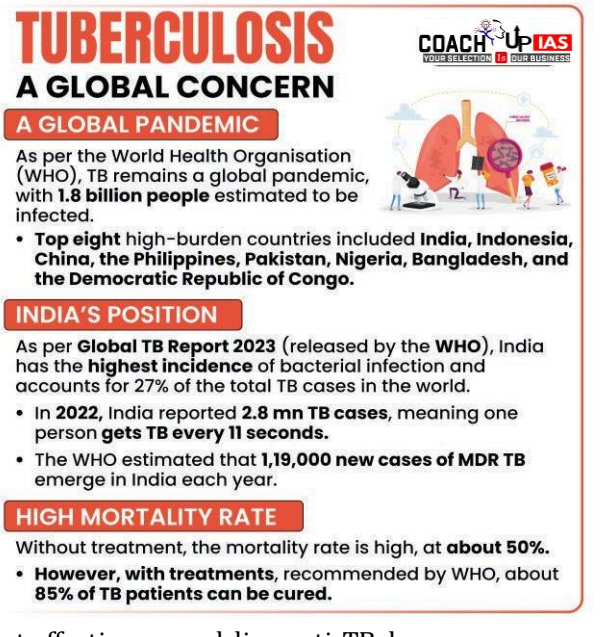
- **Lack of Political Will:** Some countries may resist committing to the treaty due to resource limitations, distrust, or insufficient political will.
- **Difficult Negotiations:** The negotiations on the treaty are complex and difficult. There are a number of different perspectives on the treaty, and it will be challenging to reach a consensus.
- **Implementation challenges:** Even if the treaty is successfully negotiated, it will be challenging to implement. This will require countries to make significant changes to their laws and policies.

Conclusion: Despite the challenges, the Pandemic Treaty is a worthwhile endeavor. The treaty has the potential to save lives and protect livelihoods. It is important to continue to work towards the successful negotiation and implementation of the treaty.

Keywords: Global Pandemic Response, International Health Regulations, Political Will

TUBERCULOSIS IN INDIA

Context: India accounted for the highest number of tuberculosis (TB) cases in the world in 2022, as revealed by the new World Health Organization (WHO) 2023 Global TB report.



About Tuberculosis:

- **Causal Agent:** It is an infectious disease caused by bacteria, *Mycobacterium tuberculosis*.
- **Transmission:**Spreads through air when infected people cough, sneeze or spit.
- **Prevention:** It is usually treated with antibiotics and can be fatal without treatment.
  - **Bacille Calmette-Guérin (BCG) vaccine** prevents TB **outside of the lungs but not in the lungs.**
- **Drug-Resistant TB:** Tuberculosis that does not respond to standard drugs is called drug-resistant TB.
  - **Types:** It has two main types:
    - **Multidrug-Resistant Tuberculosis (MDR-TB):** TB which does not respond to at least isoniazid and rifampicin, the two of the most effective TB drugs.
    - **Extensively Drug-Resistant TB (XDR-TB):** Serious form of MDR-TB caused by bacteria that do not respond to the most effective second-line anti-TB drugs.

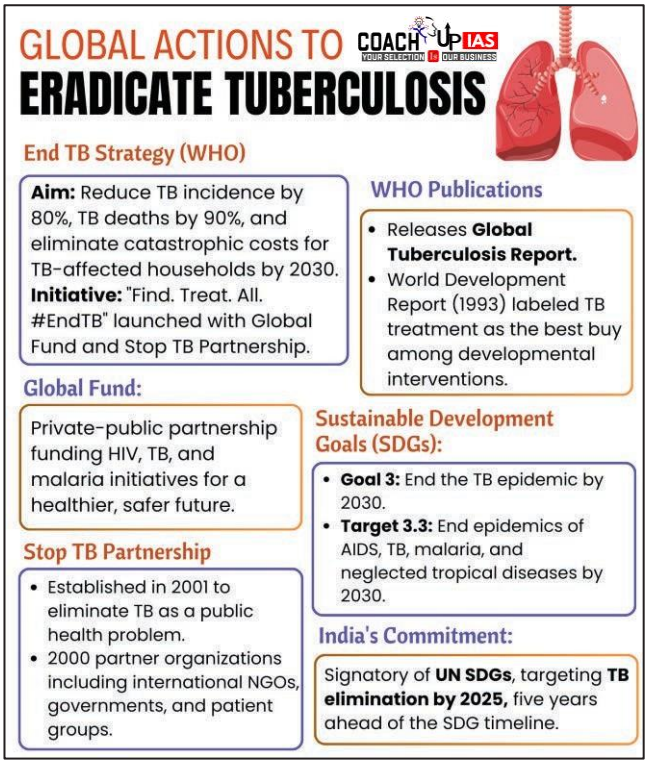
India's Efforts to Eradicate Tuberculosis:

- **National TB Programme (NTP):** The Government of India launched NTP in **1962** as District TB Centre model involving imparting BCG vaccination and TB treatment to fight tuberculosis.
- **The National Tuberculosis Elimination Programme (NTEP):** Launched in 2017 by the Ministry of Health, to eliminate TB in India through interventions aimed at reducing incidence, prevalence, and mortality.

- **The National Strategic Plan (NSP) for TB Elimination:** The NSP for TB Elimination 2017-2025 aims to rapidly **reduce TB in India by 2025** through strategies centered on **Detection, Treatment, Prevention, and Building,** aligning with SDGs and End TB targets.
- **Nikshay Poshan Yojana (NPY):** Launched in **2018** by the MoHFW, the NPY provides TB patients a **monthly Direct Benefit Transfer of Rs 500** to support their nutritional needs.
- **Nikshay Mitra:** In September 2022, India launched another nutrition support programme called Nikshay Mitra to **consented TB patients.**
- **Pradhan Mantri TB Mukt Bharat Abhiyaan (PMTBMBA):** An MoHFW initiative aims to expedite India's TB elimination by 2025 through collaboration with all community stakeholders.

Challenges Faced by India in Eradicating TB:

- **Time Constraint:** The Parliamentary Standing Committee on Health and Family Welfare reported that achieving the target to **End TB by 2025** is a major challenge due to time constraint.
- **Regional Differences in TB Cure Rate:** As India approaches its 2025 TB elimination goal, significant regional disparities exist. The national cure rate is **27.8%**, but 11 states, including Bihar and Uttar Pradesh, report lower rates.
- **Poverty:** Undernutrition and poor living conditions are major factors in TB cases in India, with the Health Ministry attributing **55% of annual TB incidence to undernutrition.**
- **Underreporting:** Under-reporting is a significant factor in India's TB prevalence, increasing transmission risks.
- **Inadequate Diagnosis:** Diagnostics for identifying high-risk individuals are inadequate, and there is a shortage of trained doctors in India to effectively diagnose and treat the disease.
- **Missing in Treatment:** Access to quality diagnosis and treatment in India is unequal. A report shows that of the 9.3% of the population screened, only 1% were tested and 3.7% of those tested were diagnosed.
- **Drug-Resistant TB:** Non-uniform TB treatment across India's private sector contributes to drug resistance, leading to MDR-TB and XDR-TB.



Way Forward:

- **Prevention and early diagnosis:** They are vital to stop TB spread, requiring enhanced monitoring for drug reactions and targeted testing of high-risk populations within districts.
- **Vaccines Development:** Investing in the development of improved prophylactic vaccines is essential for the potential elimination of TB, with a low risk of generating resistance.
- **Convergence of Policy Initiatives is Essential:** To meet the UN & WHO's 2030 goal of ending the global TB epidemic, crucial steps such as increased investment, heightened awareness, adherence to WHO guidelines, and Universal Health Coverage are necessary.
- **Reduce Stigma & Support Empowerment:** Supporting frontline TB workers, enhancing supply chains, decentralizing services, and empowering communities can reduce stigma and improve treatment outcomes.
- **Multi-Sectoral Approach:** Improving nutrition, housing ventilation, air quality, and alleviating poverty will collectively help reduce TB incidence.
- **Tapping Technology:** Adopting AI and digital health solutions for TB diagnosis, adherence, and surveillance can revolutionize TB care delivery and access.

Conclusion: India leads the world in tuberculosis cases, presenting a significant public health challenge. As 2025 targets loom, intensified efforts in early detection, innovative vaccines, and multi-sectoral strategies are essential to meet the ambitious goal of eradicating TB.

Keywords: Bacille Calmette-Gue´rin, Multidrug-Resistant Tuberculosis, Extensively Drug-Resistant TB, Extra Pulmonary TB

FOOD COLORING AGENT-RHODAMINE B

Context: Karnataka government recently banned use of harmful dyes in popular food items like Gobi Manchurian, Cotton candy, etc. imposing imprisonment of up to seven years and fines of up to Rs 10 lakh for violators.

Chemical Banned	Description	Color Produced
Tartrazine	Can induce allergic or pseudo-allergic reactions.	Yellow
Sunset Yellow	Can cause allergic or pseudo-allergic reactions.	Yellow
Carmoisine	May lead to skin rashes and respiratory allergies.	Red
Rhodamine B	Considered carcinogenic; commonly used in textile dyeing and the paper industry.	Pink

About Rhodamine B:

- **Artificial Coloring Agent:** Rhodamine B (RhB) is a contaminant commonly used in dyeing. It is an industrial dye put into candy as an artificial coloring ingredient.
- **Carcinogenic Properties:** This dye has carcinogenic qualities and may be the cause of inflammation and other disorders.
- **Chemical Properties:** Rhodamine B**,** a water-soluble fluorescent xanthene dye, has a unique chemical structure that includes a xanthene ring system and an attached amino group, making it highly soluble in water and suited for a wide range of applications.
- **Source:** It does not occur naturally and is synthesized. The synthesis involves the reaction of phthalic anhydride and aniline in the presence of certain catalysts.

Food Adulteration

- Adulteration is the act of **degrading the nature or quality of food** by incidental or intentional means through the addition or mixing of poor quality, inferior, harmful, substandard, useless, or unnecessary substances to food.
- Food Adulteration has been defined comprehensively under the **Prevention of Food Adulteration Act, 1954**.
- Most common adulterants in India
  - **Spices:** Corn starch, sawdust, and flour used as 'fillers'.
  - **Khoya** is adulterated with paper, refined oil, and skimmed milk powder
  - **Milk:** Adulterated with diluted water, detergent, fat, and even urea.
  - **Tea leaves**: Adulterated with the same colored leaves.
  - **Wheat:** Adulterated with ergot, a fungus containing poisonous substances.

Applications of Rhodamine B:

- **Textile Coloring:** Rhodamine B is used in the textile industry to dye fabrics and materials.
- **Fluorescence Microscopy**: In laboratories, Rhodamine B is a valuable tool in fluorescence microscopy and biological staining, allowing for precise visualization of cellular structures.
- **Industrial Applications:** Because of its adaptability across numerous industrial processes, it is used in ink formulations, cosmetics, and food coloring agents to give products appealing colors.

Effects of Rhodamine B on Humans:

- **Oxidative stress**: Rhodamine-B intake, can cause "oxidative stress, injury, increase in cell apoptosis, and brainstem".
- **Harming Cerebellum Tissue:** Regular consumption of Rhodamine B-containing foods can harm cerebellum tissue in the brain and brainstem, resulting in functional abnormalities.
- **Irritation in Stomach:** The immediate intake of Rhodamine B-contaminated food might result in symptoms such as stomach fullness, itching, and breathing difficulties.

Conclusion: The Karnataka government's decisive action against harmful food dyes underscores a commitment to public health and consumer safety, aiming to deter adulteration and protect citizens from potentially dangerous substances.

Ethylene Oxide in Spices:
TheFSSAI has commissioned quality checks on the **spice mixes of 2 leading spice brands** in India amidst complaints of **traces of ethylene oxide** more than the permissible levels.
About Ethylene Oxide:

- It is a flammable colorless gas with a sweet odor used for producing other chemicals like antifreeze, detergents and pesticides.
- It is also used as a **sterilizing agent** for **medical equipment and cosmetics** by destroying the DNA of bacteria and viruses.
- Ethylene Oxide is considered to be a **carcinogenic agent** and can also affect **central nervous system, and cause depression and irritation** of the eyes and mucous membranes

Keywords: Artificial Coloring Agent, Food Adulteration, Oxidative stress, Fluorescence Microscopy

TRADITIONAL MEDICINES

Context: The WHO Traditional Medicine Global Summit 2023 in Gujarat, India, concluded with the **"Gujarat Declaration"**, a document that reaffirms the global commitments to indigenous knowledge, biodiversity, and traditional, complementary, and integrative medicine.

About Traditional Medicines:

- Traditional medicine, as defined by the WHO, refers to the **knowledge, skills, and practices** that various cultures have developed over time to maintain health, prevent, diagnose, and treat physical and mental illnesses.
- Some of the well-known traditional medicine systems of India include **Ayurveda, Yoga, Siddha, Unani, Sowa-Rigpa, Naturopathy etc**.

Advantages of Traditional Medicines:

- **Holistic Approach:** Unlike modern medical systems that focus solely on specific symptoms or diseases, traditional medicine emphasizes the interconnectedness of the body, mind, and spirit.
- **Less Capital Intensive:** Relatively low levels of technological inputs are required.
- **Natural Remedies:** It often relies on natural ingredients such as herbs, plants, and minerals, which are gentler on the body and may have fewer side effects compared to synthetic drugs.
- **Preventive Care**: Traditional medicine focuses on prevention rather than just treatment.
- **Accessible and Affordable**: Traditional medicine often uses locally available resources, making it more accessible and affordable, particularly in rural or underserved areas.

- **Effective in Managing Chronic Diseases**: Scientific studies show their use is effective, e.g., for HIV/AIDS and cancer patients
- **Cultural Wisdom:** Traditional medicine is deeply intertwined with cultural practices, beliefs, and experiences, making it a valuable repository of diverse healthcare insights.

Challenges for the adoption of traditional medicine:

- **Lack of Scientific Validation:** Ayurveda has failed to keep pace with the intellectual and scientific advances of the times. So, it has diminished evidence-based quality.
- **Non-Standard Courses:** Ayurvedic practitioners' graduation courses are often nonstandard and the post-graduate courses offered at most of their institutes are of subpar quality.
- **Unregulated**: Traditional Medicine products raise concerns about safety and quality of medicinal products.
- **Trial and Error Methods:** Traditional medicine practitioners discover treatments through trial and error methwith patients and leads to an erosion of the practitioner's reputation.
- **Lack of Investment**: Despite numerous efforts made by individuals and organizations to conduct research, the lack of investment into Ayurvedic research has been a major setback.
- **Less Integration with Modern Medicine:** Ayurveda can be used safely and efficiently only in about 60%-70% of primary-care illnesses. For rest, Ayurveda needs to be integrated with modern medicine.
- **State subject:** Health being a state subject adds an extra layer of complexity to any national level initiative.

Way Ahead:

- **Bridging the Financing Gap:** Equal emphasis should be given to both AYUSH as well as Allopathy system. PPP could also be utilized to ensure adequate funding of both the systems.
- **Developing International Standards & Guidelines:** To promote the safety, efficacy and quality of T&CM.
- **Integration into the National Health System:** It will enable consumers to have a wider choice when they wish to use such services.
- **Enhance Scientific Research:** Government should invest in scientific research to validate the safety and efficacy of traditional medicine practices and remedies which will help build a stronger evidence base and increase confidence among both practitioners and the public.
- **Education and Training:** Improve the quality of education and training for traditional medicine practitioners by enhancing curriculum standards, and offering advanced courses, etc.
- **Regulation and Licensing**: There is a need to establish clear regulations and licensing requirements for traditional medicine practitioners to ensure quality services.

Conclusion: The **"Gujarat Declaration"** reaffirms a global commitment of integrating traditional medicine within modern healthcare. It emphasizes on sustainable use of medicinal biodiversity along with enhancing the credibility of traditional knowledge and practices.

Keywords: Gujarat Declaration, Ayurveda, Yoga, Siddha, Unani, Sowa-Rigpa, Cultural Wisdom

PREVIOUS YEAR QUESTIONS		
1.	How is the Government of India protecting traditional knowledge of medicine from patenting by pharmaceutical companies? (15 Mark)	2019
2.	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 the country's fight against erroneous patents. Discuss the pros and cons making this database publicly available under open-source licensing. (12.5 Marks)	2015

TRANS FAT

Context: WHO has awarded its first-ever certificates validating progress in eliminating industrially produced trans fatty-acids to five countries. Denmark, Lithuania, Poland, Saudi Arabia, and Thailand.

About Trans Fats:

- Trans fats are **unsaturated fats that have been artificially altered** to make them solid at room temperature. They are created by adding hydrogen to liquid vegetable oils, a process known as **hydrogenation**.
- It is often used in processed foods to improve texture and shelf life. They **raise LDL (bad) cholesterol and lower HDL (good)** cholesterol. This can increase the risk of heart disease, stroke, and type 2 diabetes.
- **Types of trans fats:**
  - **Naturally occurring trans fats** are found in small amounts in some animal products, such as beef, lamb, and dairy products.
  - **Industrially produced trans fats** are the type of trans fat that is most harmful to health. They are found in a wide variety of processed foods, including fried foods, baked goods, snack foods, and frozen dinners.
- **WHO's Recommendation** for eliminating Trans fat
  - Limit industrially produced **trans-fat to 2g per 100g** of total fat in all fats, oils, and foods.
  - Ban the production and use of **partially hydrogenated oils (PHO).**

Initiatives to Eliminate Industrially Produced Trans Fats

- **Regulatory Measures**: The Food Safety and Standards Authority of India **(FSSAI)** had issued directives to reduce the trans fat content in food products, from January 1, 2022.
  - The maximum limit of industrially produced trans fat in food products is **2% by mass of the total fat content**.
  - The directives also state that food products that contain **more than 0.5 grams of industrially produced trans fat per 100 grams of fat must be labeled** with the following statement: "Contains industrially produced trans fat."
- **Best-practice policy:** India became the first lower-middle-income country to implement a best-practice policy in 2022.
- **Awareness Campaign**: FSSAI has launched a mass media campaign "Heart Attack Rewind" to create awareness about the harmful effects of trans fat.

- **Eat Right Campaign**: It was a campaign launched by FSSAI aimed at eating healthy and safe food with reduced levels of salt, sugar and saturated fat.

Conclusion: Trans fats, harmful to heart health, have prompted global initiatives for elimination. Following WHO guidelines, efforts like India's regulatory measures and awareness campaigns aim to reduce trans fats in foods and safeguard public health by minimizing the risk of cardiovascular diseases.

Additional Information:
WHO calls on governments to use the **REPLACE** action package to eliminate industrially-produced trans-fatty acids from the food supply
REPLACE provides six strategic actions to ensure the prompt, complete, and sustained elimination of industri ally-produced trans fats from the food supply.

- **RE**view dietary sources of industrially-produced trans fats and landscape for required policy change.
- **P**romote replacement of industrially-produced trans fats with healthier fats and oils.
- **L**egislate or enact regulatory actions to eliminate industrially-produced trans fats.
- **A**ssess and monitor trans fats content in the food supply.
- **C**reate awareness of the negative health impact of trans fats among all stakeholders.
- **E**nforce compliance of policies and regulations.

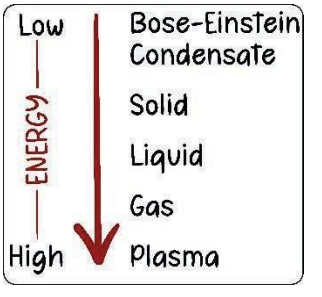
Keywords: Unsaturated fats, Partially Hydrogenated Oils, REPLACE

8 ACHIEVEMENT OF INDIANS IN SGT

BOSE–EINSTEIN CONDENSATE

Context: Bose-Einstein condensate (BEC) is a unique quantum state of matter achieved at extremely low temperatures, near absolute zero. In this state, a large number of bosons occupy the same quantum state, resulting in macroscopic quantum phenomena. This phenomenon, predicted by Satyendra Nath Bose and Albert Einstein, has opened u p new avenues for studying fundamental physics and quantum phenomena. BEC allows scientists to observe quantum effects on a macroscopic scale, providing insights into superfluidity, superconductivity, and quantum mechanics.

About Bose-Einstein condensate (BEC):



- A Bose–Einstein condensate (BEC) is a state of matter that is made up of atoms that have been cooled to very **low temperatures.**
  - At these temperatures, the atoms lose their individual identities and behave as a **single entity.**
- **Formation:** BECs are **created by cooling a gas of atoms** to very low temperatures. This can be done using a variety of methods, such as **laser cooling or evaporative cooling.**
  - Once the atoms are cooled to a low enough temperature, they will form a BEC.
- It allows scientists to study the behavior of atoms at the quantum level, which is a fundamental level of nature.

Benefits of BECs:

- **Improved Understanding of Quantum Mechanics:** BECs allow scientists to study the behavior of atoms at the quantum level. This can help us to better understand the universe and how it works.
- **Development of New Technologies**. BECs can be used to develop new technologies, such as quantum computers. Quantum computers are computers that use the principles of quantum mechanics to perform calculations.
- **Inspiration of a New Generation of Scientists and Engineers**. BECs are a fascinating and cutting-edge area of research. They can inspire a new generation of scientists and engineers.
- **Fundamental Research:** BEC provides insights into fundamental quantum behavior, allowing scientists to study phenomena such as superfluidity, quantum coherence, and quantum interference.
- **Precision Measurements:** BEC serves as a precise tool for measuring physical quantities like time, acceleration, and magnetic fields, enhancing the accuracy of scientific instruments.

Conclusion: Bose-Einstein condensate represents a remarkable achievement in the field of quantum physics. Its study has **deepened our understanding of quantum mechanics** and provided insights into **fundamental physical phenomena.**

Keywords: Quantum, Plasma, Laser cooling, Evaporative cooling.

PREVIOUS YEAR QUESTIONS		
1.	Discuss the work of 'Bose-Einstein Statistics' done by Prof. Satyendra Nath Bose and show how it revolutionized the field of Physics. (10 marks)	2018

DR. M. S. SWAMINATHAN

Context: Recently, agricultural scientist Dr M S Swaminathan was awarded **India's highest civilian award, the Bharat Ratna for his** contributions to **India's agriculture and farmers' welfare.**

MS Swaminathan Biography:

- **MS Swaminathan**: He was an **agronomist, agricultural scientist, plant geneticist, administrator, and humanitarian**, who is widely known as the **'father of the Green Revolution' in India.**
- **Early Life**: Dr Swaminathan was born on **August 7, 1925 in Kumbakonam, Madras Presidency.**
- **Death**: Dr Swaminathan passed away in **Chennai on September 28, 2023** at the age of 98.

DR MS SWAMINATHAN: AS A FATHER OF GREEN REVOLUTION IN INDIA

- **Collaborative Research:** In the 1960s, Dr Swaminathan collaborated with renowned scientist **Norman Borlaug** to conduct research in **rice and wheat** in order to boost production in **developing countries such as India and Pakistan.**
- **Crossbreeding for High-Yield Varieties:** They inter-bred **Mexican dwarf varieties** of wheat with **Japanese varieties.** This led to a **high-yield, good quality, and disease-free crop.**

OTHER CONTRIBUTIONS OF DR MS SWAMINATHAN

- **Plant Genomics**: Dr Swaminathan helped in **developing rice with C4 carbon fixation capabilities,** which allowed better photosynthesis and water usage. He also played a key role in the development of the **world's first high-yielding basmati.**
- **Radiation Botany:** Dr Swaminathan set up a **'Cobalt-60 Gamma Garden'** to study radiation mutation.
  - The aim of this research was to **increase plant responsiveness to fertilizers** and demonstrate real-world application of crop mutations.
- **Institutional Contribution:** Dr Swaminathan played a major role in building the **International Crop Research Institute** for the Semi-Arid Tropics in India; the **International Board for Plant Genetic Resources** (Biodiversity International) in Italy and the **International Council for Research in Agro-Forestry** in Kenya.
- **Formulation of MSP:** Dr Swaminathan committee recommended that the **Minimum Support Price (MSP),** which is the price farmers sell their crops to the government, should be at least 50 percent more than the weighted average cost of production.

CONCLUSION

Dr MS Swaminathan's work has not only laid the **foundation for a self-sufficient India in food production**, it also **inspired a generation of scientists** working in the agriculture sector across the world.

Keywords: Green Revolution, Radiation Botany, Minimum Support Price

PREVIOUS YEAR QUESTIONS		
1.	How did India benefit from the contributions of Sir M. Visvesvaraya and Dr. M. S. Swaminathan in the fields of water engineering and agricultural science respectively? (10 Marker)	2019

JAGADISH CHANDRA BOSE

Context: Recently, India-born American physicist-philanthropist, Mani Bhaumik, donated one million US dollars, to **honour the work of J C Bose,** whose work on **wireless telegraphy** was ignored for long by the West.

Career and Achievements of J C Bose:

- **About Jagadish Chandra Bose**: He was born on **30 November 1858 in Kolkata,** India, was an Indian polymath renowned for his contributions in several disciplines such as **physics, botany, and radio science.**
  - He is widely recognized as the **"father of radio science"** in India.
- **Significance of Bose's Work:** His work was groundbreaking and helped to lay the foundation for the development of **radio and television.**

Significant Contributions:

- **Crescograph:** The crescograph was an instrument that could measure **the growth of plants.** It was a major breakthrough in the study of plant physiology.
- **Radio Receiver:** In 1895, Bose built a radio receiver that could **detect radio waves from lightning.** This was the first time that radio waves had been detected in India.
- **Radio Waves:** Bose showed that radio **waves could be used to transmit signals** over long distances. This work helped to lay the **foundation for the development of radio and television.**
- **Botany:** Bose made significant contributions to the field of botany. He studied the growth and movement of plants, and he showed that **plants can respond to electrical and magnetic fields.**
- **Physics:** Bose made significant contributions to the field of physics. He studied the **properties of materials, and he developed new instruments** to study plant growth and movement.

Bose was a brilliant scientist and a **pioneer in the field of radio science.** His work has had a major impact on the world, and he is considered to be **one of the most important scientists in Indian history.**

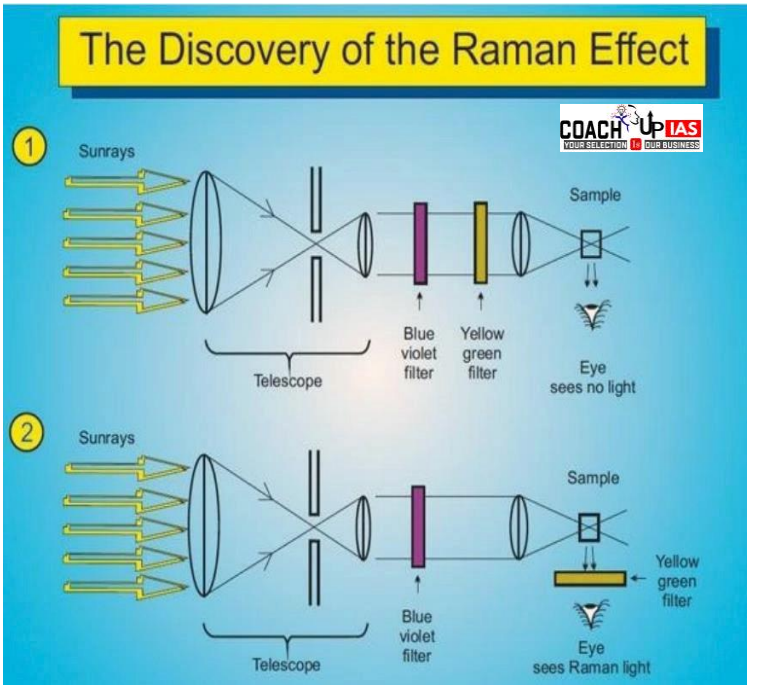
Keywords: Crescograph, Radio waves, Radio receivers.

CHANDRASHEKHAR VENKAT RAMAN

Context: The **Raman Effect** was discovered on 28 February 1928. This day is celebrated annually as the **National Science Day** by the Government of India.

SIR CV RAMAN: PIONEERING CONTRIBUTIONS TO PHYSICS AND SCIENTIFIC INQUIRY

- **Birth:** Chandrasekhar Venkata Raman was **born in Tiruchirappalli, Madras Presidency** on 7 November, 1888.
- **Initial Research:** He started research early in his student life. His first research paper, called "**Unsymmetrical diffraction bands due to a rectangular aperture",** was published in 1906 while he was still a graduate student.
- **Raman Effect:** He **developed a spectroscope** and discovered that when **light traverses a transparent material,** the **deflected light changes its wavelength and frequency**.
  - This unknown type of scattering of light, was named **"modified scattering"** was subsequently termed the Raman Effect or Raman scattering.
- **Acoustics:** As a great admirer of musical instruments, he worked out the **theory of transverse vibration of bowed string instruments** based on **superposition of velocities.**
- **Colour of Sea Water**: He conducted observation of sea water using a **spectroscope and Nicol prism.** He came to the conclusion that the **blue colour of sea water was not because of Rayleigh scattering.**
  - Later, he conducted a full-fledged study on the sea water of Bay of Bengal to come to the conclusion that visible color of water is mainly attributed to the **selective absorption of longer wavelengths of light** in the red and orange regions of the spectrum, owing to overtones of the infrared **absorbing O-H (oxygen and hydrogen combined) stretching modes** of water molecules.



- **Spectroscopic Behaviour of Crystals:** He followed a new approach towards crystal dynamics in 1948 through his investigation of the **Spectroscopic behavior of crystals.**
  - Apart from studying composition and characteristics of the diamonds, he also studied various colourful materials, such as **labradorite, agate, opal, and pearls.**
- **Angular Momentum:** Along with his student, he discovered that light photons had **angular momentum or spin.**

SIR CV RAMAN: A LEGACY OF SCIENTIFIC EXCELLENCE AND GLOBAL RECOGNITION

- **Nobel Prize in Physics**: Sir CV Raman won the **Nobel Prize in Physics** for his work on the scattering of light and for the discovery of the **Raman Effect in 1930**.
  - With this honour, he became the **first Indian, Asian and non-white individual** to win a Nobel Prize for the sciences.
- **Bharat Ratna:** In 1954, he was honoured with **India's highest civilian award**, the Bharat Ratna.

CONCLUSION

Sir CV Raman was a **pioneer of experimental Physics** in India. His contributions towards **fostering a scientific environment** in India are unparalleled.

Keywords: Raman Effect, Theory of Transverse Vibration, Angular Momentum, Spectroscopic Behaviour of Crystals, Nobel Prizes to Indians, etc.

SATYENDRA NATH BOSE

Context: Recently, a **5-day International Conference on Photonics, Quantum Information, and Quantum Communication**, was organized by the Satyendra Nath Bose National Centre for Basic Sciences in Kolkata.

About Satyendra Nath Bose:

- **Satyendra Nath Bose:** He was an **Indian mathematician and physicist,** an expert in theoretical physics. His contributions helped improve the **Standard Model of Particle Physics.**
- **Birth:** Calcutta (now Kolkata) in 1894.
- **Inspired by**: Jagdish Chandra Bose and Prafulla Chandra Ray.
- **Death**: February 4, 1974, after a severe heart attack at the **age of 80.**

Contributions of Satyendra Nath Bose:

- **Bose-Einstein Condensate**: It predicted that at **very low temperatures near absolute zero,** all particles will condense into a single state, called **Boson**. It is also known as the **Fifth state of matter.**
- **Derived Planck's law**: He had derived **Planck's law for black body radiation** (which refers to the spectrum of light emitted by any hot object) **without any reference to classical electrodynamics**.
  - Impressed by Bose's findings, **Einstein arranged for the publication of the paper** and also translated it into German.
- **Bose-Hubbard Model:** His work inspired the development of the Bose-Hubbard model which describes the **behavior of ultra-cold atoms trapped in an optical lattice.**
- **God Particles:** In the 1960s, **Peter Higgs** carried out further research using **Bose-Einstein Statistics** and wrote a paper about a very unstable particle that survives for a fraction of a second after its birth, and then it breaks apart producing other fundamental particles.
  - He called this particle **"Higgs Boson Particle" or "God Particle".**

Recognitions to Satyendra Nath Bose:

- **Padma Vibhushan:** He received the country's **second-highest civilian honour** from the Indian government in 1954.
- **Rabindranath Tagore** dedicated his only book on science – **Vishwa Parichay to SN Bose.**
- Bose was nominated for the **Nobel Prize in Physics.**
- **Bosons named after S N Bose**: Bosons are a class of elementary subatomic particles in particle physics that were named after him.

9 MISCELLANEOUS

DRONES

Context: The proposal to establish **India as a leading drone hub** aligns with the Atmanirbhar Bharat Abhiyan and the recent implementation of the **Drone Rules 2021**.

- Drones have immense potential to revolutionize various sectors, including national defense, agriculture, law enforcement, and mapping.

About:

- Drones are **unmanned aircraft (UA)** that **function autonomously or are remotely piloted**.
- They were initially designed for military and aerospace purposes, but today drones have gained popularity in various sectors, like agriculture, law enforcement, and mapping.
- Drones offer **improved safety and efficiency** compared to traditional aircraft.
- The autonomy of a drone varies, ranging from human-controlled remote piloting to advanced autonomy utilizing sensors and **LIDAR detectors** for movement calculations.

Application:

- **Surveying and Mapping:** Drones can quickly and accurately survey large areas, providing detailed maps and 3D models for construction, urban planning, and land management.
  - Ex. Use of drone technology in the **SVAMITVA scheme**
- **Agriculture and Crop Monitoring:** Drones aid in monitoring crop health, detecting pests and diseases, and optimizing pesticide use, leading to increased productivity and reduced costs.
  - Ex**. Kisan drone** assisting in insecticides and nutrients spray.
- **Search and Rescue Operations:** Drones equipped with thermal imaging cameras and GPS can efficiently locate missing persons or survivors in disaster-stricken areas, improving rescue efforts.
  - Ex**. MQ-9B Drones** imported from the US.
- **Infrastructure Inspection:** Drones facilitate the inspection of bridges, power lines, pipelines, and other infrastructure, minimizing the need for manual inspections and reducing risks for workers.
- **Environmental Monitoring:** Drones assist in monitoring wildlife, tracking deforestation, assessing pollution levels, and conducting research in remote areas, contributing to conservation efforts.
- **Delivery and Logistics:** Drones enable fast and efficient delivery of goods, especially in hard-to-reach areas, reducing transportation costs and enhancing logistics operations.
  - **Telangana government** for using drone technology to deliver vaccines in remote areas.
- **Disaster Response:** Drones aid in assessing damage, identifying hazards, and providing situational awareness during natural disasters, enabling quick and targeted response efforts.
- **Security and Surveillance:** Drones enhance security by monitoring public spaces, borders, and critical infrastructure, helping authorities in surveillance and threat detection. Eg. India's first indigenous drone defence dome ie. "Indrajaal"
- **Humanitarian Aid:** Drones are used to deliver medical supplies, vaccines, and food to remote or inaccessible areas, assisting in humanitarian relief operations.

Way Forward:

- **Training Programs:** Establish comprehensive training programs for drone pilots to ensure they possess the necessary skills beyond drone technology itself.
- **Balancing Security and Benefits:** Formulate guidelines that prioritize both security concerns and the utilization of drone technology to its fullest potential.
- **Developing Anti-Drone System:** DRDO is actively developing an anti-drone system, featuring soft kill options such as drone jamming and hard kill options like laser technology, missiles, or other drones for neutralizing threats.

- **Increasing Investments:** India should invest in its own UAV systems and counter-drone technology to effectively detect and track potential threats, particularly in critical asset areas.

Conclusion: Drones are revolutionizing numerous sectors by enhancing efficiency, safety, and accessibility. As they evolve, balancing innovation with robust security measures and expanding training programs will ensure their integrated and beneficial use across diverse fields.

India has a policy in place for the operation of drones.

- **Categorization:** Drones are categorized based on their weight and capabilities into five categories - Nano, Micro, Small, Medium, and Large.
- **Registration:** All drones except those in the Nano category need to be registered with the Digital Sky portal.
- **Operator Permit:** Operators of drones in the Micro, Small, Medium, and Large categories need to obtain an operator permit from the Directorate General of Civil Aviation (DGCA).
- **No-Fly Zones:** Certain areas such as airports, near international borders, strategic locations, etc., are designated as no-fly zones where drones are not permitted to operate.
- **Remote Pilot License:** Pilots flying drones in the Small, Medium, and Large categories are required to obtain a Remote Pilot License (RPL) from the DGCA.
- **Flight Guidelines:** Specific guidelines are provided for safe and responsible drone operations, including maximum altitude, distance from people and structures, and daylight-only operations.

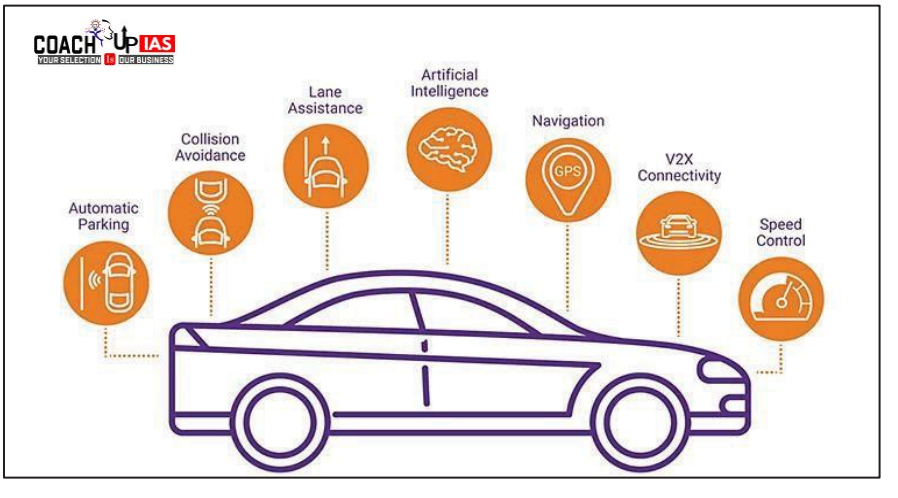
Keywords: Application of Drones, Drone Rules 2021, Kisan drone, LIDAR detectors, etc.

ADVANCED DRIVER ASSISTANCE SYSTEM (ADAS)

Context: As autonomous driving gains momentum globally, India emerges as a surprising yet significant market, with a surge in demand for Advanced Driver Assistance Systems (ADAS).

ABOUT ADVANCED DRIVER ASSISTANCE SYSTEMS (ADAS)

- **Definition**: Advanced driver assistance systems (ADAS) are in-vehicle digital tools that assist drivers with everyday tasks like navigation and parking.
  - ADAS systems use **sensors, cameras, and radar** to monitor the environment around a vehicle.
  - It includes features such as **automatic emergency braking, forward collision warning, blind spot collision warning,** lane-keeping assist, adaptive cruise control, and more
- **Objective:** To **decrease the frequency and impact of unavoidable vehicle accidents,** thereby preventing fatalities and injuries



Challenges in India for ADAS Systems:

- **Poor Road Infrastructure:** Diverse road quality from highways to rural paths complicates ADAS implementation due to inconsistent infrastructure.
- **Mixed Traffic Composition:** India's roads accommodate a mix of pedestrians, cyclists, and motor vehicles. High usage of roads by non motorized vehicles requires integration of these users in ADAS development.
- **Technological and Connectivity Limitations:** ADAS depends on reliable data and connectivity, which can be scarce in remote or underdeveloped areas.
- **Security Risks in ADAS:** Significant cybersecurity risks accompany ADAS, with potential vehicle hacking posing severe safety threats.
- **Driver Awareness and Technology Adoption**: Success of ADAS system depends on driver behavior and awareness, thus requiring driver education about ADAS systems.

FUTURE DIRECTIONS FOR ADAS SYSTEMS

- **Integration and Centralization:** Transition from distributed electronic control units (ECUs) to centralized ADAS domain controllers to enhance system integration and reduce complexity.
- **Advancement in Computing**: Upgrade the electronic architecture to accommodate higher computing performance using 64-bit processors, AI accelerators etc.
- **Data Management:** Implement more efficient data handling capabilities to manage increasing data volumes and leveraging neural networks improved processing and accuracy.
- **Enhanced Autonomy:** Progress towards higher levels of driving automation, aiming for fully autonomous vehicles that require minimal to no human intervention.
- **Cost and Reliability Focus**: Address the need to reduce costs and shorten development cycles while increasing the reliability and durability of ADAS components and systems.

Conclusion: As autonomous driving advances, India's burgeoning ADAS market highlights a crucial balance: integrating cutting-edge technology with unique local conditions to enhance road safety and vehicular efficiency, ensuring a smoother transition towards comprehensive vehicular automation.

Autonomous Driving/ Self Driving Vehicles: It is the ability of a car to drive itself with limited or no human intervention. Autonomous vehicles are equipped with technologies like ADAS that can sense their surroundings and adjust their speed and course without human input.

Keywords: Self-Driving Cars, ADAS System Sensors, RADAR System, etc.

WIFI-7 TECHNOLOGY

Context: Recently U.S. based company Qualcomm suggested that India should adopt the newest Wi-Fi 7 technology.

About Wi-Fi 7 Technology:

- Wi-Fi, or Wireless Fidelity, utilizes radio waves to facilitate **high-speed internet and network connections** among devices. The transmission of Wi-Fi signals requires a **base station, router, and accessing devices** such as smartphones and laptops.
- Wi-Fi 7 is the next-generation Wi-Fi standard, known for its **Extremely High Throughput (EHT)**.

KEY FEATURES OF WI-FI 7

- **Backward Compatibility:** Wi-Fi 7 can connect with devices operating on 2.4GHz, 5GHz, and 6GHz bands, utilizing a variety of spectrum frequencies to enhance connectivity without the need for new hardware.
- **Reduced Latency:** This new standard boosts the efficiency of cloud-based operations like file sharing and online gaming thanks to its lower latency.
- **Multi-Link Operation (MLO):** Wi-Fi 7 enhances network performance by merging multiple channels across different frequencies.
- **Enhanced Speed and Capacity:** With the potential to support up to 330 Gigabits per second per access point, Wi-Fi 7 offers a bandwidth capacity four times greater than that of its predecessor, Wi-Fi 6.

Benefits of Wi-Fi 7 Technology:

- **Empowering India's Digital Transformation:** Wi-Fi 7 fuels India's tech evolution, supporting cloud-based services and wireless applications while ensuring digital security and privacy.
- **Driving Innovation Across Sectors**: In India, Wi-Fi 7 spurs innovation in enterprise, connectivity, smartphone tech, and Edge AI, fostering progress across diverse sectors.
- **Meeting the Demands of Emerging Technologies**: Wi-Fi 7 caters to the rising IoT needs, from smart homes to industrial applications, ensuring seamless connectivity and data transmission.
- **Revolutionizing Healthcare:** Wi-Fi 7 transforms healthcare with tele-diagnostics and telesurgery, advancing patient care and medical practices.
- **Enhancing User Experiences in Advanced Applications:** Wi-Fi 7 elevates user experiences, enabling smooth streaming of 8K videos and optimizing performance in cloud gaming, AR/VR, and data-heavy tasks.

Keywords: Wi-Fi 7 Technology, Bluetooth Technology, Li-Fi Technology, PM-WANI, etc.

END TO END ENCRYPTION

Context: Indian Army develops end-to-end encrypted mobile ecosystem SAMBHAV (Secure Army Mobile Bharat Version).

About E2E Encryption: Encryption is the process of **converting information into a secure format** that conceals its content from unauthorized users, which can be reversed only by those who possess the **correct decryption key.**

- The key is some data using which a computer can **'unlock' (decrypt) some 'locked' (encrypted) text**.

- **E2E is encryption** that refers to particular locations between which information moves.
- It encrypts data between **two devices (sender and receiver).** It prevents unauthorized access during transfer, excluding third-party access such as cloud service providers, internet service providers (ISPs), and cybercriminals.
- There are two important forms of encryption**: Encryption-in-Transit and E2E encryption.**
  - **Encryption-in-transit** means it is encrypted before a message is relayed from the server to the actor (or vice versa). This scheme is used to prevent an actor from being able to read the message's contents by intercepting the relay.
  - **In E2E encryption,** the message is encrypted both in transit and at rest – i.e. when being relayed from the sender's phone to the server (or vice versa) and when it is sitting inside the server. It is only decrypted when a receiver receives the message.

About SAMBHAV

- SAMBHAV is an indigenous, secure, end-to-end mobile ecosystem.
- It is the **Indian Army's** secure **5G-based mobile platform.**
- Aligns with India's efforts towards **dual-use infrastructure** and civil-military fusion
- SAMBHAV utilizes **commercial cellular networks** rather than depending on private networks.

Mechanism of E2EE:

- The encryption keys (for scrambling and unscrambling messages) are not stored with the service provider but directly on the user's devices (endpoints).
- Messages are transformed into an **unreadable format** using a special algorithm during transmission. This **"scrambled"** data is unreadable without the decryption key.

Benefits

- **Secure Communication:** End-to-end encryption relies on public key cryptography that stores private keys on the devices involved.
- **Protection from Unwanted Access: E2EE** safeguards user data from unauthorized parties like service providers, cloud storage providers, and companies dealing with encrypted data.
- **Tamper-Resistance:** If a message is tampered with during transit, it can't be deciphered by the recipient, ensuring the tampered content remains unreadable.
- **Other Benefits:** E2E encryption empowers activists and journalists in oppressive regimes to communicate securely, safeguarding sensitive information from government surveillance and censorship.

Drawbacks:

- **Communication Endpoint Complexity:** Some E2EE systems re-encrypt data during transmission, which can expose encrypted data if endpoints are compromised.
- **Excessive Privacy Concerns:** E2E encryption debates focus on balancing privacy with the need for content moderation, as companies tackle illegal activities and compliance challenges.
- **Limited Metadata Protection:** Metadata like dates and recipients are visible despite encryption, posing a risk of information exposure.

Conclusion: E2E encryption is **a powerful tool** with significant implications for individuals, organizations, and society as a whole. It raises broader questions about **individual autonomy, government overreach, and the ethical responsibilities of technology companies in the digital age**.

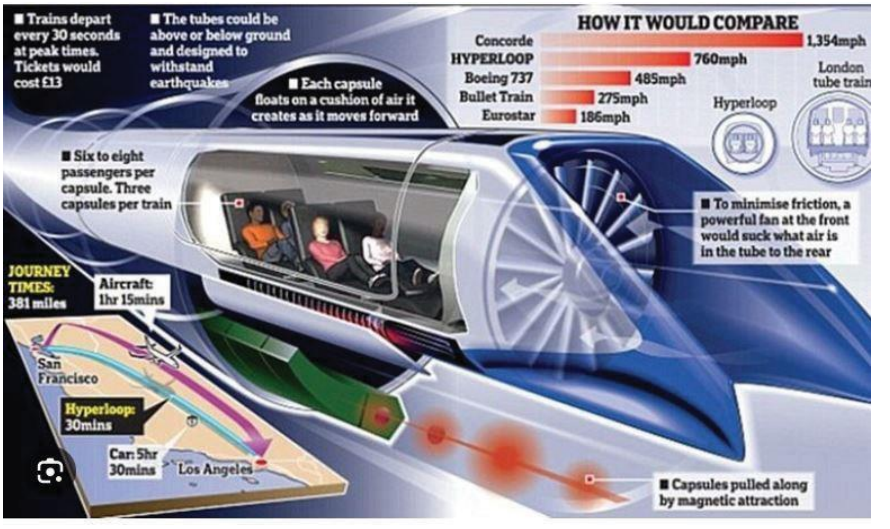
Keyword: End-to End Encryption, Quantum Encryption/ Quantum key Distribution (QKD) SAMBHAV, Secure Communication Technology, etc

HYPERLOOP

Hyperloop is a proposed high-speed transportation system that uses a pod to travel through a **low-pressure tube.** The pod is propelled by a linear motor and can travel at speeds of up to 760 mph (1,2 23 km/h).

History:

- The idea for Hyperloop was first proposed by Elon Musk in 2013. Musk envisioned a system that would use a vacuum tube to transport pods at speeds of up to 760 mph (1,223 km/h).



Working of Hyperloop:

- A Hyperloop system consists of a low-pressure tube, a pod, and a linear motor. The tube is evacuated to create a near-vacuum, which reduces air resistance and allows the pod to travel at high speeds.
- The pod is propelled by a linear motor, which uses electromagnetic fields to move the pod along the tube.

Benefits of Hyperloop:

- **Speed:** Hyperloop pods can travel at speeds of up to 760 mph (1,223 km/h), which is much faster than current transportation systems.
- **Efficiency:** Hyperloop is a very efficient transportation system. The pods are aerodynamic and the low-pressure tube reduces air resistance, which means that Hyperloop can travel long distances with very little energy.
- **Sustainability:** Hyperloop is a sustainable transportation system. The pods are powered by electricity, which is a renewable resource.
- **Safety:** Hyperloop is a safe transportation system. The pods are designed to withstand high speeds and the low-pressure tube reduces the risk of accidents.

Challenges of Hyperloop:

- **Cost:** Hyperloop is a very expensive transportation system. The cost of building a Hyperloop system is estimated to be in the billions of dollars.
- **Regulation:** Hyperloop is a new transportation system and there are no regulations in place for its construction or operation. This could make it difficult to build and operate a Hyperloop system.
- **Public acceptance:** Hyperloop is a new technology and there is some public concern about its safety and environmental impact. This could make it difficult to build public support for a Hyperloop system.
- **Technological Feasibility:** Developing the necessary technology for high-speed travel in a near-vacuum tube, including maintaining low air pressure, reducing friction, and ensuring safety.
- **Infrastructure Requirements:** Constructing a network of elevated or underground tubes that can support Hyperloop pods, including acquiring land rights and navigating regulatory processes.

Future of Hyperloop:

- **High-Speed Transportation:** Hyperloop holds the potential to revolutionize transportation with speeds exceeding 700 miles per hour, significantly reducing travel times.
- **Sustainable Infrastructure:** Hyperloop systems can be powered by renewable energy sources, reducing carbon emissions and promoting sustainable transportation.
- **Regional Connectivity:** Hyperloop networks can connect distant regions, enabling efficient commuting between cities and reducing congestion on roads and airports.
- **Economic Opportunities:** Hyperloop development can create jobs and stimulate economic growth through infrastructure construction, manufacturing, and operational roles.
- **Technological Advancements:** Continued research and development in materials, propulsion, and safety systems will drive innovation and improve Hyperloop technology.
- **Regulatory and Safety Considerations:** Developing appropriate regulations and ensuring passenger safety are crucial aspects that need to be addressed for widespread adoption of Hyperloop systems.

Conclusion: Hyperloop, a revolutionary transportation concept, holds immense potential for the future. With its high-speed, low-friction travel, it could transform the way people commute and revolutionize transportation systems, offering a promising vision of efficient and sustainable mobility.

Keyword: Hyperloop Transport System, Bullet Train, Magnetic Levitation, etc

NOBEL PRIZES

NOBEL PRIZE IN PHYSIOLOGY/MEDICINE

2023 Nobel Prize in Physiology/Medicine has been awarded to **Katalin Karikó and Drew Weissman** for their discoveries concerning **nucleoside base modifications.**

mRNA vaccines

- The discoveries were critical for **developing effective mRNA vaccines against COVID-19.**
- In our cells, genetic information encoded in **DNA is transferred to messenger RNA (mRNA),** which is used as **a template for protein production.**
- During the 1980s, efficient methods for producing **mRNA without cell culture (in a lab)** were introduced, called **in vitro transcription.**
- **In vitro transcribed mRNA** was considered unstable and challenging to deliver. Moreover, in vitro-produced mRNA gave rise to **inflammatory reactions.**
- The Nobel laureates showed that converting the RNA base **uridine to pseudouridine in mRNA produced in vitro** could reduce the inflammatory response.
- Later, **mRNA vaccines were developed against Zika virus, MERS-CoV** and COVID vaccines for **Moderna and Pfizer-BioNTech vaccines,** with their **nucleoside bases modified**.
- **Nucleoside base Modification:**
  - A nucleoside-modified **messenger RNA (modRNA)** is a **synthetic mRNA** in which some nucleosides are replaced by other **naturally modified nucleosides or synthetic nucleosides (Example uridine to pseudouridine**).
  - **modRNA (Modified RNA)** is used to induce the production of **a desired protein in certain cells**.
  - **Using modified nucleosides** is a critical approach to **mitigate the intrinsic immune-response of exogenous mRNA and increase its translation for mRNA therapeutic applications.**

NOBEL PRIZE IN CHEMISTRY

The 2023 Nobel Prize for Chemistry was awarded to **Moungi G. Bawendi, Louis E. Brus, and Alexei I. Ekimov,** for the discovery and synthesis of quantum dots.

About Quantum Dots

- Quantum dots are tiny particles which are just nanometers wide and display **distinct optical properties because of their small size**.
- They have the **same structure and composition as bulk materials**, yet unlike bulk materials, their properties can be altered by adjusting their size.
- The physical and optical properties of quantum dots, such as their **color and conductivity, are highly dependent on their size**.
- Quantum dots are known for their **ability to emit light in a wide range of colors**. The color of light emitted by quantum dots can be finely adjusted by changing their size.
- Quantum dots also hold promise in the **development of quantum computing**. Their quantum properties can be harnessed to create qubits,

Applications of Quantum Dots:

- **Convert a spectrum of light into different colors.**
- **Map biological tissues** by biochemists.
- **Used in photovoltaic cells** to improve the absorption and efficiency.
- Certain **cancer treatments use quantum dots** for targeted drug delivery.
- Used as **security markers** on currency and documents as an anti-counterfeit measure.

Nobel Prize in Physics

The 2023 Nobel Prize for Physics was shared by three scientists—**Pierre Agostini, Ferenc Krausz** and **Anne L'Huillier.**

About Nobel Prize Physics 2023:

- Nobel Prize Physics 2023 has been awarded for **"experimental methods that generate attosecond pulses for the study of electron dynamics in matter.**

- The laureates received the Prize for their work enabling the creation of **ultra-short light pulses**, allowing direct observation of the rapid world of electrons.
- The short pulses are generated on a timescale that is known as **attosecond**.

About Attosecond

- Attosecond is an infinitesimally brief unit of time that could enhance our understanding of the fundamental forces and processes that govern the universe.
- It is equivalent to one quintillionth of a second, or 10 to the power of 18 seconds.

Significance of attoseconds

- Attosecond physics gives the opportunity to understand mechanisms that are governed by electrons.
- Attosecond pulses allow scientists to capture 'images' of activities that happen in incredibly short time spans.
- Attoseconds create and manipulate extreme ultraviolet (XUV) and X-ray pulses, which are vital for imaging ultrafast processes at the atomic and molecular scale.

Keywords: Nucleoside Base Modifications, mRNA, Quantum dots, Quantum Computing, Attoseconds, X-ray pulses, entanglement, teleportation.

PREVIOUS YEAR QUESTIONS		
1.	The Nobel Prize in Physics of 2014 was jointly awarded to Akasaki, Amano and Nakamura for the invention of Blue LEDs in the 1990s. How has this invention impacted the everyday life of human beings? (15 marks)	2015

Saarthi

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SATEESH PATEL
UPSC RANK - 163

SATWIK SRIVASTAVA
SDM RANK-3

DEEPAK SINGH
SDM RANK-20

ALOK MISHRA
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GIC PRINCIPAL (PCS-2021)

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