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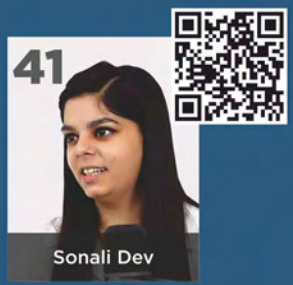

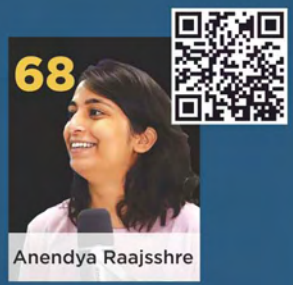

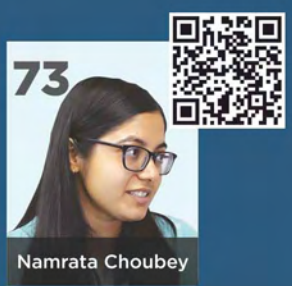

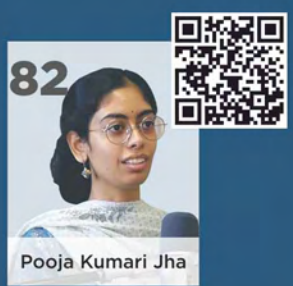

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PREFACE

Dear Aspirants,

Science and technology is an important part of the syllabus of General Studies Paper III of UPSC syllabus. UPSC has been asking about 40 marks question on this section directly. However, awareness of science and technology has fruits beyond this. Many times, the points in science and technology can be utilized in both GS Paper 1, GS Paper 2 and even in Essay and Ethics paper. Thus, it is important to be thorough with science and technology.

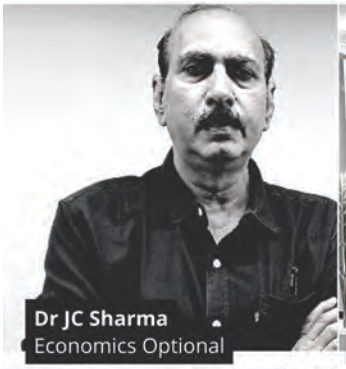
The Mains Compass for Science & Technology has been developed in accordance with demands of the UPSC exam. We have tried cover all the major technologies revolutionizing the world. Major applications of science and technology, their use cases and concerns with these technologies have been highlighted. The effort has been to comprehensively cover all topics mentioned in the syllabus.

Students are advised to supplement the Mains Compass with previous year's UPSC questions, GS QIP Mains program and Mains Test Series of Rau's IAS. Hopefully, students will excel in the coming mains.

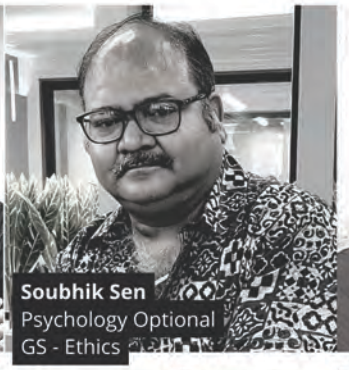
All the best!!!

Rau's IAS Team

MEET the TEAM



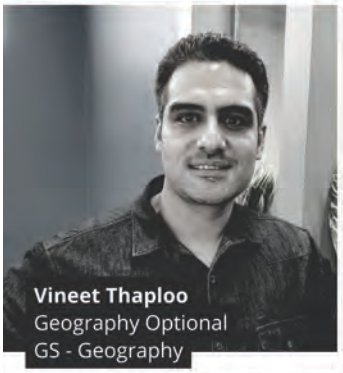
Dr JC Sharma
Economics Optional



Soubhik Sen
Psychology Optional
GS - Ethics

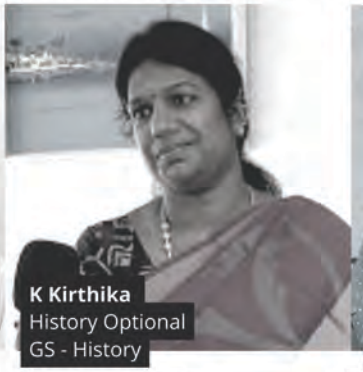
Rahul Puri
PSIR Optional
GS - IR & Security

Indrajeet Bariar
Geography Optional
GS - Geography, IR & Security



Vineet Thaploo
Geography Optional
GS - Geography

Parampreet Singh
History Optional
GS - History



K Kirthika
History Optional
GS - History

Mathimaran Raju
History Optional
GS - History

Gajanan Dwivedi
GS - History

Vikram Kaushal
Sociology Optional
GS - Society & Social Justice & Ethics

Dr Surendra Singh
Sociology Optional
GS - Society & Social Justice

Dr CP Kaushik
Anthropology Optional
GS - Env., Eco., & Bio.

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Syllabus Science & Technology

- Science and Technology developments and their applications and effects in everyday life
- Achievements of Indians in science & technology
- Indigenization of technology and developing new technology.
- Awareness in the fields of IT, Space, Computers, robotics, nanotechnology, biotechnology and issues relating to intellectual property rights.

Previous Year Questions and Theme Map

INTERNET & COMPUTING TECHNOLOGY	
YEAR	**UPSC MAINS QUESTIONS**
2019	What is CyberDome Project? Explain how it can be useful in controlling internet crimes in India.
2015	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.
2013	How does the 3D printing technology work? List out the advantages and disadvantages of the technology.

SPACE	
YEAR	**UPSC MAINS QUESTIONS**
2019	What is India's plan to have its own space station and how will it benefit our space program?
2017	India has achieved remarkable successes in unmanned space missions including the Chandrayaan and Mars Orbiter Mission, but has not ventured into manned space mission, both in terms of technology and logistics? Explain critically.
2016	Discuss India's achievements in the field of Space Science and Technology. How the application of this technology has helped India in its socio-economic development?
2015	What do you understand by 'Standard Positioning Systems' and 'Protection Positioning Systems' in the GPS era? Discuss the advantages India perceives from its ambitious IRNSS program employing just seven satellites.

NANOTECHNOLOGY	
YEAR	**UPSC MAINS QUESTIONS**
2019	What do you understand by nanotechnology and how is it helping in health sector?

BIOTECHNOLOGY AND HEALTH	
YEAR	**UPSC MAINS QUESTIONS**
2021	What are the research and developmental achievements in applied biotechnology/? How will these achievements help to uplift the poorer sections of the society?
2020	How is science interwoven deeply with our lives? What are the striking changes in agriculture triggered off by science-based technologies?
2020	COVID-19 pandemic has caused unprecedented devastation worldwide. However, technological advancements are being availed readily to win over the crisis. Give an account of how technology was

	sought to aid management of the pandemic.
2019	How can biotechnology improve the living standards of farmers?
2018	Why is there so much activity in the field of biotechnology in our country? How has this activity benefitted the field of biopharma?
2017	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?
2014	Can overuse and the availability of antibiotics without doctor's prescription, the contributors to the emergence of drug-resistant diseases in **India**? What are the available mechanisms for monitoring and control? Critically discuss the various issues involved.
2013	What do you understand by fixed dose drug combinations (FDCs)? Discuss their merits and demerits.

MISCELLANEOUS

YEAR	UPSC MAINS QUESTIONS
2021	How is S-400 air defence system technically superior to any other system presently available in the world?
2021	The Nobel Prize in Physics of 2014 was jointly awarded to Akasaki, Amano and Nakamura for the invention of Blue LEDs in 1990s. How has this invention impacted the everyday life of human beings?
2019	How is the government of India protecting traditional knowledge of medicine from patenting by pharmaceutical companies? (Answer in 250 words)
2015	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.
2014	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.
2013	Bring out the circumstances in 2005 which forced amendment to section 3(d) in the India n Patent Law, 1970. Discuss how it has been utilized by Supreme court in its judgment rejecting Novartis patent application for "Glivec." Discuss briefly the pros and cons of the decision.

NUCLEAR TECHNOLOGY

YEAR	UPSC MAINS QUESTIONS
2017	Give an account of the growth and development of nuclear science and technology in India. What is the advantage of fast breeder reactor program in India?

INDIAN SCIENTISTS

YEAR	UPSC MAINS QUESTIONS
2019	How was India benefitted from the contributions of Sir M. Visvesvaraya and Dr. M. S. Swaminathan in the fields of water engineering and agricultural science respectively?
2018	Discuss the work of 'Bose-Einstein Statistics' done by Prof. Satyendra Nath Bose and show how it revolutionized the field of Physics.

INTERNET & COMPUTING TECHNOLOGY

Previous Year Questions

YEAR	UPSC MAINS QUESTIONS
2019	What is CyberDome Project? Explain how it can be useful in controlling internet crimes in India.
2015	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.
2013	How does the 3D printing technology work? List out the advantages and disadvantages of the technology.

►BLOCKCHAIN TECHNOLOGY

- Blockchain technology is a distributed ledger technology suitable for decentralized and transactional data shared across a large network of untrusted entities.
- Blockchain technology does not operate through any central authority and is managed by a cluster of computers not owned by any single entity. Since the data is shared, it is open and transparent for everyone to see.
- Blockchain ledgers have traditionally been used as supporting structures for cryptocurrencies, such as Bitcoin and Ethereum and even digital currency LIBRA of Facebook.
- However, use of blockchain technologies in non-cryptocurrencies applications too has seen a steady rise, with some solutions allowing individuals and companies to draft legally-binding "smart contracts," enabling detailed monitoring of supply chain networks including projects focused on enabling remote voting and elections.

POTENTIAL BLOCKCHAIN APPLICATIONS

1. Transfer of land records (Property record management).
2. Digital certificates management (Education, Death, Birth, Agreements, Sale Deeds)
3. Pharmaceutical supply chain
4. e-Notary service (Blockchain enabled e-Sign solution)
5. Farm insurance
6. Identity management
7. Power distribution
8. Duty payments
9. Agriculture and other supply chains
10. eVoting

11. Electronic Health Record Management
12. Digital Evidence Management System
13. Public Service Delivery
14. IoT Device Management and Security
15. Vehicle lifecycle administration
16. Microfinance for Self-Help Groups

Art & Culture	Storing the digital artefacts related to documents in a Blockchain makes it secure and immune to tampering.
Society	Globalisation, Population census, Poverty and nutritional data
Governance	• Student's certificates, scholarship details etc., can be stored in a Blockchain network. Various stakeholders such as educational institutions, different departments can become partners and have student's records stored on consensus basis. • Bring transparency in the spending of government grants – Canada. • Switzerland is the first place in the world to accept Bitcoin payments for tax purposes. • Smart contracts. • E-Courts: Data from multiple entities such as police, judiciary, legal department, etc. can be stored in a coordinated manner. • Key features of e-governance are trust and accountability which are very well supported by the Blockchain technology.
Health care	By establishing a secure chain of network blockchain can help in handling the patient records, consent forms, billings and public health monitoring.
Economy	• Singapore is using Blockchain to enable cross-border payments. • Transparency in energy grid by tracking data and finances related to it. – Chile. • Real estate deals – Sweden • Land registry and cadastral register based on the Blockchain to collect property taxes – Ghana. • Supply chain network – the track and trace capability of Blockchain network makes it possible to avoid any inadvertent mistakes
Technological adoption/ diffusion	NFT can work on blockchain; Cryptocurrency and other digital currencies are based on blockchain.

BLOCKCHAIN APPLICATIONS IN E-GOVERNANCE

Blockchain can bring lot of value addition in e-Governance. Some are:

1. Improves transparency & accountability
2. Building trust with citizens
3. Speed up transactions
4. Protecting sensitive data
5. Reducing costs of information management
6. Improving efficiency.
7. Can be used for authentication and verification of all transactions and data
8. Create and enable smart contracts, supply chains, trusted inter-department communication and tamper evident storage.
9. Enable officials to verify proof of existence of documents.

Strengths	Weaknesses
• Distributed resilience and control • Decentralized network • Open source • Security and modern cryptography • Asset provenance • Native asset creation • Dynamic and fluid value exchange	• Lack of ledger interoperability - Customer unfamiliarity and poor user experience • Lack of intraledger and interledger governance Lack of hardened/tested technology • Limitation of smart contract code programming model • Wallet and key management • Poor tooling and poor developer user experience • Skills scarcity and cost • Immature scalability • Lack of trust in new technology suppliers

Opportunities	Threats
• Reduced transaction costs • Business process acceleration and efficiency • Reduced fraud • Reduced systemic risk • Monetary democratization • New business-model enablement • Application rationalization and redundancy	• Legal jurisdictional barriers • Politics and hostile nation-state actors • Technology failures • Institutional adoption barriers • Divergent blockchains • Ledger conflicts competition • Poor governance

CHALLENGES TO ADOPTION OF BLOCKCHAIN TECHNOLOGY

- Technology Adoption: With plethora of Blockchain platforms being developed, a careful analysis of return on investment, governance, security & privacy and throughput has to be taken into consideration while understanding suitability of Blockchain in an application context.
  - Scalability: Current transaction processing rate of Blockchain platforms varies from 7 tps (transactions per second) to 3500 tps depending on individual platform's applicability to a particular domain, architectural considerations, consensus approach, number of nodes in deployment, etc.
  - Interoperability: Interoperability across various Blockchain platforms is still in its infancy and lot of work is required to address this issue.
  - Data Format: The success of utilizing Blockchain capabilities depends on how well the transaction data format has been defined in a multi-party environment and keenly observing its related characteristics such as its dependency on other information.
- Regulatory Compliance: While advocating the usage of Blockchain for an application domain, it is important to study compliance to applicable regulatory provisions and their implications, if any, with respect to the chosen application domain. Based on the requirements, additional regulatory policies may be evolved.
- Identification of Suitable Use Cases: Different applications have different levels of security, privacy and data storage requirements depending on the number of participating entities and hence suitability of Blockchain in a particular application context needs to be analysed carefully.
- Awareness & Skill Set: Availability of skilled manpower who understands Blockchain potential and its applicability to a particular application domain is required for successful implementation of the technology.
- Data Localization: Data localization requires data about citizens or residents of a country to be collected, stored and processed inside the country, before being transferred / shared internationally. In order to restrict the data flow and localizing the data, countries have introduced new data laws. European Union introduced data protection law called the GDPR (General Data Protection Regulation). In the Indian context, the proposed Personal Data Protection Bill would govern the collection, storage and processing of personal data, including their transfer outside the country under certain conditions.
- Disposal of Records: Right to be forgotten is one of the requirements in the proposed Personal Data Protection Bill. As records stored on Blockchain are immutable, in order to enforce this requirement, appropriate measures have to be taken while implementing the Blockchain technology.
- Performance and scalability challenges:

a) Decentralised architecture of Blockchain means it will be slower than traditional systems.

b) Data is replicated on each node, and this may lead to performance issues.

c) Performance is affected due to calculations associated with encryption, decryption & hashing at every node.

c) As data stored in Blockchain cannot be modified, it becomes perpetual and is replicated at all nodes in the network. This demands heavy demand of storage especially when blocks grow.

- Skillset and Awareness related challenges

a) Lack of awareness about nature of Blockchain platforms. There is a requirement for skilled manpower in multiple technologies and tweak the functionality open source blockchains to specific requirements.

b) Blockchain technology is still evolving.

c) Trust issues with blockchain technology.

- Security, Privacy, and regulation challenges

a) Blockchain data is stored on every node. Hence, privacy is not inherent feature of blockchain technology.

b) State of regulation and compliance for Blockchain applications is still ambiguous.

- Legal challenges in Blockchain adoption in India

a) RBI has restricted virtual currencies based blockchain technology and halt usage of crypto-currency transactions in India.

b) Digital signatures are core part of Blockchain applications. Currently, there exist no details in the Information Technology Act, 2000 with respect to transactions involving immovable properties, wills and negotiable instruments. This provision excludes applicability of technology for such activities.

c) Right to be forgotten under the Data Protection Framework is contradictory to inherent Blockchain architecture where data cannot be deleted, and history of data is always accessible.

WAY FORWARD

1. A National Level Blockchain Framework can aid in scaling deployments for developed applications, emerge shared infrastructure and enable cross domain application development.
2. Focus on advanced research in Blockchain technology domain towards building a trusted public digital platform.
3. Research on standards development, interoperability, scalability & performance, consensus mechanisms, security & privacy, and detection of vulnerabilities in Blockchain technology.
4. Development of an indigenous Blockchain technology stack with open APIs, so that various uses cases can be developed on top of it and integration with existing applications.
5. Integrate Blockchain Technology with other emerging technology areas such as AI to achieve the vision of becoming global leader in these technologies.
6. Capacity building in Blockchain Technology needs to be promoted by conducting short term courses or bootcamps. It is proposed to create sandbox environments for development & testing of applications and for offering virtual training.
7. Regulatory aspects & policies also need to be focused along with Infrastructure, Research, Technology Stack, Testing & Certification and Capacity Building. It is proposed to evolve a legal and regulatory framework for Blockchain Technology.
8. Explore the potential of BCT in the proposed public digital platforms in various sectors like Agriculture, Health, Energy etc., for more security.
9. Creation of infrastructure as National Resource and offering Blockchain as a Service (BaaS).

CONCERNS OF BLOCKCHAIN IN ELECTIONS

Recently, Election Commission of India announced that it will employ Blockchain technology in management of electoral rolls in the country and for online voting systems. However, various concerns have been highlighted against this:

- Open to Hack: Internet-based election system is open to attack and manipulation regardless of the underlying infrastructure. Online voting systems are open to server penetration attacks, client-device malware, denial-of-service attacks etc., all associated with infecting voters' computers with malware or infecting the computers in the elections office that handle and count ballots.
- Misuse by Foreign Intelligence & Corporates - Online technology for voting is open to manipulation and attack by foreign intelligence and corporates as transmission of votes through the internet conduit is subject to tampering.
- Voting Preference and Pattern may become Public - Possibility of everyone's vote becoming public if the system is hacked and this will against the democratic principle of "Secret Ballot" used in all elections across the globe including India.
- Chance of Impersonation of Voters - Blockchain solutions rely heavily on the proper implementation of cryptographic protocols. If any shortcomings exist in an implementation, it may unmask the identity and voting preferences of electors or worse it may allow an individual to cast a vote as someone else. So even though the person may have voted for Party Z, the vote would eventually go to Party Y.
- Report from Russian Election - Case Study - In Russia, during the vote on the recent controversial constitutional amendment, citizens were able to cast their vote online. While the voting process was still under way, Russian media outlet reported that it was possible to access and decrypts the votes stored on the Blockchain due to a flaw in cryptographic implementation, which could have been used to unmask the votes cast by electors.
- Physical Presence at Voting Booth for Biometric Authentication may clone - An attacker may be able to clone the biometric attributes required for authenticating as another individual and cast a vote on their behalf. Physical implants or software backdoors placed on an individual system could allow

attackers to collect and deduce voting choices of individuals.

- System prone to targeted Denial-of-Service attacks – Such attacks might increase where an attacker would be able to block traffic from the system, effectively preventing, or at the very least delaying the registration of votes.
- Disenfranchising of select voters out of design or flaw – Digitised voting systems may also stand to exclude and disenfranchise certain individuals or community either due to flaws in interdependent platforms, flaws in system design, as well as general failures caused by external factors or by purposefully designed failures to exclude them from voting.
- Use of Technology no guarantee of safety in Elections: If concerns regarding use of Blockchain technology for voting is not addressed, then elections in India and democracy in particular stands compromised. Only digitisation does not make electoral process more robust. Any solution to electoral problems must be software independent and fault tolerable, where failure or tampering of one mechanism or several mechanisms would not affect the integrity or transparency of the overall electoral process.

CONCLUSION

Even if the Election Commission can design a system which is proven to be satisfactorily secure in the face of attacks, where tampering could be detected, and where the integrity of the ballot is verifiable by electors, use of such a system could perhaps only be justified for lower-level elections, and not for something as significant and politically binding as the general election.

►CRYPTOCURRENCIES

A virtual currency is a digital representation of value that can be digitally traded and functions as (a) a medium of exchange, and/ or (b) a unit of account, and/or (c) a store of value, but, unlike fiat currency like the rupee, it is not legal tender and does not have the backing of a government. A cryptocurrency is a subset of virtual currencies, and is decentralised, and protected by cryptography.

Supreme Court of India has lifted a blanket ban on cryptocurrencies.

HOW CRYPTO CURRENCY WORKS?

a) It is a virtual currency, which users buy and store in any of several available digital wallets and use it for transactions on a decentralised network that is not controlled by one bank or a government.

b) Bitcoin is among the best-known cryptocurrencies.

c) Cryptocurrency is powered by a technology called blockchain, which functions like an open ledger that gets updated in real time.

d) Each transaction on the block chain network is preserved.

CHALLENGES OF CRYPTOCURRENCIES

1. High power consumption due to crypto mining.
2. High levels of crimes related to crypt which involves crypto theft, hacking etc.
3. Misuse of cryptocurrencies for illicit activities such as money laundering, terror financing etc.
4. Lack of regulation of central banks and governments hence erodes sovereignty.

EXAMPLES OF CRYPTOCURRENCIES

1. Bitcoin
2. Ethereum
3. Dogecoin etc.

WAY FORWARD

1. Mandating firms involved in cryptocurrency ecosystems such as crypto exchanges to take greater steps for combating money laundering.
2. Broaden regulatory oversight of crypto firms.
3. Mandating measures such as KYC (Know Your Customer) and reporting of suspicious transactions to regulators.

►OPEN-SOURCE SOFTWARE (OSS)

Open-source software (OSS) is software that is distributed with its source code, making it available for use, modification, and distribution with its original rights.

- Examples of Linux, Mozilla Firefox, VLC media player, SugarCRM, etc.
- While the operating system of Apple's iPhones (iOS) is closed source, meaning it cannot be legally modified or reverse engineered, Google's Android operating system is open-source.
- Many other solutions launched by the government including Digilocker, Diksha, Aarogya Setu, the Covid-19 vaccination platform CoWIN have also been built on top of open-source digital platforms.

Indian developers are major players in this ecosystem. According to GitHub, a leading platform for open-source

software development, more than 7.2 million of its 73 million users in 2021 were from India. India ranks third after China and the US.

ADVANTAGES OF OPEN-SOURCE SOFTWARE

- Democratization: Without the equalizing force of FOSS, future of digital economy may well end up being controlled by a handful of Big Tech's monopolies.
- FOSS products are more affordable than proprietary counterparts and give increased personal control to creators and users alike.
- By harnessing crowdsourcing, open-source software allows developers to benefit from accelerated innovation, quicker development processes and having more success troubleshooting when problems arise.
- FOSS-led innovation will spur growth of new technologies like 5G/6G, microprocessor technology, Artificial Intelligence, Internet of Things, and others by building indigenous technology capabilities.
- Amazon & Google have both published open-source code that allows other companies to integrate more easily with their own cloud services. This strategy quickens adoption of Amazon and Google's technology products by making it easier to use their services, resulting in more revenue opportunities.
- Open-source revolution has taken place in parallel with the explosion of cloud, big data, and analytics technologies. The modular, fluid and constantly evolving nature of open source is in sync with the needs for faster, more flexible and more secure systems and platforms.
- Without open-source software, companies would spend a huge amount of time reinventing the wheel rather than innovating.
- Increased privacy and transparency: With data breaches affecting billions of people Open sourcing that software will let us see what's happening.
- Trust among users: more people will adopt software with trust that an open-source solution can be as trustworthy as a non-open solution.
- Internet of Things boom: IoT growth is at least in part driven by the creativity of open-source software and hardware developers.
- Democratization of AI and machine learning: Open source will democratize AI by opening it up to the community that will help drive its continued evolution and leaps forward in terms of both capabilities and use cases.
- Governance structure: Digital Public Goods and Digital Public infrastructure along with community engagement has the potential to democratize the governance structure of the nation. More accountable and responsive governance.
- COVID19India.org, a FOSS initiative that engages more than 100 active contributors to build a timely interactive map to show live updates on district-wise cases, testing, vaccination, and more. Media, academia, and the government used COVID19India.org as a base for their reporting, and the Economic Survey 2020-21 cited it as a source for Covid-19 related analysis.

PROMOTING OPEN-SOURCE SOFTWARE

- GoI had issued a Policy on Adoption of Open-Source Software in 2015.
- The government has also made the android version of the Aarogya Setu app open source.
- Major institutions like our courts, IRCTC, LIC and State Bank of India rely on FOSS to scale operations and provide timely and efficient digital services to millions.
- GovTech 3.0 has been started to focus on Open Digital Ecosystems (ODEs), the underlying philosophy suggests that the government should focus on creating the "digital commons". Promoting OSS is a part of GovTech 3.0.

By harnessing power of the crowd, open-source software allows developers to benefit from accelerated innovation, quicker development processes and having more success troubleshooting when problems arise.

DEMOCRATISING THE INTERNET SPACE

- Open-source software
- 5G
  - 5G's high throughput and low latency allows us to consume high-quality video from anywhere and connect with one another over video.
  - 5G will connect everyone and everything to the cloud, reliably and securely. When things are always-connected, we gain access to the virtually unlimited storage and processing power of the cloud, generating extraordinary efficiencies and unlocking innovation.
- Web 3.0
  - Web 1.0: only allowed read function
  - Web 2.0: also referred to as the read-write web or the social web. The growth of Web 2.0 was mainly because of important innovations such as mobile internet access, social networking, and cloud

computing.

- Web 3.0: Founded on two core technological innovations i.e., artificial intelligence and decentralized data networks, it focuses on the decentralization of data and aims to break down the massive databases stored by Internet giants and give greater control to internet consumers.
- Web 3.0 will work through blockchain making it trust less and permission less i.e. it will allow the users to interact with each other without a mediator and anyone will be able to participate without the authorization of a governing body.
- Web 3.0 will make users the content owners, data generated by any computing resource will be sold by and to users through decentralized data networks, ensuring that users retain the entire ownership and control instead of a middleman.

- Net-neutrality
- Blockchain
- NFTs

►DARK WEB

Instances of data leaks of Indians on the dark web/ dark net is on the rise. Dark web/ dark net is increasingly being used for various nefarious activities including data leaks, identity theft, illegal weapon sales, drug trafficking, cyber terrorism etc.

ABOUT DARK WEB OR DARK NET

- Darknet is a network of computers on the internet that are:
  - Not accessible through the normal search engines
  - Provide anonymity to the source of web-content.
- To access content of the darknet, we need special software to get into this network of computers.
- In simple words, web content on darknet is intentionally hidden to provide anonymity to service provider.

UNDERSTANDING INTERNET

The total web content on the internet is broadly classified into three broad categories:

1. Surface Web
2. Deep Web
3. Dark Web

SURFACE WEB

- Usual search engines such as Google, Yahoo & Bing etc. can 'look for' and extract content and present it in the form of a website/webpage.
- For this, webpages are 'indexed' by search engine.
- Only about 10-15% of web content is present on surface web accessible by common searches.

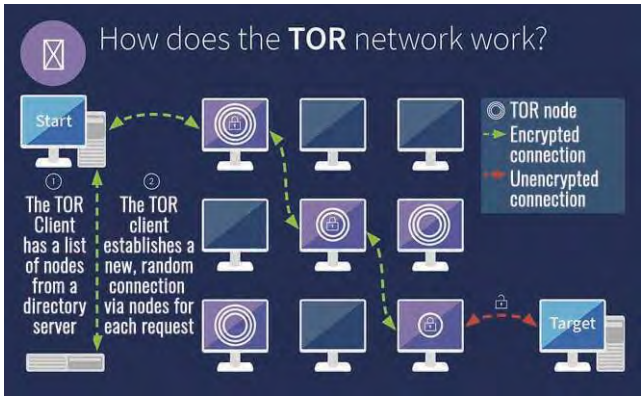
DEEP WEB

- It is a term used for all those content or webpages that are there on the internet but are not indexed by search engines and therefore not discernible by conventional search engines.
- Thus, webpages on deep web do not show up in conventional search engines like Google, Yahoo, and Bing etc.
- About 75-80% of the web content/webpages are on the deep web.
- Common examples of web content on deep web include financial data, back account details, emails, personal data etc. that are password protected and only way to access these webpages is through login.

DARK NET/DARK WEB

- It is a part of the deep web that is intentionally hidden to provide anonymity.
- Key features:
  - No webpage indexing by surface web search engines.
  - Virtual traffic tunnels via randomized network infrastructure.
  - Inaccessible by traditional browsers due to its unique registry operator.
  - Further hidden by various network security measures like firewalls and encryption.
- To do this, Dark Net uses a specialized network of computers called relays through which the information passes. Commonly, information on Dark Net passes through at least 3 relay computers between the source and destination.
- In addition, dark net uses network technology that hides the locations of these relay computers (IP address) to ensure anonymity of the users.

- Dark net can be accessed through TOR Browser (Anonymity Network).



FEATURES OF DARK NET

- While webpages on Darknet are hidden from a search engine, they can be accessed and downloaded by anyone who has the exact IP address of the webpage.
- Dark net does not provide any protection against malware, virus attack etc.
- Since data is routed through many relay computers between source and destination, communication and downloading of webpages on the dark net is slow.
- Used for both legitimate and illegitimate activities.

1. Legitimate activities of Dark Net

- Using Dark Net is per say is not illegal.
- By virtue of its ability to provide anonymity, dark net is used by human right activists, free internet activists, media personnel etc. in countries where there are severe restrictions, censorship on internet usage like that in China, Iran, Saudi Arabia etc.
- Also used by whistleblowers to maintain anonymity. Ex Edward Snowden.
- In the aftermath of glaring revelations on surveillance by USA's security agency NSA, number of users of the dark net has increased, as users are seeking privacy.

2. Illegitimate activities of Dark Net

- Increasingly, Dark net has turned into a platform for various nefarious activities including illegal weapon sales, drug trafficking, child pornography, data theft, data leaks, cyber terrorism, hacking, organized crimes, money laundering etc.
- As the location of users on Dark net is hidden due to hidden IP address, it is not possible to trace the location of the users of Dark Web.
- Instances:
  - Silk Road is a dark net website used for purchasing drugs online.
  - Data of about 100 GB including Aadhar Cards, passports, PAN Cards etc. were leaked on dark net.

THREATS OF DARK WEB

1. Malicious software
2. Government monitoring
3. Scams
4. Identity theft monitoring
5. Illegal sales of COVID-19 vaccines
6. Drug trafficking
7. Bitcoin laundering
8. Drug trafficking.

WAY FORWARD

1. Need for a global effort to tackle the threats of Dark Web.
2. Building capacities and capabilities in law enforcement agencies to tackle threats of dark web.
3. Global collaboration among law enforcement bodies to tackle threats of Dark Web.

►5G TECHNOLOGY

5G Technology is the next generation cellular technology that will provide faster and more reliable communication with ultra-low latency.

With 5G the peak network data speeds are expected to be in the range of 2-20 Gigabit per second (Gbps).

In April, South Korea and the U.S. became the first countries to commercially launch 5G services.

In India, 5G is expected to create a cumulative economic impact of $1 trillion by 2035.

WHAT 5G WILL ENABLE?

What 5G delivers that 4G and earlier networks cannot--the blazing speeds and ultra-low latencies (data transfer delays) that allow massive amounts of data to be relayed between connected devices, systems, and infrastructure in near real time.

- Empower invention of thousands of new products, technologies and services, increase productivity and allow for new industries to emerge.
- A global 5G network will unify mobile communication and connect people and devices to everything through the Internet of Things.
- Support a much larger range of applications and services, including driverless vehicles, tele-surgery and real time data analytics.
- 5G may offer opportunities by providing 'smart infrastructure' that offers lower cost and faster infrastructure delivery.

- 5G will enable vehicle-to-vehicle and vehicle-to-infrastructure communication.

All in all, 5G will fully usher in 4th Industrial Revolution. Fourth industrial revolution is current and developing environment in which disruptive technologies and trends such as the Internet of Things (IoT), robotics, virtual reality (VR) and artificial intelligence (AI) are changing the way we live and work.

APPREHENSIONS

Two of the three private telcos, Bharti Airtel and Vodafone have expressed concern about auction stating that the reserve price of these airwaves is very high.

Besides the spectrum, 5G will require a fundamental change to the core architecture of the communication system.

A report has stated that industry might require an additional investment of $60-70 billion to seamlessly implement 5G networks.

WAY FORWARD

Deployment: An early roll out of 5G services to maximize value proposition of 5G as a technology.

Technology: Build indigenous industrial and R&D capacity, especially for design and Intellectual Property.

Manufacturing: Expand manufacturing base for 5G technologies, which includes both semiconductor fabrication and equipment assembly and testing.

Strengthening Telecom sector: 5G deployment is costly; debt-ridden telecom service providers must work their finances out before they plan for acquiring 5G spectrum and rollout.

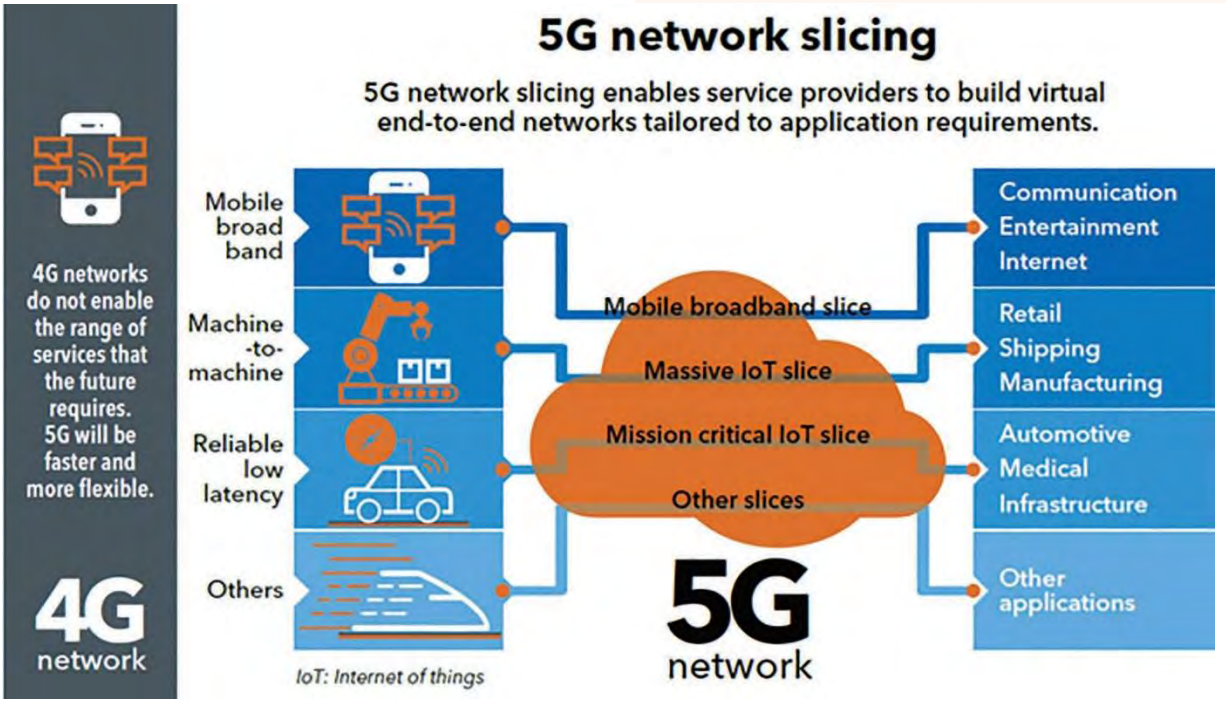
Enabling Infrastructure: India will have to make a leap in optical fibre penetration for 5G deployment. Bharat Net program also plans to link 2.5 lakh gram panchayats through optical fibre network.

To set a roadmap for the rollout of 5G, the government has set up a high-level forum, which suggested

- early allocation of spectrum
- increasing the available quantum
- lower spectrum pricing

APPLICATIONS

1. 5G technologies will enhance infrastructure efficiencies like 'vehicle platooning'. Platooning can double vehicle density in roads promoting efficient and safer use of the limited road infrastructure.
2. In manufacturing, 5G will enable use of robotics for precision manufacturing.
3. 5G can also enable better logistics to track goods from raw materials to product delivery.
4. In agriculture, 5G can enable improvement in the entire value-chain, from precision farming, smart irrigation, improved soil and crop monitoring to livestock management.
5. In the energy sector, 'smart grids' and 'smart metering' can be efficiently supported enabling growth of alternate energy technologies.
6. In healthcare, 5G can enable more effective tele-medicine delivery, tele-control of surgical robotics and wireless monitoring of vital statistics.
7. 5G will be used in in key government projects such as smart cities and Digital India.



WAY FORWARD

1. 5G spectrum auctions have been recently conducted in India. It is important to expedite the process for telecom companies to start laying down necessary infrastructure for rolling out of 5G.
2. Audit of spectrum needs to be done and spectrum lying unused with public sector needs to be available for 5G roll out.
3. Spectrum prices in India are exorbitantly high, these need to be tackled also duties on telecom sector needs to be rationalised.
4. Spectrum for Industrial use: Industry 4.0 is one of the main drivers of 5G. Industry 4.0 based solutions enable better interoperability, more flexible industrial processes, and autonomous and intelligent manufacturing. Many developed countries have allocated 5G spectrum for industrial use. However, India's present licensing policy is not conducive to growth of Industry 4.0. All possible steps should be taken in consultation with industry to roll out Industry 4.0 in India.
5. Developing and participating in generation of IPR and global standards for 5G.
6. Promotion of domestic manufacturing of telecom equipments and affordable 5G handsets.
7. Development of 5G rollout on Open RAN architecture which disaggregates hardware and software and creates open interfaces between them. This provides more choice and interoperability of Telecom service providers.
8. Uniform Right of Way rules across states.
9. Mandatory Testing and Certification of Telecom equipment's and other security requirements should be fulfilled to protect privacy of citizens and tackle possible cyber-security challenges. This is must especially for imported telecom equipment.
10. Ensuring availability of reliable power supply to telecom towers.
11. Telecom infrastructure needs to be treated as an important strategic sector and no longer only as a source of revenue. A legislation should be introduced telecom sector is declared as an important strategic sector and as an essential service and telecom infrastructure as critical infrastructure.

►INDIGENOUS 5G

Currently, Indian contribution is design ownership of telecom products is very limited and India has been significant importer of global products. TSDSI has been established to enable India industry to take lead in International standardization activities.

1. LMLC TECHNOLOGY

TSDSI in collaboration of IITs have been successful in getting the Low Mobility Large Cell (LMLC) use case accepted by ITU as one of the 5G requirements for rural areas.

Benefits:

a. Increases the distance between two base stations to 6 km against 1.7 km by other technology. This technology will be beneficial for rural India and other developing countries.
b. The base stations can be placed at Gram Panchayats and connectivity can be provided to neighboring villages and farms.
c. Reduction of Capex cost.
d. Increase in speed of internet access in rural areas.
e. These rural towers must be located where BharatNet fiber ends in 2.5 lakh Gram Panchayats. From these towers, neighboring villages numbering 3.5 lakhs must be provided wireless coverage.
f. This is for the first time a global standard is emerging from India at ITU.

2. TSDSI RIT

IIT Madras along with other institutions has developed this standard as a variation to 3GPP standards for enhanced rural connectivity. This technology is also called 5Gi technology.

Benefits:

a. Enhanced coverage in rural areas
b. Reduced capex costs.
c. This standard however, has not been adopted by ITU and thus not globally harmonised.

3. RELIANCE JIO HAS DEVELOPED ITS OWN INDIGENOUS 5G TECHNOLOGY

Concerns:

1. It is important to have globally harmonized standards for 5G to allow interoperability and economies of scale.
2. If India adopts any standard other than 3GPP, it would disconnect India from globally harmonised standard, device & network ecosystem.
3. Adopting India specific standards will delay 5G rollout, reduce 5G adoption.

4. Increase in cost of roll out of 5G.
5. The adoption of TSDSI RIT without global harmonization would make India an isolated island in the global 5G ecosystem.
6. Performance gain of proposed specifications compared to 3GPP specifications have not been established.

WAY FORWARD

1. Indian standards should be harmonized sufficiently with global standards to ensure inter-operability, roaming and to derive ecosystem benefits such as economies of scale. However, it is possible to adopt carefully enhanced variants of the global standard that specifically provide some features of importance to India such as enhanced rural broadband coverage, without compromising on either inter-operability or economy of scale.
2. ITU standards are in final stages of approval for finalization. India has not adopted any standard for 5G services yet.
3. Inter- operability and compatibility between the 3GPP 5G and the TSDSI 5Gi standards can easily be ensured since the latter is merely an enhanced version of the former. Moreover, there will be no cost implications as equipment will support both standards through mere software selection and in a manner transparent to the user.

CONCLUSION

India should adopt only those standards that are globally harmonized to ensure interoperability, economies of scale, and help build a conducive device & network ecosystem. Considering that similar efforts in the past by other countries like China, Korea, etc. have been failures due to the lack of harmonization of these standards with the global ecosystem, it is recommended to be extra careful before adopting such standards in the country.

►ARTIFICIAL INTELLIGENCE

ABOUT ARTIFICIAL INTELLIGENCE

1. Artificial intelligence is already ubiquitous in everyday life and the pace of innovation is accelerating
2. Deploying and adopting AI remains a hard problem
3. AI tools are diffusing broadly and rapidly
4. AI is changing relationships between humans and machines

APPLICATIONS IN EDUCATION

1. Optimizing learning for individuals
2. Increasing safety in training

APPLICATIONS FOR SMART CITIES

1. Improving safety
2. Enabling intelligent infrastructure
3. Optimizing complex transportation hubs
4. Sustaining the environment

APPLICATIONS FOR BASIC SCIENCES AND SPACE RESEARCH

1. Enabling extended and flexible space exploration. For e.g., development of autonomous spacecraft and smart habitats.
2. Expediting

APPLICATIONS IN HEALTHCARE

1. Enhanced drug discovery and development
    a. AI in drug design
        i. Predicting 3-D structure of target protein.
    b. AI in pharmacology
    c. AI in chemical synthesis
    d. AI in drug repurposing
    e. AI in drug screening
2. For patients:
    a. More personalized diagnosis, prognosis and therapy
    b. Enhanced relationship with care provider
3. Computer vision for diagnosis and surgery (AI enabled medical imaging)
4. Intelligent personal health records

ROBOTICS AND AI POWERED DEVICES

Robots are being used extensively in healthcare to replace human workforce, augment human abilities and assist human healthcare professionals. For ex.

a. Robots used for surgical procedures such as laparoscopic operations.
b. Robotic assistants for rehabilitation and patient assistance
c. Robots that are integrated into implants and prosthetics
d. Robots used to assist doctors and their staff with their tasks.
e. Mitigating the effects of disabilities. For e.g., assisting the visually impaired by

APPLICATIONS OF AI IN AGRICULTURE

1. Crop yield prediction & price forecasts: Identify the output yield of crops and forecast prices for next few weeks will help farmers to obtain maximum profits.
2. Intelligent spraying: Artificial Intelligence based sensors can detect weed affected areas and can precisely spray herbicides in the right region reducing the usage of herbicides.
3. Predictive insights: Insights on right time to sow seeds for maximum productivity. Insights on the impacts created by the weather conditions.
4. Agriculture robots: Using autonomous robots for harvesting huge volumes of crop at a higher volume and faster pace.
5. Crop and soil monitoring: Using AI, farmers can monitor crop health for diagnosing pests/soil defects, nutrient deficiencies in soil etc.
6. Disease diagnosis: Using AI farmers can preempt diseases in their crops. This will help increase productivity of farming.

APPLICATIONS OF AI IN NATIONAL SECURITY

1. Artificial intelligence is a 'dual use' technology - it can be used for civilian and military purposes.
2. Likelihood of reckless or unethical uses of AI-enabled technologies by rogue states, criminals or terrorists is increasing.

a. Many security applications of Artificial intelligence will require only modest resources & workable expertise.

b. AI algorithms are often accessible.

c. Hardware is available 'off-the-shelf' and available to consumers (Ex. Graphics Processing Units).

d. 'Deepfake' capabilities can be easily downloaded and used by anyone. AI-enabled tools

3. AI-enabled capabilities will be tools of first resort in a new era of conflict: State and non-state actors can use AI to attack India even by avoiding direct military confrontation.

BIG DATA IN HEALTHCARE

1. Research studies
2. Government agencies
3. Public records
4. Wearable devices
5. Electronic health records
6. Social media
7. Search engines
8. Patient portals.

CHALLENGES WITH ARTIFICIAL INTELLIGENCE

UNHRC in its recent report on 'The right to privacy on Digital age' has highlighted the following concerns with Artificial Intelligence.

- Artificial intelligence systems can facilitate and deepen privacy intrusions through increased collection and use of personal data.
- States and businesses often rushed to incorporate AI applications, failing to conduct due diligence.
- The data used to inform and guide AI systems can be faulty, discriminatory, out of date or irrelevant.
- Opaque decision making, undermining people's freedom of expression and State accountability.
- Long-term storage of data poses risks, as data could in future be exploited in yet unknown ways.
- Unprecedented level of surveillance across the globe by state and private sector.
- Biased datasets relied on by AI systems can lead to discriminatory decisions, which poses acute risks for already marginalised groups.
- Biometric technologies, which include facial recognition, are increasingly used to identify people in real-time and from a distance, potentially allow unlimited tracking of individuals.
- Lack of international and global regulations for controlling and regulating AI.
- Artificial intelligence based natural language processing applications have been shown to learn social biases such as those based on gender, race and religious groups that can perpetuate harmful stereotypes. For ex. AI system GPT-3 disproportionately associates Muslims with violence.
- Challenges of Anthropomorphizing: Misplaced trust on Artificial Intelligence: Users may trust the AI system too much. Computers and robots have a reputation of being honest. While algorithms rarely make mistakes in their calculations, does not mean that their decisions are smart or meaningful. For ex. Navigation devices have been known to let drivers enter illegal and dangerous locations. Therefore, robots need to be aware of the certainty of their own results and communicate this to users.

►ARTIFICIAL INTELLIGENCE IN DEFENCE

- Artificial Intelligence, Robotics and Machine Learning have tremendous potential to enhance the efficiency and response capabilities of our defence forces.

Artificial Intelligence is becoming a necessary component of modern combat. Modern militaries are actively pursuing AI research in the fields of intelligence collection and analysis, cyber operations, information operations, command and control and use in a variety of autonomous vehicles.

- AI-based products and systems enable quicker decision-making.

ROLE OF ARTIFICIAL INTELLIGENCE IN DEFENCE

1. Artificial Intelligence based automation
2. Autonomous/Unmanned/Robotic Systems
3. Blockchain based automation
4. Cyber Security
5. Human behaviour Analysis
6. Intelligent monitoring systems
7. IOT/Smart cities

a. Internet of Battle things (IoBT): Smart Helmets for improving

8. Lethal Autonomous Weapon Systems:
9. Logistics & Supply Chain Management
10. Manufacturing & Maintenance
11. Operational Data Analytics
12. Perimeter Security Systems
13. Process flow automation of large systems
14. Simulators/Test equipment
15. Speech/Voice Analysis Systems using Natural Language Processing

STEPS TAKEN TO ADVANCE AI IN DEFENCE

1. Creation of Defence AI Council (DAIC) for providing guidance to enable and effect development of operating framework, policy level changes and structural support for AI adoption.
2. Defence AI Project Agency (DAIPA):
3. Setting of Task Force for AI in Defence
4. Specific targets given to DPSUs for Ai product development.
5. Rs 100 crore allocated by each service for AI implementation.
6. AI infrastructure for storage and computing under creation.
7. User review conducted

►DEEPFAKES

- These are fake videos or audio recordings that look and sound just like the real.
- While the act of faking content is not new, deepfakes leverage powerful techniques from machine learning and artificial intelligence to manipulate or generate visual and audio content with a high potential to deceive.
- The main machine learning methods used to create deepfakes are based on deep learning and involve training generative neural network architectures, such as auto-encoders or generative adversarial networks (GANs).
- Access to commodity cloud computing, algorithms, and abundant data has created a perfect storm to democratize media creation & manipulation. Deepfakes are a new tool to spread computational propaganda & disinformation at scale and with speed.

DEMERITS

- Fabricate media: swap faces, lip-syncing, and puppeteer — mostly without consent and bring threat to psychology, security, political stability, and business disruption.
- Use against women:
  - The very first use case of malicious use of a deepfake was seen in pornography, inflicting emotional, reputational, and in some cases, violence towards the individual.
  - Pornographic deepfakes can threaten, intimidate, and inflict psychological harm and reduce women to sexual objects. Deepfake pornography exclusively targets women.
- Threat to internal security
  - A deepfake could act as a powerful tool by a nation-state to undermine public safety and create uncertainty and chaos in the target country.
  - It can be used by insurgent groups and terrorist organizations, to represent their adversaries as making inflammatory speeches or engaging in provocative actions to stir up anti-state sentiments among people.
- Undermining Democracy
  - To undermine a discourse: A deepfake can also aid in altering the democratic discourse and undermine trust in institutions and impair diplomacy. False information about institutions, public policy, and politicians powered by a deepfake can be exploited to spin the story and manipulate belief.
  - Sabotaging image: A deepfake of a political candidate can sabotage their image and reputation. A well-executed one, a few days before

polling, of a political candidate spewing out racial epithets or indulging in an unethical act can damage their campaign. There may not be enough time to recover even after effective debunking. Voters can be confused, and elections can be disrupted. A high-quality deepfake can inject compelling false information that can cast a shadow of illegitimacy over the voting process and election results.

SOLUTIONS

- Multi-stakeholder and multi-modal approach: Collaborative actions and collective techniques across legislative regulations, platform policies, technology intervention, and media literacy can provide effective and ethical countermeasures to mitigate the threat of malicious deepfakes.
- Role of Media:
  - Media literacy for consumers and journalists is the most effective tool to combat disinformation and deepfakes.
  - Media literacy efforts must be enhanced to cultivate a discerning public.
  - As consumers of media, we must have the ability to decipher, understand, translate, and use the information we encounter.
  - Even a short intervention with media understanding, learning the motivations and context, can lessen the damage. Improving media literacy is a precursor to addressing the challenges presented by deepfakes.
- Creating regulations:
  - Meaningful regulations with a collaborative discussion with the technology industry, civil society, and policymakers can facilitate disincentivizing the creation and distribution of malicious deepfakes.
  - We need easy-to-use and accessible technology solutions to detect deepfakes, authenticate media, and amplify authoritative sources.

WAY FORWARD

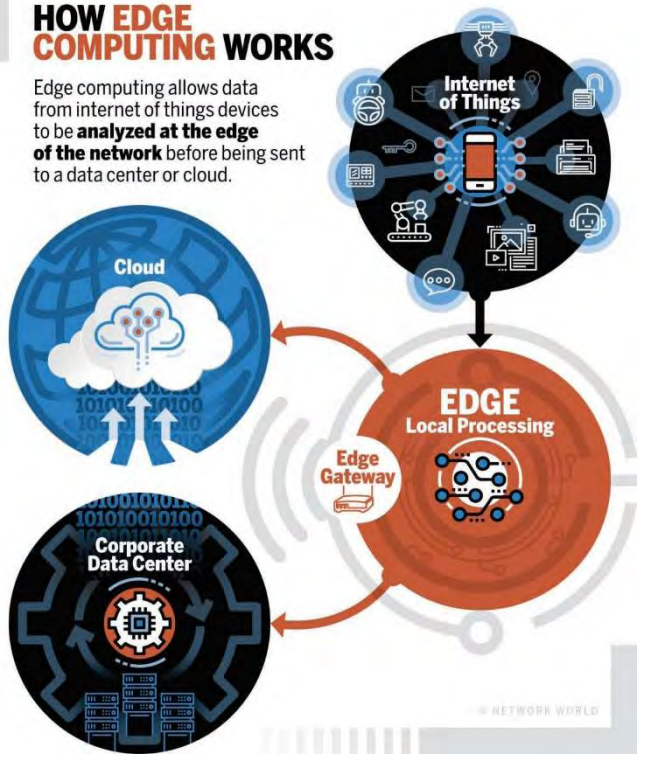
- Deepfakes can create possibilities for all people irrespective of their limitations by augmenting their agency. However, as access to synthetic media technology increases, so does the risk of exploitation. Deepfakes can be used to damage reputations, fabricate evidence, defraud the public, and undermine trust in democratic institutions.
- Use of tools developed by Google, Facebook & Twitter for verifying content.
- Accountability: Internet Regulations and social media accountability needs to be enforced. Efforts should be made to protect dignity of females and children.
- To counter menace of deepfakes, we all must take responsibility to be a critical consumer of media on Internet, think and pause before we share on social media, and be part of the solution to this infodemic.

►EDGE COMPUTING

- Edge computing enables data to be analyzed, processed, and transferred at the edge of a network – where things & people produce or consume that information.
- Brings computation & data storage closer to devices where it is being gathered, rather than relying on a central location that can be thousands of miles away.

BENEFITS OF EDGE COMPUTING

- Useful for real time data processing applications.
- Very low or no latency.
- Cost effective: as processing is done locally.
- Faster response time
- Interoperability between legacy and modern devices.
- Reliable operations with intermittent connectivity; low pressure on bandwidth
- Enhanced data security and privacy for users.
- Reduction of energy consumption



- Reduced amount of data that needs to be processed in a centralized or cloud-based location.
- Enables Internet of Things as it has scalability, low latency, longer battery life for devices, efficient data management
- 5G networks are expected to be 1000 times faster than 4G networks. Edge computing was developed due to exponential growth of IoT devices, which connect to internet for either receiving information from cloud or delivering data back to the cloud. Many IoT devices generate enormous amounts of data during their operations.

EDGE COMPUTING VS CLOUD COMPUTING

- Basic difference between edge computing & cloud computing is where the data processing takes place.
- Existing Internet of Things (IoT) systems perform all their computations in the cloud using data centres.
- Edge computing, on the other hand, essentially manages the massive amounts of data generated by IoT devices by storing and processing data locally.

CHALLENGES WITH EDGE COMPUTING

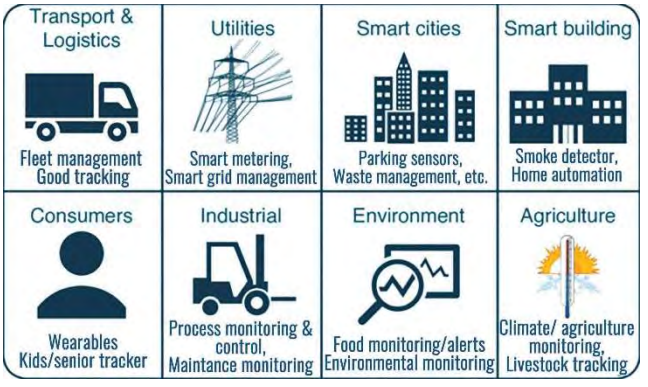
- Manage massive number of disparate devices in field.
- Process unprecedented volumes of both structured and unstructured data.

►INTERNET OF THINGS (IOT)

- IoT is a seamless connected network system of embedded objects/ devices, with identifiers, in which communication without any human intervention is possible using standard and interoperable communication protocols.
- Internet of things (IoT) is extension of Internet connectivity into physical devices & everyday objects.
- Embedded with electronics, Internet connectivity, and other hardware like sensors, these devices can communicate and interact with others over the Internet, and they can be remotely monitored and controlled by computers and smart phone.

APPLICATIONS OF INTERNET OF THINGS

- Smart cities: Cellular communication enabled Smart municipal bins will send alerts to municipal services when a bin needs to be emptied
- Agriculture: Sensing for soil moisture & nutrients, controlling water usage for plant growth & determining custom fertilizer are uses of IoT.
- Energy utilization: Smart Grids will be able to detect sources of power outages, can automatically take inputs of solar panel, making possible distributed energy system



- Healthcare: Personalized analysis of an individual's health and tailor-made strategies to combat illness will be possible. Enhanced patient monitoring and better health outcomes.
- Manufacturing: The IoT intelligent systems enable rapid manufacturing of new products, dynamic response to product demands, and real-time optimization of manufacturing production and supply chain networks, by networking machinery, sensors, and control systems together.
- Environmental monitoring: to assist in environmental protection by monitoring air or water quality, atmospheric or soil conditions. It can even include areas like monitoring the movements of wildlife and their habitats
- Supply chain: By placing RFID tags on individual products, the exact location of single items in a large warehouse can be shared, thus saving search time, streamlining infrastructure, and lowering labour costs.
- Elderly, sick and disabled population can be particularly assisted using IoT technology with greater care.
- Overall boosting of efficiency which will result in economic growth and employment creation.

STEPS TAKEN BY GOVERNMENT

1. Centres of Excellence for Internet of Things have been established at Bengaluru, Gurugram and Gandhi Nagar. These COEs aim to enable India to emerge as innovation hub in IoT through democratisation of innovation and realisation of prototypes.
2. Development of standards in IoT.
3. Higher R&D in IoT

4. Skill development and human resource development for IoT.

CHALLENGES WITH IOT

1. Lack of openness in IoT technology, research & development.
2. IoT devices gather a lot of personalised data, which can be used to breach privacy of individuals.
3. IoT can soon become indispensable for consumers.
4. Possibility of greater government monitoring, civil rights violations and suppression of dissent.
5. Lack of development of standards and protocols which are accepted widely.
6. Threat of cyber-security violation and hacking.

WAY FORWARD

1. India should play a leadership role in R&D, development of standards and protocols for IoT technology.
2. To safeguard against loss of privacy, a comprehensive data security legislation as suggested by B N Sri Krishna Committee should be enacted.
3. Greater collaboration between technology developers, law enforcement agencies, government and other stakeholders.

NARROW BAND INTERNET OF THINGS (NB-IOT)

NB-IoT technology is a low power wide area technology that may be used almost everywhere.

- Will allow many devices to connect to IoT, allowing development of new applications.
- Designed for applications that send tiny quantities of data across great distances.
- Secure and dependable since it runs on licensed spectrum, offering assured service quality.
- Integrates into cellular system ensuring easy deployment. Links devices to existing mobile networks more easily, effectively.
- Securely and reliably handles tiny quantities of very occasional two-way communication.
- Optimised for low power consumption.
- Extended long-range coverage and deep penetration both indoors and underground.

►INTERNET GOVERNANCE

While the cyberspace has enabled new modes of digital interaction like work-from-home etc. it is also becoming increasingly vulnerable to attacks, even state-sponsored ones. This has highlighted the need for Internet Governance.

- On one hand China and Russia have been blamed for such state-sponsored attacks (for instance in Australia, UK, US, India etc.). On the other side, the governments across the world have imposed restrictions and bans on technology products like the recent app bans in India and US, ban on 5G technology rollout from Huawei in UK and US etc.
- While national laws have been evoked to protect the domestic assets, given the cross-border nature of the internet and digital technologies, the need for a global framework to govern the internet is desperately felt to keep the cyberspace secure.

WHAT IS INTERNET GOVERNANCE?

Refers to the rules, policies, standards, and practices that coordinate and shape global cyberspace. Currently there is no global internet governance framework.

NEED FOR INTERNET GOVERNANCE FRAMEWORK

Internet has fundamentally changed the social, economic, and political milieu of the world by its sheer reach. This has enabled one country to shape activities in another. E.g.: Arab Spring was triggered by Social Media Platforms owned by US companies.

- Cross-border nature: Data is seen as the new engine of growth and thus where the data is produced, who owns the data and for what purpose have significant impact on the economies. Further with increasing deployment of digital technology the critical infrastructure of countries is vulnerable to attacks from across borders.
- Power Struggle: Internet is used by both state and non-state actors of one country to influence political and social life of another. E.g., Russia in US elections.
- Equitable Use of Internet: While the use of internet for development was discussed as early as 1998 in the UN there is no consensus among countries about what constitutes internet governance. Ex. Although the users of internet are spread across the world yet the infrastructure like undersea cables that fuel the internet is dominated by few countries.
- Lack of uniform cyber laws: Given the cross-border nature of data flow, countries lack jurisdiction over another. Thus, there is an increasing need for "cyber norms" that can balance competing demands of national sovereignty and transnational connectivity.

ACTIONS TAKEN FOR INTERNET GOVERNANCE

As stated above, the first time the issue of use of internet for development was discussed at the UN platform in 1998. Accordingly, the UN set up a mechanism called Group of Governmental Experts to

discuss the issue of internet governance. However, the problem is this body has limited membership and thus proven ineffective.

For the first time in October 2019, this was made more inclusive by another mechanism called Open-Ended Working Group which included all 193 members.

►SEMICONDUCTOR FAB

Electronics industry is the world's largest and fastest growing industry with applications in all sectors of the economy. Semiconductors are a key enabler in the advancement of electronics industry and will play an even greater role with introduction of new technologies such as IoT, AI, 5G, smart cars, smart factories, data centres, robotics etc.

GLOBAL SEMICONDUCTOR MICROCHIPS SHORTAGE

1. Factories that makes these chips had to shut down temporarily due to the pandemic.
2. Concentration of microchip manufacturing: Microchips are designed by just a handful of companies such as Samsung, Intel, NVIDIA, and Qualcomm. However, most of these companies do not manufacture microchips. These companies usually outsource manufacturing to third parties. The biggest manufacturer is Taiwan Semiconductor Manufacturing Company (TSMC) and Samsung.
3. Increase in demand of semiconductor microchips: Need for technology for working from home, fluctuations in the automotive sector, deployment of 5G infrastructure, a push for hardware for artificial intelligence.
4. Supply chain disruptions due to closing of shipping lines and non-availability of containers etc.

Impact of global microchip shortages:

Lack of availability microchips led to shortages. Many manufacturing industries were adversely affected such as telecom, automotive and electronics.

CHALLENGES IN SETTING UP OF SEMICONDUCTOR FAB IN INDIA

1. Semiconductor manufacturing is a complex and research-intensive sector.
2. Capital intensive nature of this industry.
3. Rapid changes in technology.
4. Semiconductors are at heart of electronic products and constitute a significant part of the total value of bill of material (BOM).

NEED FOR DEVELOPMENT OF SEMICONDUCTOR FABS

1. In recent years, electronics manufacturing has substantially in India. India is steadily moving up the value chain from Semi-Knocked Down (SKD) to Completely Knocked Down (CKD) stage of manufacturing.
2. National Policy of Electronics 2019 aims to develop India as a global hub for Electronics System Design and Manufacturing (ESDM) and create an enabling environment for industry to compete globally.

WAY FORWARD

1. Incentivise and attract investment in setting up of Semiconductor FABs in India.
2. Ease of doing business for fab manufacturing.
3. Research and development in the semiconductor design and fabrication technologies.
4. Mandating a public sector firm for fab manufacturing.

►NATIONAL STRATEGY FOR ADDITIVE MANUFACTURING

ABOUT ADDITIVE MANUFACTURING

- Additive manufacturing is defined as the technology that constructs a 3-D object from a digital 3D model or a CAD model by adding material layer by layer.
- Addition of material can happen in multiple ways, namely power deposition, resin curing, filament fusing.
- Deposition and solidification are controlled by computer to create a 3-D object.

GOAL OF NATIONAL STRATEGY FOR ADDITIVE MANUFACTURING

1. Position India as a global hub for additive manufacturing development & deployment.
2. Create and protect the integrity of India's Additive Manufacturing intellectual properties.

MATERIALS USED IN ADDITIVE MANUFACTURING

1. Thermoplastics
2. Metals
3. Ceramics
4. Biomaterials

APPLICATIONS AND ADVANTAGES OF ADDITIVE MANUFACTURING

INDUSTRY	ADVANTAGES
Aerospace & Defence	• Low volume production of high value products with complex geometries. • Fuel efficiency through weight

	reduction of parts. • Improved product utility through on-demand production of replacement parts.
Automotive	• Cost effective solution for customisation of luxury vehicles. • Obsolescence management for defective parts. • Testing & production of lightweight, high strength parts.
Electronics	• High resolution, multi-material, large area fabrication of electronic devices that are free of printed circuit boards (PCBs). • Production of complex, lightweight impact resistant structures with multiple functionalities. • Designing of complex geometry parts with embedded electronics, sensors and antennas, which cannot be produced by conventional manufacturing process. • Internal manufacturing of circuits and circuit boards which reduces procurement time and eliminates intellectual property related issues.
Healthcare	• Production of customised implants, devices, dental crowns etc. • Reduction in healthcare costs due to minimal re-intervention enabled by accurate diagnosis. • Rapid response time during emergencies through rapid scaling of production. • Staff training in specific applications, leveraging datasets of patients affected by rare pathologies. • Patient centric healthcare through personalisation of drugs for complex patient specific release profiles.
Consumer goods	• Fabrication of complex internal and external structures compels innovative product design. • Faster time to market and cost-effective customisation of customer centric products. • Decentralised manufacturing reducing transferred costs to consumers.

POTENTIAL IMPACT OF ADDITIVE MANUFACTURING

Additive manufacturing is expected to impact the manufacturing ecosystem significantly.

1. Economic competitiveness

   Upstream supply chains will be flattened and simplified as semi-fabricated products replace raw materials.

   Will enable supplier consolidation as a single source may suffice for a variety of parts, increasing production agility.

   Enable fast and cost-effective manufacturing of smaller batches and greater product customisation.

   On-demand manufacturing will rationalise warehousing and distribution thus reducing physical inventory and costs.

2. Increase in Gross Value Addition (GVA): Lead to democratisation of innovation, thereby developing new technology-driven industries and jobs.
3. Workforce: Increase in productivity will lead to reduction of employment in manufacturing.
4. Social implications: Considerable reduction in use of raw materials due to material efficient designs.
5. Innovation diffusion

a) Enables greater design flexibility through modification of virtual design models and new material properties.

b) Allows for limited design constraints without the risk of high expenditure thereby boosting innovation in product development process.

c) Enhanced product differentiation and flexibility in design innovation.

6. Healthcare

a) Potential to fabricate biomedical implants, prosthetics, skin and tissues and intricate organs.

b) Specialised surgical instruments and medical devices can be manufactured quickly and cost effectively.

7. Military superiority

a) Advancement in additive manufacturing has the potential to fortify India against military and cyber warfare.

b) Transformation of Indian military supply chain:

i) In place of storing important stocks, military entities will only require adequate Additive manufacturing

facilities and raw materials to help the manufacturing process even in severe places.

ii) Transformation of physical inventory into a digital one will help in reduction of supply chain overhead, conveyance costs and additional logistical challenges faced by military forces in the battleground.

CHALLENGES TO ADOPTION OF ADDITIVE MANUFACTURING (AM)

1. Cost of equipment & material
2. Lack of formal AM standards
3. Lack of AM ecosystem
4. Monopoly of AM market by foreign OEM's
5. Lack of skilled manpower
6. Domestic market transition
7. Lack of clarity around the issue of liability
8. Legal & ethical issues

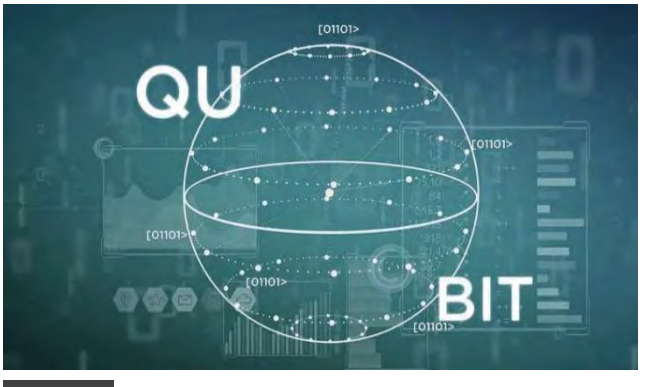
RECOMMENDATIONS

India must adopt additive manufacturing technologies in all manufacturing segments including defence and public sectors and position itself as a pioneer in restructuring its supply chain. A conducive ecosystem for design, development and deployment of these technologies should be created.

1. National Additive Manufacturing Centre to function as an aggregator of knowledge and resources and accelerator for technology adoption and advancement.
2. Development of a Phased Manufacturing Program
3. National strategy to address the human resource and skill development needs for additive manufacturing.
4. Research & IP creation by enhanced funding, creation of centre of excellence in additive manufacturing, IP Access forum and International R&D Partnership.
5. Supply chain development by incentives through government procurement policies, preferential market access policy and creation of regional industrial innovation clusters etc.

►QUANTUM COMPUTING

- Quantum computers work differently from classical computers. By exploiting principles of quantum mechanics, they can easily tackle computational problems that may be tough for classical computer as size of numbers and numbers of input grows bigger.
- Quantum computers do not look like desktops or laptops that we associate 'computer' with. Instead, they resemble air-conditioned server rooms of offices or stacks of central processing units from past that are connected by tangled wires in freezing rooms.
- Conventional computers process information in 'bits' or 1s and 0s, following classical physics under which our computers can process a 'one' or a '0' at a time. The world's most powerful supercomputer today can juggle 148,000 trillion operations in a second and requires about 9000 IBM CPUs connected in a particular combination to achieve this feat.
- Quantum computers compute in 'qubits' (or quantum bits). They exploit properties of quantum mechanics, the science that governs how matter behaves on atomic scale. In quantum computing, processors can be a 1 and a 0 simultaneously, a state called quantum superposition. While this accelerates speed of computation, a machine with less than 100 qubits can solve problems with a lot of data that are even theoretically beyond capabilities of powerful supercomputers. Because of quantum superposition, a quantum computer — if it works to plan — can mimic several classical computers working in parallel.
- The ideas governing quantum computers have been around since the 1990s, but actual machines have been around since 2011, most notably built by Canadian company D-Wave Systems.



BENEFITS

- Speed and capability of classical supercomputers are limited by energy requirements. Along with these they also need more physical space. That translates into reduced processors and reduced energy.
- A quantum computer can solve problem rapidly because it can attack complex problems that are beyond scope of a classical computer. Basic advantage is speed as it can simulate several classical computers working in parallel. Several encryption systems used in banking and security applications are premised on computers being unable to manage mathematical problems that are computationally demanding beyond a limit. Quantum computers, in theory, can surpass those limits.

CHALLENGES

1. Technology has not matured yet.
2. India currently has not functional or experimental quantum computers.
3. Quantum computers are prone to errors and are not stable.
4. The technology is very costly.
5. They are highly sensitive to disturbances from environment, even necessary controls and observations perturb them. Available and upcoming Quantum Devices are noisy and techniques to bring down the environmental error rate are being intensively pursued.

STEPS BY GOVERNMENT

1. Launch of National Mission Quantum Technologies and Applications (NM-QTA).
2. Peripheral research based on Quantum technologies have started in India.
   a. QSIM which is quantum computer simulator has been launched to make it easier for researchers to practice.
   b. Quantum random number generator has been developed by Indian researchers.

►QUANTUM KEY DISTRIBUTION

Cryptography is seen as an essential part of our everyday life and the importance of it is increasing each passing day. Concerns of data security be it financial transactions, security for strategic and defence purpose have cryptography at the centre.

Modern cryptography is classified into two main forms:

Private key cryptography: Same key is used for encryption as well as decryption of the message i.e., sender and receiver of the message must hold same key

Public key cryptography: Sender encrypts the message with public key while receiver decrypts the message with private (secret) key. Thus, anyone will be able to send an encrypted message, but intended recipient will be only one to be able to decrypt it.

Need for Quantum Key Distribution:

Modern cryptographic schemes have some drawbacks.

Security of private key cryptography depends on the length of the key. Larger the key, more secure it is. With increase in computational power of computers, efficient algorithms and anticipation of more efficient quantum computers, the resource-oriented problem of secure key distribution has come up.

Security of public key cryptography depends on the complexity of mathematical theories they are based and hence, they are vulnerable to efficient algorithms. With the impending dawn of quantum computation, public key cryptography might soon cease to be staying unbreakable.

QUANTUM KEY DISTRIBUTION

It is a cryptographic technique which allows two remote users to establish a secure key between them which can be used further for secure communication, using the principles of quantum mechanics. The most important advantage of QKD is that, in principle, the users can detect the presence of an eavesdropper who is trying to gain information from the transmission of information occurring between the sender and the receiver. If the eavesdropping level is below a certain threshold, a key can be established which is guaranteed to be secured. The most important features of quantum mechanics which are used are

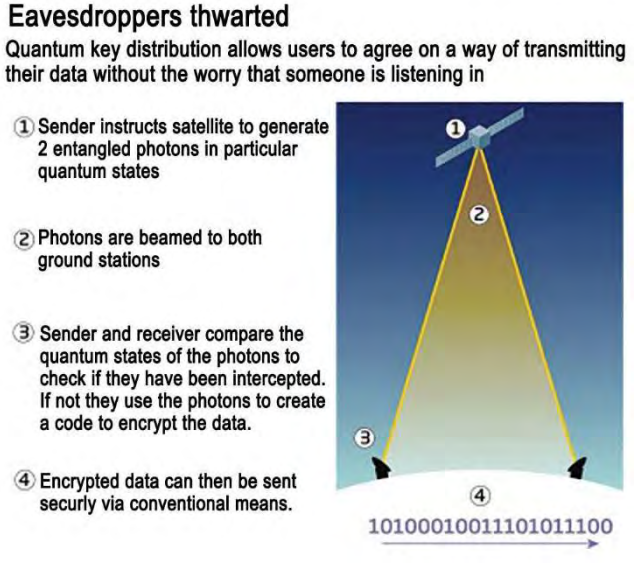
Heisenberg's uncertainty principle which puts a fundamental limit to the knowledge an observed might have of a quantum system.

No-cloning theorem which states any arbitrary quantum state cannot be copied to generate replicas.

Quantum Entanglement which creates a non-classical correlation between two quantum entities.

Two protocols have been developed for Quantum Key Distribution:

- BB84 protocol which uses 4 different polarisation states of photons to encode key bits.
- B92 protocol is modified version of BB84 protocol which uses two polarisation states of photons.



Uses of Quantum Key Distribution:

- Secure communication with satellites and ground stations.
- Since it is unhackable it offers for secure communication especially for defence, national security related data.

Challenges of using Quantum Key Distribution technology: Technology is slow and requires expensive equipment to send and receive individual photons.

CONCLUSION

As concerns of data security increases especially for critical public infrastructure and onset of more powerful computers and Quantum computing on the corner, it is important to invest in Quantum Key Distribution to make our communication network more secure. Thus, India should make more investment in these field. Government has launched National Mission for Quantum Technologies in this regard.

►NATIONAL MISSION ON QUANTUM TECHNOLOGIES & APPLICATIONS (NM-QTA)

Government in budget 2020 has announced a National Mission on Quantum Technologies & Applications (NM-QTA) with a total budget outlay of Rs 8000 Crore five years.

ABOUT QUANTUM TECHNOLOGY

Quantum Technology is based on the principles of quantum theory, which explains the nature of energy and matter on the atomic and subatomic level.

It concerns the control and manipulation of quantum systems, with the goal of achieving information processing beyond the limits of the classical world.

Quantum principles will be used for engineering solutions to extremely complex problems in computing, communications, sensing, chemistry, cryptography, imaging and mechanics. Quantum field has not yet matured for commercialization, due to the extreme scientific challenges involved.

- Quantum computers compute in 'qubits'. They use the properties of quantum mechanics like *Superposition* and *Entanglement*, principles that governs how matter behaves on the atomic scale.
- Quantum mechanics has increased our understanding of the universe like the structure of matter, the interaction of light and matter. It has also led to inventions such as lasers and revolution of semiconductor transistors.
- "Quantum supremacy" has opened the door for the actual realization of this path breaking technology.

APPLICATIONS OF QUANTUM TECHNOLOGY

- Advancement of science/innovation:
  - It can help in solving some of the fundamental questions in physics related to Einstein theory of relativity, gravity, black hole etc.
  - It can boost the Genome India project
- Boosting advancement of other technologies:
  - Quantum computing is an integral part of Industrial revolution 4.0.
  - Success in it will help in Strategic initiatives the Internet-of-Things, machine learning, robotics, and artificial intelligence across sectors will further help in laying the foundation of Knowledge economy.
  - Harnessing Quantum Computers statistical as the potential to accelerate or otherwise improve machine learning relative to purely classical performance
  - QC could potentially supercharge AI, plus manage an autonomous-vehicle-choked traffic future and accelerate its logistics.
- Quantum improvement of Haber Process: It can reduce the energy consumption and greenhouse gas emissions.
- Financial modelling: faster calculations for risk related to an investment.
- Logistics & Scheduling: Quantum computing can make logistics more efficient. For example, airlines can figure out how to stage their airplanes for the best service at the lowest cost.
- Encourage entrepreneurship and start-up ecosystem development.
- Pharmaceutical: India's interest in the pharmaceutical and healthcare industry is huge.
  - Quantum computing could reduce the time frame of the discovery of new molecules and related processes.
  - tracking protein behaviour or even modelling new proteins could be made easier and faster.
  - Tackling chronic diseases like cancer, Alzheimer's and heart ailments is a big possibility of the technology.
- Weather prediction can be improved by quantum modelling.
- Improved batteries for electric vehicles cell

chemistry of the batteries can be better harnessed.

- Climate change: Collection of data regarding climate change can be streamlined in a better way through quantum technology. This in turn will have a profound impact on agriculture, food technology chains and the limiting of farmland wastage.
- Secure Communication: Significant for cyber security as it promises unimaginably fast and unhackable satellite communication.
- Internal security: Prepare India to develop these emerging and disruptive technologies to secure our communications and financial transactions.
- Disaster Management: Tsunamis, drought, earthquakes and floods may become more predictable with quantum applications.

CHALLENGES IN QUANTUM TECHNOLOGY

- Technological challenge:
  - The challenge lies in harnessing properties of quantum superposition in a highly controlled manner. It is difficult to maintain 'superimposition' and 'entanglement' for a long time.
  - Challenge of scaling up Qubits in the processor.
  - A careful choice of materials, design and engineering is required to get them to work.
  - Creating algorithms & applications for quantum computers.
- Slow Progress in policy implementation: Although the NM-QTA was announced in the 2020 Budget speech, the mission has still not received any approval and no funds were allocated, disbursed or utilised under NM-QTA during the FY 2020-21.
- Limited Private Sector Involvement in NM-QTA: For NM-QTA, no private sector partners had been identified yet.
- Absence of research ecosystem: small pool of skilled professionals, absence of common platform, Industry-academia gap, low international collaboration, low patent application etc.
- Supply chain hurdle: Absence of indigenous development of critical quantum components.
- Security Related Issues: Quantum computing will have a disruptive effect on cryptographic encryption, which secures communications and computers. If this technology goes into the wrong hands, all the government's official and confidential data will be at risk of being hacked and misused.

INITIATIVES TO PROMOTE QUANTUM TECHNOLOGY

- Department of Science & Technology unveiled Quantum-Enabled Science & Technology (QuEST) and committed to investing Rs. 80 crores over next three years to accelerate research.
- In the 2020 Budget speech, the Finance Minister of India announced National Mission for Quantum Technologies and Applications (NM-QTA) with a total outlay of ₹8000 crore over five years for strengthening the quantum industry in the country.
- National Mission for Quantum Frontier: This mission aims to initiate work in control of quantum mechanical systems with many degrees of freedom.
- In 2021, government inaugurated C-DOT's Quantum Communication Lab and unveiled the indigenously developed Quantum Key Distribution (QKD) solution.
- 'Quantum Computer Simulator (QSim) Toolkit': It provides first quantum development environment - to academicians, industry professionals, students, and the scientific community in India.

ABOUT NM-QTA

Quantum Technologies & Applications is one of 9 missions of national importance, being driven by Prime Minister's Science and Technology Innovation Advisory Council (PM-STIAC) through (Principal Scientific Advisor) PSA's office to leverage cutting edge scientific research for India's sustainable development.

Areas of focus would both be in fundamental science and towards developing technology platforms in Four (4) identified verticals viz., (i) Quantum Computing & Simulations; (ii) Quantum Materials & Devices; (iii) Quantum Communications; & (iv) Quantum Sensor & Metrology.

The mission can help prepare next generation skilled manpower, boost translational research, and encourage entrepreneurship and start up ecosystem.

Quantum principles will be used for engineering solutions to extremely complex problems in computing, communications, sensing, chemistry, cryptography, imaging, and mechanics.

Their applications which will be boosted include those in aero-space engineering, numerical weather predictions, simulations, securing the communications & financial transactions, cyber-security, advanced manufacturing, health, agriculture, education.

It can bring India in the list of few countries with an edge in this emerging field. India will have a greater advantage in garnering economic growth and dominant leadership role.

RATIONALE

New economy is based on innovations that disrupt established business models. Artificial intelligence, Internet-of-Things (IoT), 3D printing, drones, DNA data storage, quantum computing, etc., are re-writing the world economic order.

Quantum technology is opening new frontiers in computing, communications, cyber security with wide-spread applications.

It is expected that lots of commercial applications would emerge from theoretical constructs which are developing in this area.

►NATIONAL SUPERCOMPUTING MISSION

Mission was set up to provide the country with supercomputing infrastructure to meet increasing computational demands of academia, researchers, MSMEs, and start-ups by creating the capability design, manufacturing, of supercomputers indigenously in India.

India has produced just three supercomputers since 2015 —less than one a year on average — under the National Supercomputer Mission (NSM).

OBJECTIVES OF NSM

- Make India leaders in Supercomputing and to enhance India's capability in solving grand challenge problems of national and global relevance.
- Empower scientists & researchers with state-of-art supercomputing facilities and enable them to carry cutting-edge research in their respective domains
- Minimize redundancies and duplication of efforts, and optimize investments in supercomputing
- Attain global competitiveness & ensure self-reliance in the strategic area of supercomputing technology.
- Target: To establish a network of supercomputers ranging from a few Tera Flops (TF) to Hundreds of Tera Flops (TF) and three systems with greater than or equal to 3 Peta Flops (PF) in academic and research institutions of National importance across the country by 2022.
- This network of Supercomputers envisaging a total of 15-20 PF was approved in 2015 and was later revised to a total of 45 PF (45000 TFs), a jump of 6 times more compute power within the same cost and capable of solving large and complex computational problems.

PERFORMANCE OF NSM SO FAR

NSM's first supercomputer — PARAM Shivay installed in IIT-BHU, Varanasi. This supercomputer has 837 Teraflop capacity.

Second supercomputer with a capacity of 1.66 Petaflop was installed at IIT-Kharagpur.

Third system, PARAM Brahma is at IISER-Pune, has a capacity of 797 Teraflop.

There will soon be 11 supercomputers; expected to be installed by 2020 or latest by March 2021.

APPLICATION AREAS OF SUPERCOMPUTERS

- Climate Modelling
- Weather Prediction
- Aerospace Engineering including CFD, CSM, CEM
- Computational Biology
- Molecular Dynamics
- Atomic Energy Simulations
- National Security/ Defence Applications
- Seismic Analysis
- Disaster Simulations and Management
- Computational Chemistry
- Computational Material Science and Nanomaterials
- Discoveries beyond Earth (Astrophysics)
- Large Complex Systems Simulations and Cyber Physical Systems
- Big Data Analytics
- Finance
- Information repositories/Government Information Systems

►BROADBAND IN INDIA

Broadband is a basic infrastructure essential for improving socio-economic development, job creation

INDIA'S BROADBAND LANDSCAPE

1. Rapid expansion of internet and broadband usage: Overall average data usage per month has increased at CAGR of 76% from 2015 to 2020 reaching 13.5 GB in December 2020. This happened due to upgradation of mobile networks to 4G which facilitated online education, remote working for professionals and higher OTT viewership.

2. Dominance of mobile based broadband: Mobile based broadband accounted for 97% of total broadband connections. Overall broadband connections in India are about 74.5 crores out of which 72.5 crores are mobile broadband connections. 4G accounts for 98.7% of total data traffic consumed across the country.
3. Rural India not left behind: India's digital revolution continues to be propelled by rural masses. Rural India accounts for 38% of broadband users in 2020. Rural data consumption accounts for 45% of overall mobile data usage.
4. Fixed line broadband's share is limited: Only 9% of households have access to fixed broadband. FTTH broadband connections constitute only 30% of the fixed broadband connections in the country.
5. Still millions are untouched by internet and the possibilities it opens: Despite rapid spread of broadband and the increasing opportunities it brings, nearly 45% of India's population still does not have access to broadband.
6. Low Speed: As per Ookla speed test global Index, India ranked 131st among 140 nations in terms of mobile broadband and 66th among 177 countries in fixed broadband. Reasons for low speed are:
   a. Lower spectrum availability for access as well as backhaul
   b. Lower fiberisation of towers
   c. Power outages
7. Right of Way Issues: As RoW permissions are required by all types of utility services. Right of way issues hamper quick scale up of broadband in remote areas.

STEPS TAKEN BY GOVERNMENT

1. National Broadband Mission has been launched to provide broadband access to all villages by 2022.
2. Telecom reforms: Ex. Relaxing AGR dues and rationalizing Spectrum Usage Charges will make telecom companies financially resilient to make further investments to increase broadband coverage.
3. Launch of PM-WANI project will facilitate setting up of public Wi-fi hotspots, termed public data offices.

RECOMMENDATIONS

TRAI has made following recommendations for boosting penetration of high-speed broadband across India.

1. New definition of broadband: Minimum speed for an internet connection to be called Broadband to be raised to 2 Mbps. National Digital Communications Policy 2018 aims to provide universal access of 50 Mbps to every citizen.
2. Standardized categories in fixed line broadband connections:

Name of category	Internet download speed
Basic Broadband	Between 2 to 50 Mbps
Fast Broadband	Between 50 and 300 Mbps
Super-fast Broadband	More than 300 Mbps

3. Encouraging cable operators to provide broadband services by addressing issues related to computation of Adjusted Gross Revenue (AGR) by removing revenue from operations other than telecom activities from the total gross revenue on which AGR is applicable.
4. Passive as well as active infrastructure sharing should be allowed under the Internet Service License and Internet service authorization.
5. For efficient utilisation of available spectrum and supporting mobile broadband speed enhancement, entire spectrum allocation for International Mobile Telecommunications (IMT) purposes should be assigned to service providers on a regular basis.
6. In rural and remote areas, BharatNet network should be quickly implemented by implementing PPP.
7. Radio spectrum available for backhauling purpose should be assigned to service providers on demand and time-bound manner.
8. National Right of Way (RoW) Policy: As RoW permissions are required by all types of utilities like telegraph, electricity, water, gas etc. from authorities for establishment, maintenance of underground, overground infrastructure and such permissions are regulated under different laws, rules and regulations, it leads to
9. Incentivize establishment of common ducts to be shared on non-discriminatory basis with service & infrastructure providers for establishing telegraph lines.
10. Financial and taxation incentives for internet service providers for boosting broadband coverage especially in rural and remote areas.

11. TRAI needs to set up strong Quality of Service Rules and establish telecom ombudsman to stop protect consumers. Mandating ISPs to provide details about network congestion,

NATIONAL BROADBAND MISSION (NBM)

- Objective: To provide broadband access to all villages by 2022.
- Facilitate universal & equitable access to broadband services across the country, especially in rural and remote areas.
- Laying down around 30 Lakhs km route Optical Fiber Cable, increase tower density from 0.42 to 1.0 tower per thousand of population by 2024 and significantly improve quality of services for mobile and internet.
- Envisages Rs 7lakh crore investment in next 3-4 years.
- Provide internet connectivity to one lakh villages which will push our economy to 5 trillion-dollar milestone.
- Significantly improving quality of services for mobile and internet.
- Increasing fiberisation of towers to 70% from 30% at present.
- Enable strengthening of technological infrastructure for education, health, industry & development

SPACE

Previous Year Questions

YEAR	UPSC MAINS QUESTIONS
2019	What is India's plan to have its own space station and how will it benefit our space program?
2017	India has achieved remarkable successes in unmanned space missions including the Chandrayaan and Mars Orbiter Mission, but has not ventured into manned space mission, both in terms of technology and logistics? Explain critically.
2016	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?
2015	What do you understand by 'Standard Positioning Systems' and 'Protection Positioning Systems' in the GPS era? Discuss the advantages India perceives from its ambitious IRNSS program employing just seven satellites.

►SPACE SCIENCE

BENEFITS OF SPACE SCIENCE

Art & Culture	E-visit to museums, remote sensing to monitor the conditions of ancient architectures etc.
Society	Fulfills people's curiosity about universe, removes superstition,
Polity & Governance	High resolution data helps in Urban planning.
Social Issues	'Village Resource Centers' have been created by ISRO to provide space-based services (tele-medicine, tele-education etc) directly to rural areas. EDUSAT has provided connectivity to schools and colleges.
International relation and cooperation	Cooperation and trust building among nations,
Economy – Infrastructure, Agriculture, Manufacturing, Energy, Employment	Remote Sensing Satellite data has helped improve agricultural productivity. Space mining has the prospect for infinite supply of precious and scarce resources like He-3, cobalt, rare earth metals etc Attracts young people towards career in Science, Astronomy, Mathematics, Physics etc
Technological enhancement/	

Innovation dispersion	
Environment & Ecology	Study of Martian surface and atmosphere will help in understanding climate change on earth. Earth Observation Satellites helps in effective resource management.
Security	International preparedness for protecting earth from catastrophic event.
Disaster management	BHUVAN helps in management of natural disaster using space-based inputs. Desertification and land degradation mapping

CHALLENGES OF SPACE SCEINCE

Technological challenge	Increased space Debris
Economic challenge – skilled manpower, financial resource,	R&D expenditure in India is less than 1%. Manufacturing semiconductor chips and ancillary equipment like transponders, sensors etc. are miniscule.
Governance challenge – robust institutions, process regulation	State centric nature of space governance. Obsolete space laws and regulations. United Nations Committee on Peaceful Uses of Outer Space for discussing issues of international space law and policy. Five United Nations treaties on outer space under UNCPUOS: • Outer Space Treaty • Rescue Agreement • Liability Convention • Registration Convention • Moon Agreement Formation of space oligopoly due to space privatization
Security	Cyber-attacks on space assets Militarization and weaponization of space
International cooperation	Cooperation and trust building among nations,
Ethical challenge	Ethical concern over space-based data collection due to dual use of satellites. Uneven distribution of benefit of space exploration

WAY FORWARD

People	Increased space debris
Institution	IN-Space must be more effective in increasing the private sector participation in space; the conflict in the role of ISRO – acting as both promotor and regulator – must be resolved.
Governance/regulation	Clear policy on space exploration, setting up an independent space regulator, implementation of Drone policy etc.
Technological advancement, new uses, alignment with other technologies	Recognition of Intellectual Property Rights in space to encourage private participation.
International relation and cooperation	Cooperation for an International Code of Conduct for Outer Space Activities, Prevention of Arms Race in Outer Space.
Ethical challenge	Ethical concern over space-based data collection due to dual use of satellites. Uneven distribution of benefit of space exploration

►USES OF SPACE TECHNOLOGY

Space technology applications, derived through synergistic use of earth observation, communication & navigation satellites and complemented with ground-based observations, play a key role in harnessing benefits of space technology for national development.

Satellite based Earth observation is a cost-effective means of obtaining essential and reliable data. Such data on natural resources have become an integral part

of planning and implementation of action plans for managing land & water resources, developing urban & rural infrastructure, monitoring weather & climate, protecting environment including disaster risk reduction.

APPLICATIONS FOR AGRICULTURE

a) Estimation of crop acreage and production Use of seasonal (Kharif, Rabi & Summer) space images for advance information on the crop acreage and production estimation for major crops.

b) For Agricultural drought assessment and monitoring

c) For Crop Insurance related assessment and relief

d) Soil Health Card Applications:

e) Mapping and monitoring of various plantation crops at national level for inventory & management (Tea, Coffee, Spices, Rubber)

f) Space based inputs for the management of in-season fertiliser demand and potential.

g) Mapping and monitoring of plantation crops. (Tea, Coffee, Rubber, Spices etc.)

h) Mapping & monitoring, optimal produce for inland and aquaculture activities.

APPLICATIONS FOR ENERGY

Use of space technology for potential solar energy harvesting, potential roof top energy harvesting, night-lights.

APPLICATIONS FOR EDUCATION

a) Satellite based education for remote areas in mass scale using SATCOM technology to improve the literacy in rural areas.

b) Use of Tele-education and Distance learning programs and integrate programs through the Digital India network

APPLICATIONS FOR DISASTER MANAGEMENT

a) Assessment of various disaster-prone areas using space technology can give us an idea about the extent of vulnerability of an area to a disaster.

b) During a disaster, space technology can help us better plan disaster response. For ex. (i) Satellite phones can help us communication in the event of formal communication networks not functioning. (ii) Judge the extent of disaster affected area and direct resources to most affected areas.

(c) Space technology can help us in better planning to make infrastructure and settlements disaster resilient to reduce disaster risk.

APPLICATIONS FOR ENVIRONMENT MANAGEMENT

(a) Mapping and monitoring of India's forest and biodiversity resources, annual forest loss, monitoring of India's reserved forests, national parks, sanctuaries and forest boundaries etc. Inputs for forest management plans.

b) Forest biomass estimation. Monitoring of coral reefs, mangroves, coastal areas, islands etc.

c) Monitoring of desertification and land degradation.

d) Monitoring of snow, snow line, glacier and glacial lakes.

e) Forest fire location using thermal satellites during fire season. Agriculture stubble burning and burnt area analysis.

f) Environmental monitoring for air, water, atmosphere, climate change etc. The availability of higher frequency bands allows enhanced traffic, increase protection from jamming and lower probability of intercepting transmissions from covert terminals. Satellite communication system has several advantages which are being extensively exploited for military applications.

They include the following:

a. A single satellite can provide communication coverage over a large geographical area.

b. Satellite transponders have large transmission capacities that enable them to support high data rates.

c. The inherent flexibility has the advantage to control remotely and hence less vulnerable to direct attack.

d. They are physically remote and hence less vulnerable to direct attack.

APPLICATIONS FOR STRATEGIC AND MILITARY

Space technology has many spinoffs effects in military and space fields. Space warfare is an emerging field of warfare. Though the Outer Space Treaty expressly bans the militarisation of space, however, satellite communication technology is currently being used for the following purposes:

a) Used in guided missile systems: Satellites are guided by location feed to strike their targets.

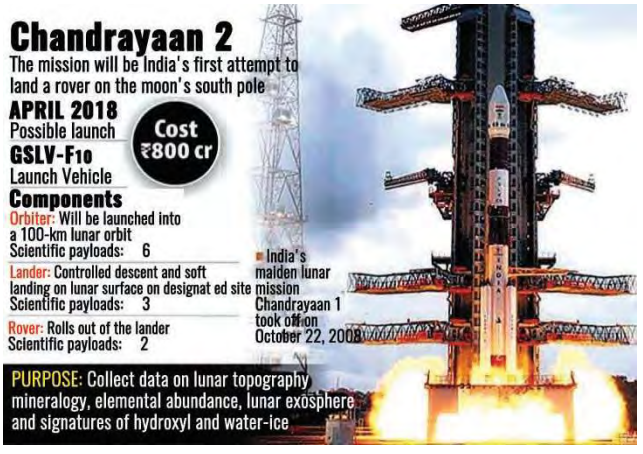
b) Used in missile defence systems: They use satellite feed to locate incoming satellites and destroy them.

c) Used in reconnaissance and surveillance systems. Ex. India's AWACS.

d) Satellites can be destroyed adversely affecting communications networks.

►CHANDRAYAAN-2

Many people were disappointed when Chandrayaan-2, India's second mission to the Moon, failed to land softly on the lunar surface. That did not, however, imply that the entire mission had been in vain.



ABOUT CHANDRAYAAN-2

- Chandrayaan-2 was made up of three parts: an Orbiter, a Lander, and a Rover, all of which were equipped with scientific instruments for studying the moon.
- Orbiter would circle the moon at 100 kilometers, while the Lander and Rover modules would be detached and land softly on the moon's surface.
- The Lander module was called Vikram after Vikram Sarabhai, India's space pioneer, while the Rover module was named Pragyaan, which means knowledge.
- The Lander was unsuccessful. However, the Orbiter was orbiting the moon all this while and sending significant data, which has advanced the understanding of moon.

UTILITY OF THE ORBITER

- The Orbiter component of the mission has been performing well. It has eight instruments on board.
- Each of these sensors has generated a substantial quantity of data that throws fresh light on the moon and provides new insights that might be useful in future exploration.

SOME OF THE SIGNIFICANT RESULTS SO FAR

1. Water
    - Chandrayaan-1, India's first mission to the Moon, verified the existence of water on the Moon. However, the spectrographic signature for Water and Hydroxyl ions is same. Using data from Chandrayaan-1, it was not confirmed whether the signature was from water or hydroxyl ions (OH-ions).
    - The Imaging Infrared Spectrometer (IIRS) onboard Chandrayaan-2 was able to differentiate between hydroxyl and water molecules using considerably more sensitive equipment and discovered distinct signals for both.
    - This is the most exact data on the existence of water molecules on the Moon that has been discovered so far.
    - Water was formerly thought to be only found in the Moon's polar regions. Water signals have now been discovered by Chandrayaan-2 at all latitudes, albeit their quantity varies.
2. Minor elements
    - The Large Area Soft X-ray Spectrometer (CLASS) analyses the Moon's X-ray spectra to look for key elements including magnesium, aluminum, silica, calcium, titanium, iron, and others.
    - This equipment has identified minor elements like chromium and manganese for the first time using remote sensing.
    - The discovery might pave the way for a better understanding of magmatic development on the Moon, as well as deeper insights into nebular circumstances and planetary differentiation.
    - For the first time, CLASS has mapped approximately 95% of the lunar surface in X-rays.
    - For the first time, sodium, a minor element on the Moon's surface, was identified without ambiguity.
3. Study of Sun
    - One of the payloads, the Solar X-ray Monitor (XSM), has acquired data on solar flares in addition to monitoring the Moon through the Sun's radiation.
    - For the first time, XSM has detected a substantial number of microflares outside the active area.
    - This has huge ramifications for our knowledge of the process that causes the solar corona to heat up, which has been a long-standing mystery.

SIGNIFICANCE OF THE FINDINGS

- While the Orbiter payloads add to what we already know about the Moon's surface, subsurface, and exosphere, they also lay the way for future Moon missions.
- Future study will focus on four areas: lunar surface mineralogical and volatile mapping, surface and subsurface characteristics and processes, measuring

water in various forms across the Moon surface, and maps of elements found on the moon.

- The investigation of permanently dark areas, as well as craters and boulders under the regolith, the loose deposit that makes up the top surface and extends up to 3-4m in depth, was a significant result of Chandrayaan-2. This should aid scientists in determining future landing and drilling locations, including those for human missions.

FUTURE MOON MISSIONS

- JAXA-ISRO partnership LUPEX mission, slated to launch in 2023/2024, is one of the prospective Moon missions that hopes to make use of such data. Its goal is to learn more about lunar water resources and determine if the lunar polar area is suitable for establishing a lunar colony.
- NASA's Artemis mission aims to enable human landing on Moon in 2024, with long-term lunar exploration planned by 2028.
- Chinese Lunar Exploration Program intends to create a platform for large-scale scientific exploration at the lunar south pole, like the International Lunar Research Station (ILRS).

WAY FORWARD

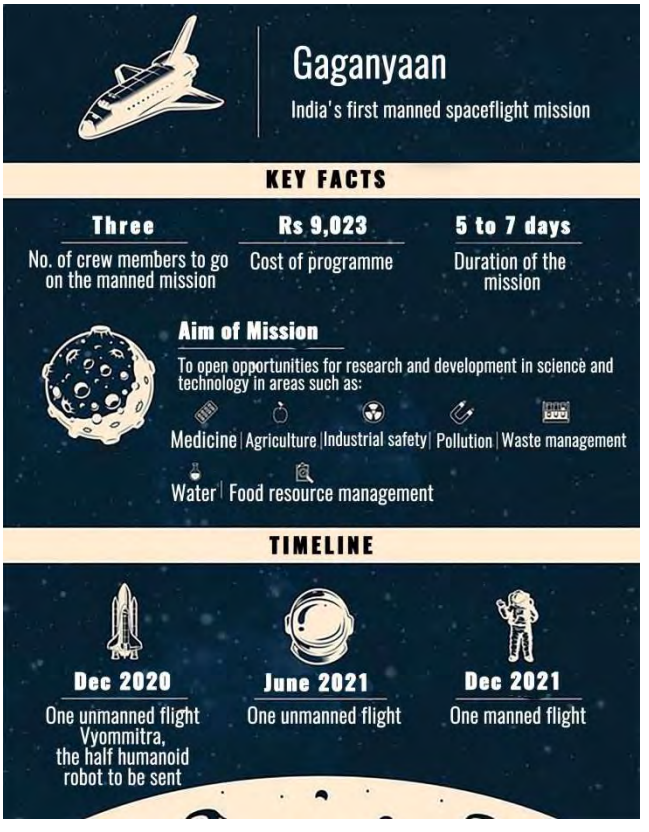
1. ISRO should develop competence in developing soft landing capability, which will increase our knowledge of moon and other planets of solar system in future.
2. Chandrayaan-3 mission should be planned with a well functional rover and lander and take forward the findings of Chandrayaan-2 orbiter.

►GAGANYAAN

- India's Mission sent a three-member crew to space. It aims for demonstration of Indian Human Spaceflight capability to low earth orbit for a mission duration ranging from one orbital period to a maximum of 7 days.
- A human rated GSLV Mk-lll will be used to carry the orbital module which will have necessary provisions for sustaining a 3-member crew for the duration of the mission.
- Gaganyaan will be launched after the second unmanned mission planned in 2022-23.

SALIENT FEATURES OF GANGAYAAN MISSION

- The spacecraft will be placed in a low earth orbit of 300-400 km.
- The spacecraft will comprise of a crew module and service module that constitute an orbital module.
- It weighs approximately 7 tons and will be carried by a rocket.
- Crew module's size will be 3.7 meters and 7 meters.
- Aims to send a three-member crew to space for a period of five to seven days.
- Crew will do microgravity experiment during the mission.
- Crew will be selected by Indian Air Force (IAF) and ISRO jointly after which they will undergo training for two-three years.
- Crew, while coming back to Earth, could land in Arabian Sea off Gujarat coast or in Bay of Bengal or even on land.



TECHNICAL CHALLENGES IN GAGAYAAN MISSION

- Pressure maintenance: 'Gaganayan' has to create an atmosphere like Earth inside a small volume & ensure that is adequate maintained throughout the mission.
- Crew escape System: to prepare for any emergency from launch phase onwards and ensure reliability of such a system. Environmental Control & Life Support System (ELCSS), space suit and crew support systems are still in the developmental phase.
- Re-entry and Recovery: The spacecraft's re-entry into the atmosphere must be very precise, even the slightest deviation could lead into a disaster.

- Radiation-proof module: In space stations, astronauts receive over ten times the radiation than what people are subjected to on Earth.
- Coping with change in gravity field: Transitioning from one gravity field to another has impact on the physical bodies. It affects hand- eye and head-eye coordination.
- Psychological preparedness: Due to isolation, one may encounter depression, fatigue, sleep disorder and psychiatric disorders.
- Threat from Space Debris: There is increasing threat of Space debris in the low earth orbits which can result in depressurization of the cabin of the crew module in case of a collision with small debris.

BENEFITS OF GAGANYAAN PROGRAM

- Establish a broader framework for collaboration between ISRO, academia, industry, national agencies and other scientific organizations.
- Allow pooling of diverse technological and industrial capabilities and enable broader participation in research opportunities and technology development benefitting large number of students & researchers.
- Flight system realization will be through Industry.
- Generate employment and train human resources in advanced technologies.
- Spur research and development within the country in niche science and technology domains.
- Technology spinoffs in medicine, agriculture, industrial safety, pollution, waste management, water & food resource management etc.
- Provide a micro-gravity platform in space for conducting experiments & test bed for future technologies.
- Give impetus to economic activities within the country in terms of employment generation, human resource development and enhanced industrial capabilities.
- Enable India to participate as a collaborating partner in future Global space exploration initiatives with long term national benefits.

Science & Technology	• Development of research ecosystem. • Low gravity experiment can be conducted. • Development of advances material to protect the astronauts, pressure control systems, better navigation control etc
Polity & Governance	• Government has announced a new organisation, IN-SPACe, to increase private participation in the space sector. • Establish a broader framework for collaboration between ISRO, academia, industry, national agencies and other scientific organizations.
Social Issues	• Help in enhancement of science and technology levels in the country and help inspire youth. • Additional human resource development. • Development of technology for social benefits.
International relation and cooperation	• Human Space Flight Centre of the ISRO and the Russian government owned Glavkosmos signed a contract for the training. • Candidates will study in detail systems of the Soyuz manned spaceship. • Ground monitoring station will be developed in collaboration with Australia.
Economy – Infrastructure, Agriculture, Manufacturing, Energy, Employment	• Help in improvement of industrial growth. Gaganyaan mission is expected to source nearly 60% of its equipment from the Indian private sector. • Gaganyaan mission would create 15,000 new employment opportunities.
Technological enhancement/ Innovation dispersion	Enhanced S&T level of the country • Human Space flights are frontier field in science and technology. • Human spaceflight program will provide a unique platform in space for conducting experiments and test bed for future technologies. • It will thrust significant research in areas such as materials processing, astro-biology, resource mining, planetary chemistry, planetary orbital calculus and many other areas.

	• Other missions like Chandrayaan-3, Shukrayaan Mission will get boosted.
Environment & Ecology	Study of sun and solar radiations, remote sensing of sea and forest, climate change modelling etc
Security	Quantum mechanics experiments can help in advancement of quantum computing and Quantum Key Distribution techniques.
Ethical consideration	Dignity and honor to the nation. India will be 4th country to launch human space mission. This will also enhance leadership opportunity for India.

ABOUT GSLV MK III & CARE

- GSLV Mk III is a three-stage heavy lift launch vehicle developed by ISRO. It has two solid strap-on, a core liquid booster and a cryogenic upper stage.
- GSLV Mk III is designed to carry 4-ton class of satellites into Geosynchronous Transfer Orbit (GTO) or about 10 tons to Low Earth Orbit (LEO).
- Two strap-on motors of GSLV Mk III are located on either side of its core liquid booster, designated as 'S200', each carry 205 tons of composite solid propellant.
- Two clustered Vikas liquid Engines of L110 liquid core booster will further augment thrust of vehicle.
- CARE is acronym for Crew Module Atmospheric Re-entry Experiment. The mission would be used as a platform for testing re-entry technologies envisaged for Crew Module including validating performance of parachute-based deceleration system.

►SATELLITE INTERNET

Various private companies are aiming to deliver broadband satellite Internet around world through their fleet of Low Earth Orbit (LEO) satellites. Some companies are planning to develop space-based internet through Geostationary Satellite for selective users. Space based internet can help make internet available to parts where conventional ground-based internet cannot reach.

INTERNET FROM LOW EARTH ORBIT SATELLITE

- Positioning of Satellites: LEO satellites are positioned around 500-2000km from earth, compared to stationary orbit satellites which are approximately 36,000km away.
- Latency: Latency, or the time needed for data to be sent and received, is contingent on proximity.
  - As LEO satellites orbit closer to earth, they can provide stronger signals & faster speeds than traditional fixed-satellite systems.
  - Because signals travel faster through space than through fiber-optic cables, they also have potential to rival if not exceed existing ground-based networks.
- Higher Investment: LEO satellites travel at a speed of 27,000 kph and complete a full circuit of the planet in 90-120 minutes.
  - As a result, individual satellites can only make direct contact with a land transmitter for a short period of time thus requiring massive LEO satellite fleets & consequently, a significant capital investment.
  - Due to these costs, of three mediums of Internet – fiber, spectrum & satellite, latter is most expensive.

SPACE INTERNET FROM GEOSTATIONARY SATELLITE

- Positioning of Satellites: Geostationary orbit is located at a height of 35,786 km over Earth's surface, directly above the Equator.
  - Most existing space-based Internet systems use satellites in geostationary orbit.
  - Satellites in this orbit move at speeds of about 11,000 km per hour, complete one revolution of the Earth while the earth rotates once on its axis.
  - To the observer on ground, therefore, a satellite in a geostationary orbit appears stationary.
- Coverage: The signals from one geostationary satellite can cover roughly a third of the planet — and three to four satellites would be enough to cover entire Earth.
- Easier Connectivity: As satellites appear to be stationary, it is easier to link to them.
- Latency Issues: The transmission from a satellite in geostationary orbit has a latency of about 600 milliseconds. Geostationary satellites are located at higher altitudes compared to LEO, thus longer distance that needs to be covered, results in greater latency.

RELATED INITIATIVES

- 'Five to 50' service (One Web): One Web, a private company, has successfully launched constellations of 218 satellites in LEO.
  - Company only has one more launch to complete before it obtains the capacity to enable its 'Five to 50' service of offering internet connectivity to all regions north of 50 degrees latitude.

- Five to 50 service is expected to be switched on by June 2021 with global services powered by 648 satellites available in 2022.

- Star link: It is a venture of SpaceX.
  - Star link currently has 1,385 satellites in orbit. Company has started testing in North America.
  - However, Star link's satellites fly closer to the earth and therefore, the company requires a larger fleet to provide global connectivity than One Web.
- Project Kuiper: It is a project of Amazon announced in 2019.
- Loon Project: Google launched its 'Loon' project in 2013, using high-altitude balloons to create an aerial wireless network. The project was later abandoned.

ADVANTAGES OF SPACE BASED INTERNET

- Reduced Latency: 20-30 milliseconds roughly time it takes for terrestrial systems to transfer data. Transmission from a satellite in geostationary orbit has a latency of about 600 milliseconds.
- High Bandwidth: Satellite internet connections can handle high bandwidth usage, so internet speed /quality shouldn't be affected by lots of users or "peak use times."
- Viability: Signals from satellites in space can overcome obstacles faced by fibre-optic cables or wireless networks easily.
- Quick recovery post-disaster.
- We don't need a phone line for satellite internet.

DISADVANTAGES

- More vulnerable to bad weather.
- Coverage: Due to its lower height, its signals cover a relatively small area.
- Space Debris: Generate more space debris.
- Difficulty in Space Studies: Constellations of space internet satellites will make it difficult to observe other space objects and detect them. Light reflected from man-made satellites can interfere with and be mistaken for light coming from other space bodies.
- Light Pollution: Increased risk of light pollution.

ISSUES IN LEO SATELLITES LAUNCH

- Regulation Issues: During days of Sputnik and Apollo missions, governments dominated & regulated space-based activities. Most LEO based internet initiatives are being developed by private companies. As a result, there are questions related to regulation of these companies, especially given large number of nations that contribute to individual projects. It makes regulatory framework complicated.
- Logistic Challenge: There are logistical challenges with launching thousands of satellites into space as well.
- Difficulty in Space Observation: Satellites can sometimes be seen in the night skies which creates difficulties for astronomers as the satellites reflect sunlight to earth, leaving streaks across images.
- Interruptions: Satellites travelling at a lower orbit can interrupt frequency of those orbiting above them.
- Space Junk: There are already almost one million objects larger than 1cm in diameter in orbit, a by-product of decades of space activities. Those objects, colloquially referred to as 'space junk,' have potential to damage spacecraft or collide with other satellites.
- Telcom and Internet regulations: Currently, TRAI regulates telecom and internet companies in India. It is not clear how access to space-based internet will be regulated in India. Current, regulations need to be updated.

►LASER COMMUNICATION IN SPACE

Recently, NASA has launched its new Laser Communications Relay Demonstration (LCRD). It is first-ever laser communications system that will pave the way for future optical communications missions.

- Laser communication in space is use of free-space optical communication in outer space.
- Laser uses infrared light, has a shorter wavelength than radio waves. This will help transmit more data in a short time.
- Optical communications will help increase bandwidth 10 to 100 times more than radio frequency systems.
- It takes roughly nine weeks to transmit a completed map of Mars back to Earth with current radio frequency systems. With lasers, we can accelerate that to about nine days.
- Communication may be fully in space (an inter-satellite laser link) or in a ground-to-satellite or satellite-to-ground application.
- In outer space, communication range of free-space optical communication is currently of order of several thousand kms, suitable for inter-satellite service.
- It has potential to bridge interplanetary distances of millions of kms, using optical telescopes as beam expanders.

LI-FI

- Li-Fi, or light fidelity, is a Visible Light Communications (VLC) system.
- Unlike Wi-Fi, which uses radio waves, Li-Fi runs on visible light.
- It transmits data at terabits per second speeds—more than 100 times the speed of Wi-Fi.
- It accommodates a photo-detector to receive light signals and a signal processing element to convert the data into 'stream-able' content.

Advantages of LIFI

- Li-Fi could make a huge impact on internet of things, with data transferred at much higher levels with even more devices able to connect to one another.
- Due to its shorter range, Li-Fi is more secure than Wi-Fi.
- Li-Fi systems consume less power.

Disadvantages of LIFI

- Main challenge is to create a Li-Fi ecosystem, which will need conversion of existing smartphones into Li-Fi enabled ones by the use of a converter/adapter.
- Visual light can't pass through opaque objects and needs line of sight for communication.
- Interference from external light sources, such as sunlight and bulbs

Potential applications of LIFI

- Li-Fi can be used in street & traffic lights. Traffic lights can communicate to vehicles and with each other. Through use of Li-Fi, traffic control can be made intelligent and real-time adaptable. Each traffic and street light post can be converted into access points to convert roadsides into wireless hot spots.
- Vehicles having LED-based headlights and tail lamps can communicate with each other and prevent accidents by exchanging information.
- Visible light being safer, they can also be used in places where radio waves can't be used such as petrochemical and nuclear plants and hospitals.
- They can be used in aircraft, where most of control communication is performed through radio waves.
- Li-Fi can easily work underwater, where Wi-Fi fails completely, thereby throwing open endless opportunities for military & navigational operations.
- Transmitting power wirelessly, wherein smartphone will not only receive data through Li-Fi, but will also receive power to charge itself.

►SPACE DEBRIS

- Most Space debris comprises human-generated objects, such as pieces of spacecraft, tiny flecks of paint from a spacecraft, parts of rockets, satellites that are no longer working, or explosions of objects in orbit flying around in space at high speeds.
- Most space junk is moving very fast and can reach speeds of 18,000 miles per hour, almost seven times faster than a bullet.

KESSLER SYNDROME

- Proposed by NASA scientist Donald Kessler in 1978. It states that if there was too much space junk in orbit, it could result in a chain reaction where increased objects collide and create new space junk, to the point where Earth's orbit becomes unusable. Also known as collisional cascading.
- This cascade of collisions first came to NASA's attention in 1970s when derelict Delta rockets left in orbit began to explode creating shrapnel clouds.
- Kessler proposed it would take 30-40 years for such a threshold to be reached and today, experts think we are already at critical mass in low-Earth orbit at about 560 to 620 miles (900 to 1,000 kilometers).

HOW CAN KESSLER SYNDROME BE AVOIDED?

- Successful 'passivation' of all spacecraft, which would limit on-orbit breakups, and widespread, i.e., more than 90%, adoption of effective disposal strategies at end of missions would contribute to containing growth of space debris.
- Clean Space by cutting debris production from future space missions.
- Then an urgent need to reduce total mass of current debris, such as robotic salvage of derelict satellites.

WAYS TO CLEAN SPACE DEBRIS

- Removing dead satellites from orbit and dragging them back into the atmosphere, where they will burn up. To do this-
  - Use a harpoon to grab a satellite.
  - catching it in a huge net.
  - using magnets to grab it.
  - firing lasers to heat up the satellite.
  - execute a collision avoidance maneuver.
  - increasing its atmospheric drag so that it falls out of orbit.
- However, these methods are useful for large satellites orbiting Earth. There is not a way to pick up smaller pieces of debris such as bits of paint and metal.

- There are international guidelines for getting rid of old satellites and rockets from Inter-Agency Space Debris Coordination Committee (IADC).
- By making sure that satellites are removed from orbit in a reasonable amount of time once they are no longer active, we can mitigate the problem of space junk in the future.

CHALLENGES IN SPACE DEBRIS REMOVAL

- Space is a global common, with rising incomes, participation of developing countries has increased in space activities. Unfortunately, there is an explosion risk in removing more dangerous objects.
- Issue of property rights: one cannot grab a satellite or rocket that belongs to another country without their permission.
- It is hard to eliminate space debris as there are huge chances of creating more junk while doing it.
- Most satellite operators require hours or days to plan and execute a collision-avoidance maneuver.
- Lack of an international body to set rules on space traffic and debris. Thus far, space missions have been supervised at the national level only and states have been encouraged to translate non-binding space debris guidelines into national regulations.
- Lack of availability of an updated and up-to-date list of space objects: The main global catalogue of space objects is published by Space-Track.org by US Space Command, a branch of US military. This catalogue lacks some satellites and is not comprehensive.

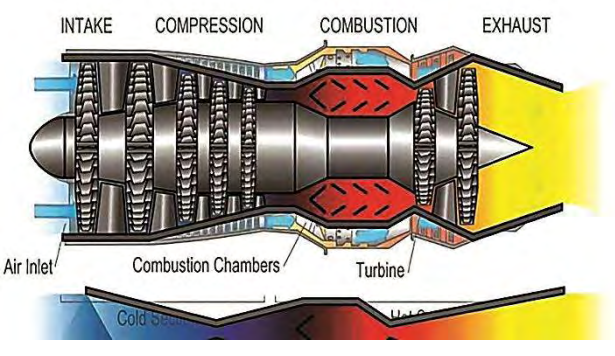
WAY FORWARD

- Spacefaring nations must minimize risks to people and property on Earth of re-entries of space objects & maximize transparency regarding those operations.
- All spacefaring nations and commercial entities must act responsibly and transparently in space to ensure safety, stability, security, and long-term sustainability of outer space activities.
- International binding agreement for the management of debris and space traffic needs to be negotiated as space is common good. International harmonization of space traffic would be required for an efficient and interference free use of space.
- High-accuracy assessment and prediction tools are essential for reducing risk to current systems and future launches.
- Space Debris Monitoring & Space Traffic Management (ISRO's NETRA Project).
- Space traffic management is a crucial area that requires attention since satellites in orbit can come in the way of each other.
- Space Debris management & monitoring play a crucial role as space participation intensifies.
- Space debris monitoring removal has an estimated market revenue of around 2.7 billion dollars in 2020s.
- Space junk is no one countries' responsibility, but the responsibility of every spacefaring country.
- Problem of managing space debris is both an international challenge & opportunity to preserve space environment for future space exploration.

►SCRAMJET TECHNOLOGY

Hypersonic air-breathing scramjet technology was successfully demonstrated by DRDO with a flight test of hypersonic technology demonstrator vehicle (HSTDV), which will lead to development of hypersonic cruise missiles and vehicles in future.

- In aerodynamics, a hypersonic speed is one that greatly exceeds speed of sound, often stated as starting at speeds of Mach 5 and above.
- HSTDV is an unmanned scramjet demonstration aircraft for hypersonic speed flight. It is being developed as a carrier vehicle for hypersonic and long-range cruise missiles.
- It will have multiple civilian applications including launching of small satellites at low cost. HSTDV program is run by DRDO.
- **WHAT IS SCRAMJET ENGINE?**



- Scramjets are a variant of a category of jet engines called air breathing engines. Ability of engines to handle airflows in multiples of speed of sound, gives it a capability of operating at those speeds.
- A ramjet operates by combustion of fuel in a stream of air compressed by the forward speed of the aircraft itself, as opposed to a normal jet engine, in which the compressor section (the fan blades) compresses the air. The air flow through a ramjet engine is subsonic,

or less than the speed of sound. Ramjet-propelled vehicles operate from about Mach 3 to Mach 6.

- A scramjet (supersonic-combustion ramjet) is a ramjet engine in which the airflow through the engine remains supersonic, or greater than the speed of sound. Scramjet powered vehicles are envisioned to operate at speeds up to at least Mach 15.
- Advantages of scramjet engine
  - Does not have to carry oxygen tank.
  - No rotating parts makes it easier to manufacture.
  - Less weight and simple design.
  - As hydrogen is used as a propellant and combustion is carried out at supersonic velocity with the help of oxygen from the atmosphere.
  - Steam (H2O) is being exhaust gas which is eco-friendly in nature.

NEED OF SCRAMJET ENGINES

Presently, satellites are launched into orbit by multi-staged satellite launch vehicles that can be used only once (expendable). These launch vehicles carry oxidizer along with the fuel for combustion to produce thrust. Nearly 70% of the propellant (fuel-oxidizer combination) carried by launch vehicles consists of oxidizers. Launch vehicles designed for one-time use are expensive and their efficiency is low because they can carry only 2-4% of their lift-off mass to orbit. Thus, there is a worldwide effort to reduce the launch cost.

- Next generation launch vehicles must use a propulsion system which can utilize atmospheric oxygen during their flight through atmosphere which will considerably reduce total propellant required to place a satellite in orbit.
- Ramjet & Scramjet and are concepts of air-breathing engines, being developed by various space agencies.

ABOUT RAMJET AND SCRAMJET ENGINE

1. Ramjet

- A ramjet is a form of air-breathing jet engine that uses vehicle's forward motion to compress incoming air for combustion without a rotating compressor. Fuel is injected in combustion chamber where it mixes with hot compressed air and ignites.
- A ramjet-powered vehicle requires assisted take-off like a rocket assist to accelerate it to a speed where it begins to produce thrust.
- Ramjets work most efficiently at supersonic speeds around Mach 3 (three times the speed of sound) and can operate up to speeds of Mach 6. However, the ramjet efficiency starts to drop when the vehicle reaches hypersonic speeds.

2. Scramjet

- A scramjet engine is an improvement over ramjet engine.
- Scramjet draws oxygen from air when rocket travels through atmosphere. Though, ordinary rockets also draw oxygen from air, but they use compressor to draw in air, compress and ignite to burn fuel.
- Scramjet's heating and compression is done by movement of rocket itself as it is moving at supersonic speed. Thus, it is known as Supersonic Combustion Ramjet, or Scramjet.

WHAT ARE HYPERSONIC MISSILES?

- Hypersonic Weapons are much harder to track & intercept than traditional projectiles because they can travel more than five times speed of sound and maneuver in mid-flight.

HYPERSONIC TECHNOLOGY

- Speed: 5 or more times the Mach or speed of sound.
- Mach Number: It describes an aircraft's speed compared with the speed of sound in air, with Mach 1 equating to the speed of sound i.e., 343 m per second.
- Technology Used: Most hypersonic vehicles primarily use the scramjet technology, which is a type of Air Breathing propulsion System. This is extremely complex technology, which also needs to be able to handle high temperatures, making the hypersonic systems extremely costly.

TYPES

- Hypersonic cruise missiles: These are the ones that use rocket or jet propellant through their flight and are regarded as being just faster versions of existing cruise missiles.
- Hypersonic Glide Vehicle (HGV): These missiles first go up into the atmosphere on a conventional rocket before being launched towards their target.

IMPORTANT HYPERSONIC MISSILES

Only USA, Russia and China have hypersonic missiles

AVANGARD

- Russia's nuclear capable, hypersonic boost glide vehicle.
- Capable of hitting target more than 6000 km
- Can travel at a speed of 20 Mach (20 times the speed of sound).

KINZHAL

- Russia's nuclear capable air launched ballistic missile.
- It has a range of more than 2000 km.
- Can travel at speeds of 10 Mach.

STARRY SKY 2 HYPERSONIC AIRCRAFT

China's first hypersonic aircraft with waverider technology. Known as waverider for its ability to ride on the shock waves it generates.

DONGFENG MISSILES BY CHINA

HYPERSONIC TECHNOLOGY IN INDIA

- India, too, is working on hypersonic technologies.
- As far as space assets are concerned, India has already proved its capabilities through the test of ASAT under Mission Shakti.
  - Hypersonic technology has been developed and tested by both DRDO and ISRO.
  - Recently, DRDO has successfully flight-tested the Hypersonic Technology Demonstrator Vehicle (HSTDV), with a capability to travel at 6 times the speed of sound.
  - Also, a Hypersonic Wind Tunnel (HWT) test facility of DRDO was inaugurated in Hyderabad. It is a pressure vacuum-driven, enclosed free jet facility that simulates Mach 5 to 12.

SIGNIFICANCE

- They are a mix of the speed of a ballistic missile and maneuvering capabilities of a cruise missile
- While cruise missiles achieve speeds of 550 mile per hour, the hypersonic missiles aircrafts can reach speeds more than 3500 miles per hour.
- Capable of penetrating any antimissile defence system currently available that are designed to intercept cruise and ballistic missiles.
- Specifically designed for increased survivability against modern ballistic missile defence systems.

SUGGESTIONS FOR INDIA

- India should focus on developing indigenous capacity to develop hypersonic weapons. Hypersonic capacity will increase the credibility of India's nuclear deterrence.
- India's missile defence system should be upgraded to respond to the threat of hypersonic weapons.
- Technology transfer and partnerships should be undertaken with friendly countries to get hypersonic technology for India.

►IN-SPACE & NSIL

- IN-SPACE aims to boost private sector participation in entire range of space activities. Such reforms will lead to accelerated growth of space sector and will enable Indian Industry to be an important player in global space economy.
- With this, there is an opportunity for large-scale employment in the technology sector and India becoming a Global technology powerhouse.

INDIAN NATIONAL SPACE PROMOTION AND AUTHORIZATION CENTRE (IN-SPACe)

- IN-SPACe will provide a level playing field for private companies to use Indian space infrastructure.
- Handhold, promote and guide private industries in space activities through encouraging policies and a friendly regulatory environment.
- IN-SPACe is an independent nodal agency under Department of Space (DOS) for allowing space activities and usage of DOS owned facilities by non-government private entities (NGPEs) as well as to prioritize the launch manifest.

IN-SPACe is to be established as a single window nodal agency, with its own cadre, which will permit and oversee the following activities of NGPEs.

a. Space activities including building of launch vehicles and satellites and providing space-based services as per the definition of space activities.

b. Sharing of space infrastructure and premises under the control of ISRO with due considerations to on-going activities.

c. Establishment of temporary facilities within premises under ISRO control based on safety norms and feasibility assessment

d. Establishment of new space infrastructure and facilities, by NGPEs, in pursuance of space activities based on safety norms and other statutory guidelines and necessary clearances.

e. Initiation of launch campaign and launch, based on readiness of launch vehicle and spacecraft systems, ground and user segment.

f. Building, operation, and control of spacecraft for registration as Indian Satellite by NGPEs and all the associated infrastructure for the same.

g. Usage of spacecraft data and rolling out of space-based services and all the associated infrastructure for the same.

NEW SPACE INDIA LIMITED (NSIL)

- Public Sector Enterprise 'New Space India Limited (NSIL)' will endeavor to re-orient space activities from a 'supply driven' model to a 'demand driven' model, thereby ensuring optimum utilization of our space assets.
- NSIL is a CPSE under Department of Space and has been incorporated as a wholly owned Government of India company under DOS and is commercial arm of ISRO.
- These reforms will allow ISRO to focus more on research & development activities, new technologies, exploration missions and human spaceflight program.
- Some planetary exploration missions will be opened to private sector through an 'announcement of opportunity' mechanism.

NSIL MANDATE

- Owning satellites for Earth Observation and Communication applications and providing space-based services
- Building satellites and launching them as per demand • Providing Launch Services for satellite belonging to customer
- Building launch vehicles through Indian Industry and launch as per satellite customer requirement
- Space based Services related to Earth Observation and Communication satellites on commercial basis
- Satellite building through Indian Industry
- Technology Transfer to Indian Industry.

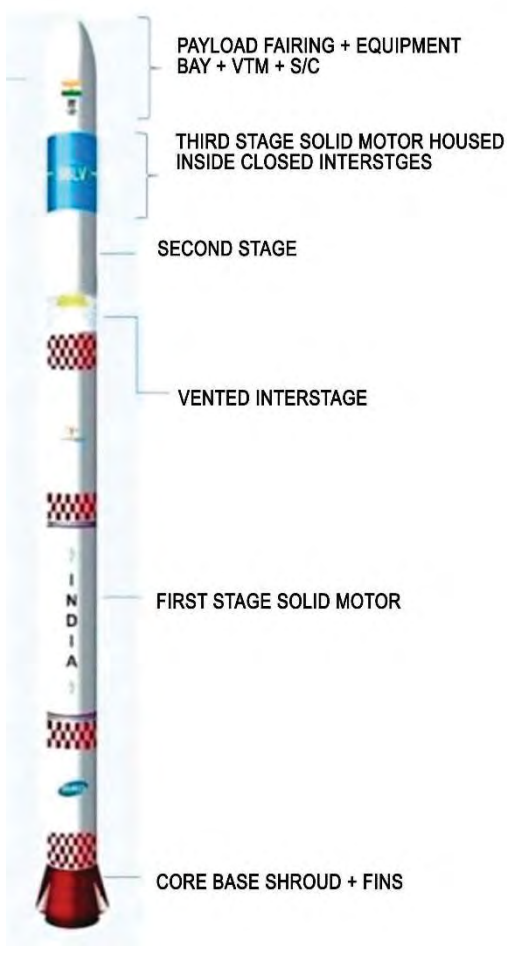
►SMALL SATELLITE LAUNCH VEHICLE (SSLV)

Developed by ISRO to cater to emerging global small satellite launch service market. It is designed to meet 'Launch on Demand' requirements in a cost-effective manner.

Manufacturing of SSLV will be through Indian industry partners led by New Space India Limited, ISRO's commercial arm.

IT WOULD HELP IN

- Reduced Turn-around time
- Launch of Demand i.e., it can be launched on a short time based on the demand for launch services.
- Cost optimization for realization and operation
- Flexibility in accommodating multiple satellites (Ride Sharing)
- Minimum launch infrastructure requirements
- Heritage of proven design practices.



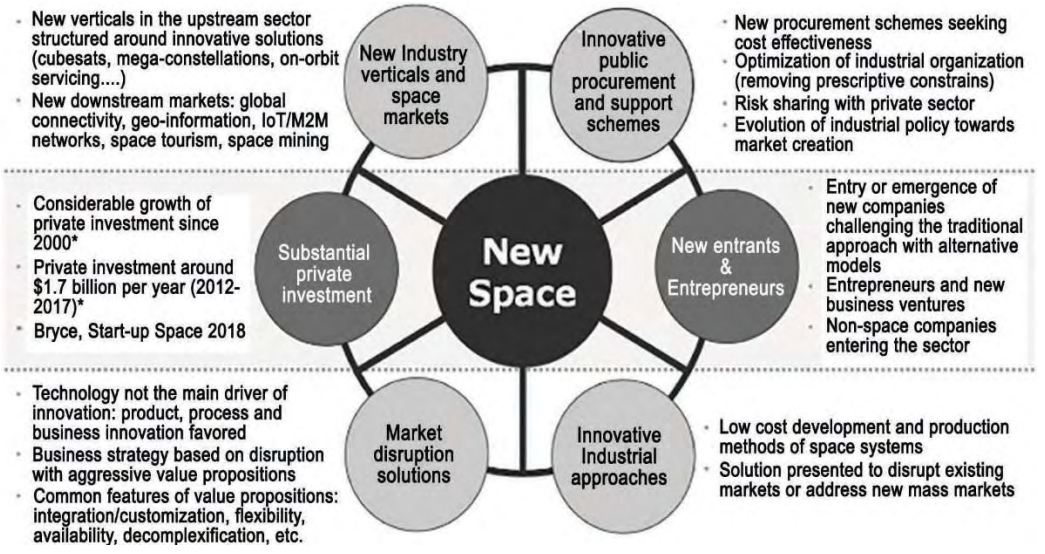
►COMMERCIALISATION OF SPACE SECTOR

Collaboration between NASA and SpaceX is amazing. With its reusable rockets, large capsules to carry payloads and crew and competitive pricing, SpaceX has revolutionised the space sector.

- Collaboration between NASA & SpaceX is remarkable because it has taken American space program to a level that had not been possible for NASA to achieve by itself. Having their own rockets to transport astronauts to International Space Station and back has prevented Americans from spending hugely on the mission, as they were doing earlier. This was possible only because of NASA's active collaboration with SpaceX. Thus, opening of space sector could have many such advancements in store.

- Space tourism could become more common as space travel becomes less expensive. Companies such as Virgin Galactic, Blue Origin & SpaceX offer space flights, however for a very high fee.

- In India too, government has started to cede its control over the space industry, starting from hiring of vendors and active outsourcing of rocket components to the present idea of allowing external agencies to use ISRO facilities.



NEED FOR PRIVATE SECTOR IN SPACE INDUSTRY

1. Increasing Demand: ISRO's annual budget has crossed Rs. 10,000 crore and will grow annually. However, demand for space- based services in India is far greater than what ISRO can provide. Therefore, private sector investment will provide the additional boost in the sector. It will also increase entrepreneurship in the space sector after recent decision of central government on opening the sector for private participation.
2. Overall growth of space sector: Private sector participation is needed to ensure overall growth of space sector. ISRO has a strong association with the industry, particularly with Public Sector Undertakings (PSUs) like Hindustan Aeronautics Limited and large private sector entities like Larsen and Toubro. But most private sector players are Tier-2/Tier-3 vendors, providing components and services. Assembly, Integration and Testing (AIT) role is restricted to ISRO. Role of private industries should be deepened.
3. Very less global contribution: Global space industry is estimated to be $350 billion and is likely to exceed $550 billion by 2025. Despite ISRO's capabilities, India's share is estimated at $7 billion (just 2% of global market). Private sector role is must to increase India's contributions globally.
4. International trends and experience: Elon Musk's "SpaceX" and its high-profile projects have highlighted the increasing significance of the private players in the space sector. In India, despite the various strategic, security and regulatory constraints, a limited private ecosystem has evolved around the ISRO. Private are merely contracting with national space agencies to build satellites and subsystems. Contrarily, the current trend is developing entire vertically integrated operations without licensing or purchase agreements with national agencies.

BENEFITS OF PRIVATE SECTOR'S IN SPACE INDUSTRY

1. Greater pool of resources - Public resources (land, labour, capital) are limited. Private sector participation will open new pool of resources and talent. It will bring more funding, and experience into space exploration activities.
2. Human Capital: Restricting space activities to ISRO, limits proper utilization of talent of the country. With demographic dividend, private sector participation can exploit the human resources contributing to space explorations in India.
3. More time for ISRO: Today every space mission is done by ISRO, whether its communication satellite or any weather monitoring satellite. With increased role of private player, ISRO can concentrate more on its path breaking innovations like Reusable PSLVs, Cryogenic rockets, mars inhabitation.
4. Technological advancement– Commercialization will develop better technologies. It will allow integration of other technologies like artificial intelligence into space exploration activities. With experience from space activities, private sector can increase role of technology in other areas. Ex. Startups in India are

developing alternative fuels without hydrazine to make space travel eco-friendly.

5. Risk Sharing- Every launch consists of Risk. Privatizing helps in sharing the risk of cost factor. Failure costs will be distributed. Also with increased private participation, failures will reduce due to increased available human capital and mind. Joint venture brings the knowledge from various stakeholders minimizes failures and increases productivity.
6. Commercial demand- There is need to enhance internet connectivity for the masses, which is another demand-pull factor for increased commercial interest in space. Asteroid mining is also another potential area that looks promising, with scope for monetization and disrupting commodity markets.

CONCERNS OF PRIVATE SECTOR IN SPACE INDUSTRY

1. Data Risk– Though space it gives an opportunity to entrepreneurs but raw data of ISRO in the hands of public is sensitive and consists of danger of misuse or improper utilization of data.
2. Regulation- Though it is a profitable investment, regulation of private sector participation is not easy. The time taken for regulatory clearances and unstable political institutions can cause delays and hurdle in decision making of investors.
3. Revenue loss– ISRO will lose a fair amount of money it is earning through its space activities. This will reduce government revenue.
4. Unfair commercial practices– Allowing private sector may lead to lobbying and unfair means to get space projects or launch of any satellite for their own profit. It may also lead to leakage of sensitive information by private players to other countries and companies to make profit.

SOME RECOMMENDATIONS

1. A facilitating foundation: There needs to be a neutral facilitating foundation without any self-interest.
2. Demarcating space & defence: Issues around national security will always be a concern with privatizing space activities. However, this will only hold back the country in expanding products/services. This may also lead to an ecosystem of Indian space entrepreneurs creating holding companies in space commerce friendly countries and operating their product/service, eventually creating loss of high-technology jobs and tax revenues for the country. The recent decision of government to open space sector will help in private players participation.
3. Promoting start-ups: Boost start-ups by private players and will encourage young scientists to take future steps in this regard. A dedicated fund vehicle can be set up which would disburse money based on a national prize event, like Google's XPRIZE, with industry leaders being the primary promoters (with the backing of ISRO) and bringing potential investors and stakeholders on the same table to promote innovation and entrepreneurship in this sector.
4. ISRO and Antrix providing mentorship: Emergence of Bengaluru as an IT and aerospace hub should be leveraged for space industry. Dedicated infrastructure to enable technology development should be allocated to space ventures emerging from India to assist them in the start-up stage.
5. Mentorship by senior ISRO and Antrix executives will ensure they operate within the Indian space policy framework but are still able to leverage technical expertise built by ISRO in an appropriate manner.
6. Space laws: The enactment of space legislations to define regulatory, legal, and procedural regimes with transparent timelines for pursuing space activities by the private space industry is currently at a nascent stage. Space Activities Bill needs to be enacted.
7. Manufacturing in space sector: The government has taken significant steps in the creation of an active investor mindset by rolling out programs like 'Make in India.' But no significant proposals have been mooted for manufacturing space-related systems in India. So, there is a need for a transparent strategy on how the potential of the space sector can be leveraged under this program.
8. Establishing space focused think-tanks: Need to establish an independent, wholly space-activities-focused think-tank like European Space Policy Institute, with experts in space while preserving its independence. Such a think-tank will provide a fair assessment of national goals, key insights on space program management, dual use of technologies, economic impacts of space expenditures, space law, international cooperative space agreements etc.
9. Setting up industry-academia linkups in Space research.

►IRNSS

Indian Regional Navigation Satellite System (IRNSS) is a completely home-grown solution of ISRO which enables navigation in Indian Ocean region using a combination of GEO and GSO satellites. It is also known as NAVIC.

NAVIC system has been designed to provide localisation fixes (Resolution of 20m or better) over Indian sub-continent.

Its information is available in two forms:

1) Standard Positioning Service (SPS): For civilian users
2) Restricted Service (RS): It's location feed is much more precise; however, can be used by only authorised users.

APPLICATIONS

a) Satellite based navigation systems technology advancement in design of application specific integrated circuit (ASIC) has resulted in development of cheap, low power, ground based receivers and their associated circuitry.

b) Considerable miniaturisation of hardware has allowed deployment of these devices in small form-factor, portable devices which enable distributed, on-the-go localisation.

c) This information has a lot of business potential, thus the development of an indigenous system, dovetails well with Make in India, Start-up India, Smart Cities and 'Digital India program.

d) Some use cases:

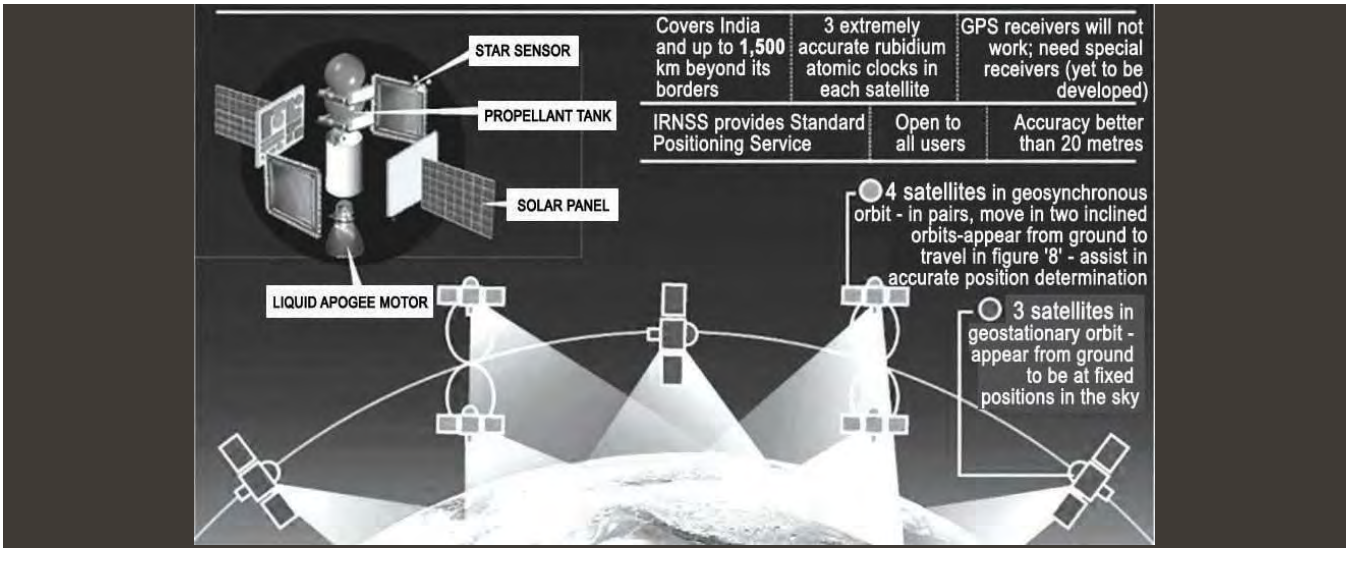
i) Railways: Wagon tracking

ii) Vehicle tracking system for State Transport buses, all public service vehicles.

iii) Tracking of fishing vessels

iv) Tracking and geo-fencing of mechanised vehicles in service.

v) Disaster management.



►ANTI-SATELLITE MISSILE TEST (MISSION SHAKTI)

India has carried out a successful test of an Anti-Satellite (ASAT) weapon, launching an interceptor missile from the Balasore range in Odisha to hit a live satellite in Low Earth Orbit. It thus became the fourth country in the world to develop an ASAT capability.

The satellite used in the mission was one of India's existing satellites operating in lower orbit.

India joins an exclusive group of space faring nations consisting of USA, Russia and China.

OBJECTIVE OF THIS MISSION

- The technology is aimed at destroying, if necessary, satellites owned by enemy countries
- Satellites are extremely critical infrastructure of any country these days. Many crucial applications are now satellite-based. These include navigation systems, communication networks, broadcasting, banking systems, stock markets, weather forecasting, disaster management, land and ocean mapping and monitoring tools, and military applications.
- Destroying a satellite would render these applications useless. It can cripple enemy infrastructure, and bring it down on knees, without causing any threat to human lives.

RATIONAL FOR THE TEST

- India has a long & rapidly growing space program.
- Expanded rapidly in last five years. Mangalyaan Mission to Mars was successfully launched. Thereafter, government has sanctioned Gaganyaan Mission which will take Indians to outer space.

- India has undertaken 102 spacecraft missions consisting of communication satellites, earth observation satellites, experimental satellites, navigation satellites, apart from satellites meant for scientific research and exploration, academic studies and other small satellites. India's space program is a critical backbone of India's security, economic and social infrastructure.
- The test was done to verify that India has the capability to safeguard our space assets. It is the Government of India's responsibility to defend the country's interests in outer space.

This move represents a departure from India's long-standing position on weaponization of outer space. As a major spacefaring nation, India has consistently advocated the peaceful uses of outer space and proactively participated in the negotiation of the Outer Space Treaty of 1967, which clearly provides for the demilitarization of outer space. Recently, in a 2018 session of the United Nations Commission for Disarmament, India reiterated its opposition to the "weaponization of outer space and [that it would] support collective efforts to strengthen the safety and security of space-based assets."

IS IT AGAINST OUTER SPACE TREATY?

- India is a party to all the major international treaties relating to Outer Space. India already implements a number of Transparency and Confidence Building Measures(TCBMs) – including registering space objects with the UN register, prelaunch notifications, measures in harmony with the UN Space Mitigation Guidelines, participation in Inter Agency Space Debris Coordination (IADC) activities with regard to space debris management, undertaking SOPA (Space Object Proximity Awareness and COLA (Collision Avoidance) Analysis and numerous international cooperation activities, including hosting the UN affiliated Centre for Space and Science Technology Education in Asia and Pacific. India has been participating in all sessions of the UN Committee on the Peaceful Uses of Outer Space.
- India supported UNGA resolution 69/32 on No First Placement of Weapons on Outer Space. We see the No First Placement of weapons in outer space as only an interim step and not a substitute for concluding substantive legal measures to ensure the prevention of an arms race in outer space, which should continue to be a priority for the international community.
- India supports the substantive consideration of the issue of Prevention of an Arms Race in Outer Space (PAROS) in the Conference on Disarmament where it has been on the agenda since 1982.

►GEOSPATIAL DATA

Ministry of Science and Technology has released new guidelines for Geo-spatial sector in India, which deregulates existing protocol and liberalises the sector to a more competitive field. The sector will be deregulated and aspects such as prior approvals for surveying, mapping and building applications based on that have been done away with. For Indian entities, there will be complete deregulation with no prior approvals, security clearances and licences for the acquisition and production of geospatial data and geospatial data services, including maps.

- Geospatial Data (also known as "spatial data") is used to describe data that represents features or objects on the Earth's surface. Whether it is man-made or natural, if it has to do with a specific location on the globe, then it is geospatial.
- There are many ways geospatial data can be used and represented. Most commonly, it is used within a GIS (Geographic Information System) to understand spatial relationships and to create maps describing these relationships. A GIS can also help you regulate, customize, and analyse geospatial data.

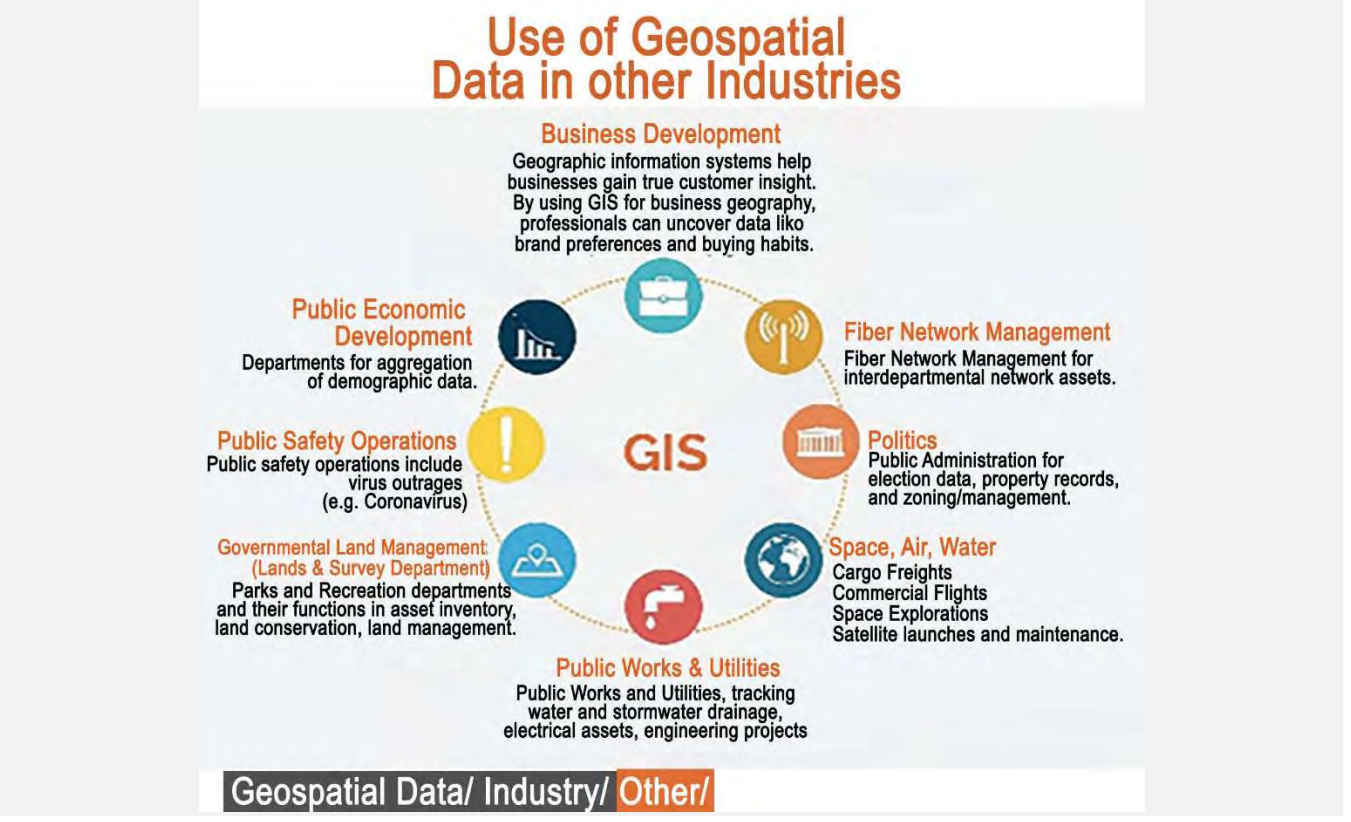
SOME EXAMPLES OF GEOSPATIAL DATA INCLUDE

- Vectors and Attributes: Points, lines, polygons, and other descriptive information about any location can be known via vectors and attributes.
- Point Clouds: Collected by LiDAR systems, they can be used to create 3D models of areas and localities.
- Raster and Satellite Imagery: This helps in getting a bird's eye view of what the Earth looks like via high-resolution imagery.

- Mapping data useful for private companies
  - Geospatial data is foundational and will play a vital role in every manner of planning, governance, services, infrastructure, and applications.
  - This mapping data will be helpful for private companies who are seeking maps and data that suit their specific purposes. Ex., local delivery of products and services requires highly specific details of a locality within a town. This, in turn, could lay groundwork for future smart city projects.

Advantage of privatization of geospatial data in India:
This data will help drive efficiencies in the agriculture

sector. While facilitating the rise of new-age industries, increased participation of the private sector will increase the growth of new technologies, platforms, and applications of geospatial data which will directly contribute to the country's progress.



►DRONE RULES, 2021

1. Unmanned Aircraft Systems, commonly known as drones, offers benefits to almost all sectors of economy, agriculture, mining, infrastructure, surveillance, emergency response, transportation, geo-spatial mapping, defence & law enforcement etc.
2. Drones can be significant creators of employment and economic growth due to their reach, versatility, and ease of use, especially in India's remote and inaccessible areas.
3. In view of its traditional strengths in innovation, information technology, frugal engineering and huge domestic demand, India has potential to be global drone hub by 2030
4. Earlier, Drone rules published by Ministry of Civil Aviation were perceived to be restrictive in nature as they involved paperwork, red-tapism, required permissions for every drone flight and very few 'free to fly' green zones. These rules have been replaced with the present rules.

SALIENT FEATURES

1. Built on a premise of trust, self-certification and non-intrusive monitoring.
2. Several approvals abolished: unique authorization number, unique prototype identification number, certificate of manufacturing and airworthiness, certificate of conformance, certificate of maintenance, import clearance, acceptance of existing drones, operator permit, authorisation of R&D organisation, student remote pilot licence, remote pilot instructor authorisation, drone port authorisation etc.
3. Digital sky platform shall be developed as a user-friendly single window system. There will be minimal human interface and
4. Interactive airspace map with green, yellow and red zones shall be displayed on the digital sky platform. No permission required for operating in green zones.
6. Green zone means airspace up to a vertical distance of 400 feet or 120 metre that has not been designated as a red zone or yellow zone in airspace map; and the airspace up to a vertical distance of 200 feet or 60 metre above the area located between a lateral distance of 8 and 12 kilometre from the perimeter of an operational airport.
7. No restriction on foreign ownership in Indian drone companies.

8. Import of drones to be regulated by DGFT.
9. Coverage of drones increased from 300 kg to 500 kg. This will cover drone taxis also.
10. Pilot Training: DGCA shall prescribe drone training requirements, oversee drone schools and provide pilot licenses online.
11. These rules apply to all persons owning or possessing and in the entire ecosystem of drones and all drones operational in India.
12. Drones with weight less than 500 kg will be covered under these rules. While drones with more than 500 kg are regulated under Aircraft Rules, 1937. These rules do not apply to drones used by the army, navy and air force.
13. Classification of Drones: Drones are classified according to the weight including payload as under:
    - Nano drone: Less than 250 gm
    - Micro drone: Between 250 gm and 2 kg
    - Small drone: Between 2 kg and 25 kg
    - Medium drone: Between 25 kg to 150 kg
    - Large drone: More than 150 kg
14. All drones operational in India should necessarily have a unique identification number
15. Airspace Map: Central Government will publish an airspace map for drone operations segregating the entire airspace of India into red, yellow and green zones.

APPLICATIONS OF DRONES

1. In Meteorology: Drones can be deployed to gather atmospheric data. Currently, weather related data is gathered using atmospheric balloons which have radiosondes. However, weather balloons and radiosondes are unretrievable as they drift afar from weather stations that release them in the atmosphere.
2. In Defence: For reconnaissance, intelligence gathering border management, attack weapons.
3. In Economy: Driverless delivery, civil and commercial aviation, land survey, field survey etc.
4. For healthcare: Delivery of vaccines to remote locations.
5. In Environment: Monitoring of forest fires, wildlife range, forest monitoring, check poaching and illegal activities in jungles etc.
6. Disaster management: Post disaster relief and survey, providing of emergency services etc.
7. Entertainment: Cinematography, videorecording, hobbies etc.

►DRONES IN AGRICULTURE

APPLICATION OF AGRICULTURE

- Widespread seed planting
- Spraying of fertilisers
- Crop health monitoring
- Soil Assessment & Irrigation planning: Sensors can identify which parts of a field are dry or need improvement.
- Damage assessment for agri-insurance
- Yield estimation: Near infrared sensors can monitor photosynthesis.
- Accurate Mapping of fields and pastures
- Livestock management

DRONES FOR SPRAYING IN AGRICULTURE

Challenges in conventional methods:

- Extra chemicals use
- Farm labor shortage
- Lower spray uniformity
- Environmental pollution
- Less area coverage
- Higher cost of pesticide application
- Less effective in controlling pests and diseases

Benefits of using drones in Agriculture for spraying

- No direct contact with spraying chemicals
- High field capacity and efficiency (20-40 ha per day)
- Wastage reduction: 30% saving of pesticides
- Water saving: 90% water saving with ultra-low volume spraying
- Lower cost of spraying
- Easy to use and maintain
- Promotes local entrepreneurship
- Digital farming - attractive farming

GOVERNMENT INITIATIVES

- PLI Scheme for Drones, 2021
- Drone Rule, 2021
- Digital sky platform
- Agriculture drone finance schemes for micro-entrepreneurs
- SOP and Guidelines for Drones for Agrochemical Spraying and Soil Nutrients

CHALLENGES OF USING DRONES IN AGRICULTURE

- Flight time & range
- Life cycle of battery
- High initial cost of drones
- Drone training institutes not available
- Lack of availability of certified drone pilots
- Land holding, high tension electric lines, trees
- Certified formulations, chemicals and nutrients
- Connectivity (interruptions)
- Performance weather dependent and weather highly variable, windy & rainy conditions restricts drone flying
- Knowledge and skills: Requires specialised skills and knowledge
- Legislative and regulatory issues:
  - Lack of knowledge to drone operators
  - Dynamically changing
  - Permissions

WAY FORWARD

- Adoption:
  - Demonstrations: Weekly demos by KVKs, CHCs with dashboard for tracking
  - Digital tools: Sensitization videos, crop spraying recipes, SOPs in multiple languages
- Affordability:
  - Subsidy implementation: Rollout procedure not clear at state level, needs central level handholding & tracking
  - Financing issues: Banks not recognizing drones under Agri Infrastructure Fund, needs sensitization.
- Accessibility: Not discoverable: Enable farmers to find nearest Kisan drone manufacturer, training centers, operator and list all of them on Farms Apps.

►JAMES WEBB TELESCOPE

European Ariane 5 rocket launched NASA's James Webb Space Telescope (JWST), the biggest and most powerful space telescope yet constructed, from French Guiana, on the northeast coast of South America.

FEATURES OF JAMES WEBB TELESCOPE

- Successor of Hubble Telescope.
- Most powerful infrared telescope of NASA.
- A product of collaboration among NASA, European Space Agency (ESA) and Canadian Space Agency.
- It is expected to reveal new and unexpected discoveries, and help humanity understand origins of universe. Webb will gaze into epoch when very first stars and galaxies formed, over 13.5 billion years ago.
- Designed to explore a period known as Epoch of Reionization, which came after dark ages that followed big bang. During dark ages, universe was cast in a gaseous fog of neutral hydrogen & helium, making it opaque to some types of light. As first luminous objects formed and evolved, high-energy light they emitted ionized gas through which it propagated, making it more transparent.
- Study atmospheres of a wide diversity of exoplanets.
- Search for atmospheres like Earth's, and for signatures of key substances such as methane, water, oxygen, carbon dioxide, complex organic molecules, in hopes of finding the building blocks of life.

GOALS OF JAMES WEBB SPACE TELESCOPE

- Search for first galaxies that formed after Big Bang.
- Determine how galaxies evolved from their earlier formation until now.
- Observe formation of stars from first stages to formation of planetary systems.
- Measure physical & chemical properties of planetary systems; investigate potential for life in such systems.

REASONS FOR INFRARED WAVELENGTH

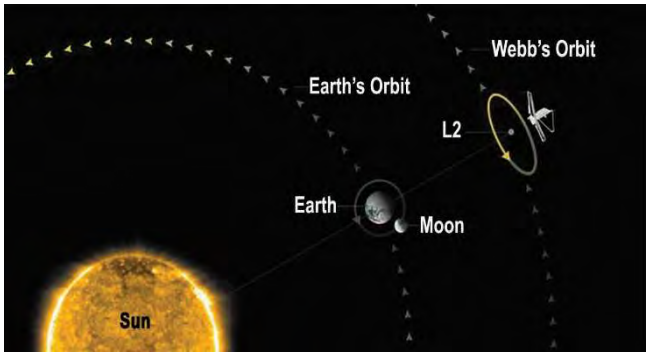
- Can see beyond dust clouds: Unlike short, tight wavelengths of visible light**,** longer wavelengths of infrared light slip past dust more easily**.** Thus, universe of star and planet formation 'hidden' behind clouds of dust comes into clear view for Webb's infrared instruments.
- Allows study of early universe: Through a process called cosmological red shifting, light is stretched as universe expands, so light from stars that is emitted in shorter ultraviolet and visible wavelengths in stretched to the longer wavelengths of infrared light.

ORBIT OF JAMES WEB SPACE TELESCOPE:

- Placed in second Lagrange Point (L2). Webb's orbit is a halo orbit around L2 locations.
- Webb's orbit follows a special path around L2 that allows it to stay on Earth's night side (directly 'behind' the Earth as viewed from Sun) and track along with Earth while moving around the Sun.
- As an infrared observatory, Webb must be protected from all bright, hot sources to see faint heat signals of distant objects in universe. Because Webb will always stay on Earth's night side as it moves around Sun, its orbit ensures that one side of its sunshield will

continuously face Sun, Earth and Moon to block their view from the telescope's optics.

- Webb will always be at same general location relative to Earth, allowing it to stay in contact through NASA's Deep Space Network.
- The location will allow to be perpetually bathed in sunlight to generate power via the solar array while providing an unobstructed view of deep space.
- Webb can only point to roughly half the sky at any given moment. However, as Webb rotates around the sun, Webb can access entire sky over a year.
- About Lagrange Points: There are 5 Lagrange Points in the Sun-Earth Systems. These are positions in space where the gravity of the Sun and Earth balances the centripetal force required for a spacecraft to move with them. This makes Lagrange points useful for reducing the amount of fuel it takes for a spacecraft to remain in orbit.



ENGINEERING MARVEL

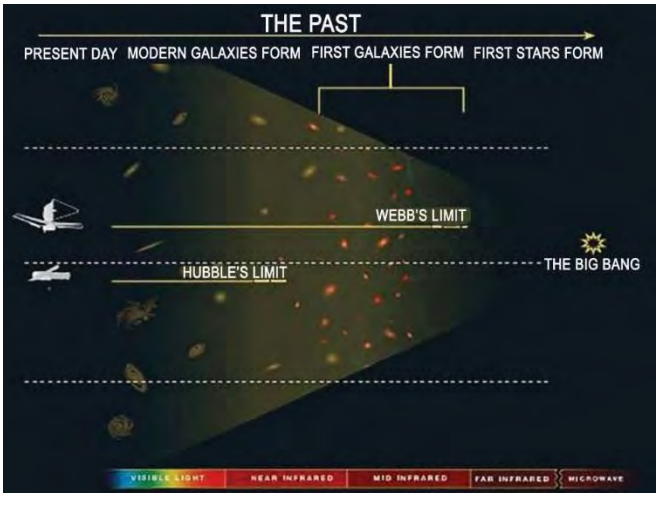
- While looking away from Sun, JWST features one huge mirror with a diameter of 21 feet (height of a standard two-story structure) that will collect infrared light flowing in from the deep space.
- It will be protected by a five-layer, tennis court-sized, kite-shaped sunscreen that will block the sun's heat and maintain the exceptionally cold temperatures that the sensors are meant to work at.
- Temperatures on sun-facing side may reach 110°C, while temperature on opposite side is kept at –200° to –230°C.
- To detect exceedingly weak heat signals from faraway galaxies, extremely low temperatures are required.
- The mirror, as well as sunscreen, are much too huge to fit inside any rocket. They were designed to be collapsible and would be unfolded in space.

HUBBLE TELESCOPE

- It was launched into low Earth orbit in 1990.
- Hubble Space Telescope has made more than 1.4 million observations, including tracking interstellar objects, capturing a comet colliding with Jupiter, and discovering moons around Pluto.
- Hubble has captured galaxies merging, probed supermassive black holes and has helped us understand the history of our universe.

WEBB VS HUBBLE TELESCOPE

Wavelength	• JWST will observe primarily in infrared range and provide coverage from 0.6 to 28 microns. • Hubble sees mainly in ultraviolet and visible part of spectrum. It could observe only a small range in infrared from 0.8 to 2.5 microns. • Infrared region of electromagnetic spectrum covers wavelength range from approximately 0.7 to 100 microns.
Size	• Webb's primary mirror has a diameter of 6.5 metres while Hubble's mirror was much smaller 2.4 metres in diameter. • Webb will have a larger field of view compared to the camera on Hubble. • Webb also carries a large sun shield.
Distance	• Webb's near & mid-infrared instruments will help study first formed galaxies, exoplanets and birth of stars. • Hubble can see equivalent of "toddler galaxies" while Webb Telescope will be able to see "baby galaxies".



NANOTECHNOLOGY

Previous Year Questions

YEAR	UPSC MAINS QUESTION
2019	What do you understand by nanotechnology and how is it helping in health sector?

►NANOTECHNOLOGY

Nanotechnology is understanding and control of matter at nanoscale, at dimensions between approximately 1 and 100 nanometres, where unique phenomena enable novel applications. It involves ability to see and to control individual atoms and molecules.

WHAT IS SPECIAL AT NANO SCALE LEVELS

1. Quantum Effects begin to dominate at nanoscale:

- When particle size is made to be nanoscale, properties such as melting point, fluorescence, electrical conductivity, magnetic permeability, and chemical reactivity change as a function of the size of the particle. Ex, at nanoscale gold particles are not in yellow color but appear red or purple.
- Tunability of properties: Result of quantum effects of nanoscale. Scientists can by changing size of the particle can fine-tune a material property of interest.
- Tunnelling: Quantum tunnelling is a micro nanoscopic phenomena in which a particle violates principles of classical mechanics by penetrating barrier higher than kinetic energy of the particle. This principle is used in Scanning Tunnelling Microscope, Resonant tunnelling diodes, which are used as switching units in fast electronic circuits.

2. Far higher surface area per unit mass: As surface area per mass of a material increases, a greater amount of material can encounter reactivity. Ex. A single cubic centimeter of nanoparticles has a total surface area of one-third larger than a football field.
3. Majority of biological processes occur at nanoscales. Ex. Strand of DNA is two nanometers in diameter.

APPLICATIONS IN HEALTHCARE

1. Use of Gold nanoparticle as probes for detection of targeted sequences of nucleic acids. They are being clinically investigated as potential treatments for cancer and other diseases.
2. Better imaging & diagnostic tools enabled by nanotechnology are paving way for earlier diagnostics, more individualized treatment options, and better therapeutic success rates.
3. Drug delivery: Nanotechnology is being used to develop a nanoparticle which can encapsulate or help deliver medication directly to cancer cells and minimize risk of damage to healthy tissue. This can change the way cancer is treated today and protect patients from the toxic effects of chemotherapy.
4. Nanotechnology in regenerative medicine: Novel nanomaterials can be engineered to mimic crystal

mineral structure of human bone or used as restorative resin for dental applications.

APPLICATIO IN ELECTRONICS AND IT

Nanotechnology has greatly contributed to major advances in computing and electronics, leading to faster, smaller and more portable systems than can manage and store larger amounts of information. These continuously evolving applications include:

- Transistors, basic switches, that enable all modern computing are smaller through nanotechnology. Transistors as small as one nanometer have been made. Smaller, faster and better transistors have lower power consumption and device portability.
- Magnetic Random-Access Memory (MRAM) allows computers to boot instantly, also. MRAM is enabled by nanometer-scale magnetic tunnel junctions
- Ultra-high-definition televisions use quantum dots to produce more vibrant colors while being more energy efficient.
- Flexible, bendable, foldable, rollable and stretchable electronics are becoming mainstream. They are being integrated into products such as wearables, medical applications, aerospace etc.
- Nanoparticle copper suspensions have been developed as a safer, cheaper and more reliable alternative to lead-based solder and other hazardous materials commonly used to fuse electronics in the assembly process.

APPLICATIONS IN AGRICULTURE

- Nano fertilizers: At nanoscale, plants can better assimilate fertilizers and increase fertilizer use efficiency.
- Nano pesticides:
- Nano sensors: Applications of Nano biosensors in agriculture
  i. Delivery of fertilizers
  ii. Supply of micronutrients
  iii. Nano pesticides
  iv. Nano herbicides
  v. Nano fungicides
  vi. Detection plant viruses, soil health and pathogens
- Nanotechnology for polluted soil remediation: Nanotechnology can play a key role in soil remediation that involves removing soil contaminants and enhancing soil quality and fertility. This can be achieved by high specific area and high reactivity of nanomaterials due to smaller particle size which make nanomaterials easier to deliver into soils. These characteristics increase efficacy of nanomaterials in soil remediation than other traditional materials, especially in situ remediation due to its easier delivery into soils.
- Nano packaging of food products
- Food safety

Health	Nanomedicine; Smart pills; Nanobots: arteries can be unblocked, cells can be selectively attacked A contamination sensor, using a flash of light can reveal the presence of E-coli. Improve solubility of vitamins, antioxidants, healthy omega, etc.
Economy Infrastructure, Agriculture, Manufacturing, Energy, Employment.	• Nanosensors & delivery systems can allow for precision farming through efficient use of natural resources like water, nutrients, chemicals etc. • Liquid Nano Urea is sprayed directly on leaves of plants and gets absorbed by the stomata-pores found on the epidermis of leaves. • Revolutionized electronic manufacturing industry • Reduced size of integrated circuits' transistors • Improved the display screens of the electronic devices. • Reduced power consumption, weight, and thickness of the electronic devices. • Improved efficiency of solar panels. • Improve efficiency of fuel consumption. • Stain and wrinkle resistant cloths
Technological enhancement/ Innovation dispersion	• Development of research ecosystem. • Biofortification through nano-fertilizer. • Additive manufacturing • Better material design • Personalized health care • Precision farming

Environment & Ecology	• Solar panels more efficient and cheaper. • Energy storage is more efficient Nanocapsule can enable effective penetration of herbicides, chemical fertilizers and genes into targeted part of plant. This ensures a slow and constant release of necessary substance to plants with minimized environmental pollution. Potential to detect, identify, filter and neutralize harmful chemical or biological agents in the air, soil and water.
Security	• Better and efficient defence equipment • Nanobots for intelligence gathering
Disaster management	Nano-composites for nuclear shielding and protection

CHALLENGES OF NANOTECHNOLOGY

- Nanotoxicology: Some nanomaterials can display toxic properties towards humans and environment. Toxicity of nanoparticles of certain materials cannot be seen with larger particles of same material. Nanomaterials, even made of inert elements (gold) can become highly active at nanometer dimensions.
- Nanomaterials can bioaccumulate in living organisms and ecology leading to contamination.
- Weaponisation of nanotechnology: Use of nanotechnology in weapons technology. This technology if its falls in the hands of terrorist and insurgent groups can cause much damage.
- Nano pollution: Most nanoparticles are of very small dimensions; they can easily enter food chain and bio-accumulate. They can float into air as PM-10 or PM-2.5 particles. Ultrafine particles which are even smaller than PM 2.5 are of the order of nanoparticles and are a cause of concern.
- Lack of development of standards for nanotechnology. Presently, there are no Rules, Standards and guidelines for development of nanotechnology.

►GUIDELINES FOR NANO-BASED AGRI-INPUT AND FOOD PRODUCTS

Nanotechnology refers to controlling, building and restructuring materials on scale of atoms and molecules. Innovative nano-intervention in agriculture and food sector could generate low-cost, high-efficacy solutions in terms of products and processes.

Nanotech has potential to positively impact the agri-food sector by minimizing adverse problems of agricultural practices on environment and human health.

Hydrogels, nano clays & nano zeolites enhance water-holding capacity of soil, hence facilitating slow release of water.

Nano-sensors can detect plant viruses & soil nutrient levels.

- Minimize leaching, improve the uptake of nutrients by plants, and mitigate eutrophication
- Improving food security and productivity
- Efficient use of agricultural natural resources like water, nutrients and chemicals through precision farming.
- Smart packaging and storage of crops.
- Promoting social and economic equity

IMPORTANCE OF GUIDELINES

Guidelines apply to Nano-Agri-Input Products (NAIPs), Nano-Agri Products (NAPs) and nano composites, not to conventional formulations with incidental presence of natural nanomaterials.

Implementation of standards should be conducted as per BIS with additional criteria for NAIPs and NAPs.

These guidelines are harmonized with applicable provisions for NAIPs and NAPs as per international guidelines of REACH, OECD etc.

CONCERN AREAS

- Phytotoxicity and reactivity of nanomaterials in environment and possible adverse effect on human health is yet to be examined.
- Lack of knowledge and developmental methods for assessment of nanotechnology.
- Absence of regular & systematic classification of nanomaterials creates consumer reluctance for such products.

These guidelines will pave way for significant benefits on 'Doubling Farming Income by 2022' and 'National Mission on Sustainable Agriculture'. FSSAI and Ministry of Agriculture should carefully evaluate the effect of nano-inputs before allowing them.

►NANOTECHNOLOGY IN AGRICULTURE

- Nanofabrication: Can enable study of plant's regulation of hormones such as auxin, which is

responsible for root growth & seedling establishment. Helps understand how plant roots adapt to their environment, especially to marginal soils.

- Crop disease detection Nanotechnology devices and tools like nanocapsules, nanoparticles and viral capsids can be used for the detection and treatment of diseases.
- Nutrient management: enhancement of nutrients absorption by plants, the delivery of active ingredients to specific sites and water treatment processes.
- Pest management: Use of target-specific nanoparticles can reduce damage to non-target plant tissues and amount of chemicals released into environment.
- Farm management: Nanostructures with unique chemical, physical, and mechanical properties like electrochemically active carbon nanotubes, nanofibers and fullerene can be used for soil analysis, easy bio-chemical sensing and control, water management and delivery, pesticide and nutrient delivery.
- Smart Dust technology can be used for monitoring various parameters like temperature, humidity, and perhaps insect and disease infestation to create distributed intelligence in vineyards and orchards.
- Precision farming: There is a need to switch to precision farming in the face of climate change. Nanotechnology holds the key for precision farming.
- Food management: Nanotechnology can aid in smart packaging to monitor freshness properties of food, and check integrity of packages during transport, storage, and display in markets. Eases quality management process.
- Livestock Upkeep**:** Food & nutritional products containing nano-scale additives, nano-sized, multi-purpose sensors to assess physiological status of animals. Nanoparticles may enhance nutrient uptake & help in efficient utilisation of nutrients for milk production.

CONCERNS WITH NANOTECHN IN AGRICULTURE

- Phytotoxicity & reactivity of nanomaterials in environment and possible adverse effect on exposed workers.
- Loss of biodiversity: Reduces important bacterial diversity with declining taxa of Rhizobia, rhizobium response to these nanoparticles' treatment.
- Concerns of Cytotoxic and genotoxic effects of cellular nanomaterials on Nano Agri Products. Risk of nanoparticles toxicity is higher in plants due to their miniscule size that can easily translocate within plant body.
- Insufficient regulatory measures and public opinion in relation to nanotechnology in agricultural sector.
- Lack of knowledge and developmental methods for risk and life-cycle assessment of nanotechnology in agriculture.

►GRAPHENE

- An allotrope of carbon with a sheet like structure.
- A solitary layer (monolayer) of carbon molecules.
- One molecule thick. Slenderest compound known.
- Has the structure square of Graphite.
- Tougher than diamond yet more flexible than rubber, harder than steel yet lighter than aluminum.
- The lightest material known.
- The most grounded compound found (between 100-300 times more grounded than steel).
- The best conductor of heat and electricity.
- Impermeable to gases. Graphene is known for against bacterial properties.
- One of the most encouraging nanomaterials on account of its novel mix of brilliant properties.

PROPERTIES OF GRAPHENE

- Electronic properties: atomic arrangement of carbon in graphene permits electrons to effectively go at high speeds without dissipating energy.
- Mechanical properties are a result of sp2 bonds that structure the hexagonal cross section and go against an assortment of in-plane disfigurements.

USES OF GRAPHENE

- Energy storage and solar cells
- Lubrication
- Graphene ink
- Transistors and memory
- Flexible, stretchable and foldable electronics
- Photodetectors
- Face Mask, etc.

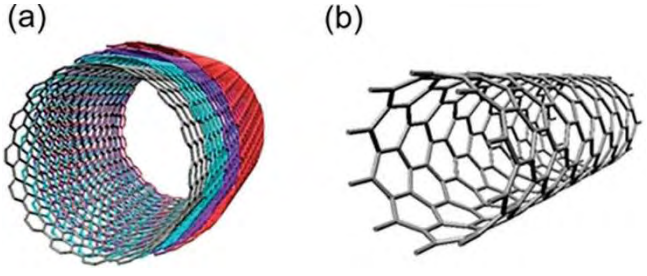
GRAPHENE MASK AND CORONAVIRUSES

- Graphene is known for anti-bacterial properties. It has also shown to be effective in against COVID-19 virus.

- All carbon-containing materials, like cellulose or paper, can be changed over into Graphene.
- Graphene is reusable.

►CARBON NANOTUBES

Carbon nanotubes are cylindrical large molecules consisting of a hexagonal arrangement of hybridized carbon atoms, which may be formed by rolling up a single sheet of Graphene (single-walled carbon nanotubes) or by rolling up multiple sheets of Graphene (multi-walled carbon nanotubes).



PROPERTIES OF CARBON NANOTUBES

1. Strongest and stiffest materials discovered yet in terms of tensile strength and elastic modulus.

2. Very good thermal conductors along the tube, exhibiting a property known as ballistic conduction.

3. High surface area per unit mass ratio.

SINGLE-WALLED VS MULTI-WALLED CARBON NANOTUBES

Single-walled carbon nanotubes	Multi-walled carbon nanotubes
It is a single layer of Graphene.	It has multiple layers of Graphene.
Requires catalyst for synthesis.	Can be produced without catalyst
Bulk synthesis is difficult	Bulk synthesis is easy
More defection during functionalization	Less defection, but difficult to improve
Poor in purity	Purity is high
Less accumulation in the body	More accumulation in the body
It can twist easily	Difficult to twist
Easy characterization and evaluation	Difficult characterization and evaluation.

APPLICATIONS OF CARBON NANOTUBES

1. CNT based transparent electrodes can be developed which are essential components of organic solar cells as well as organic light emitting diodes.
2. Electrodes for Lithium-Ion Batteries
3. Super capacitors
4. Metal/CNT Capacitors
5. Polymer/CNT Composite Capacitors
6. CNT based electronic components such as nanowires, transistors and switches.
7. CNTs are promising candidates for catalysts.
8. Immobilization of bio macromolecules
9. Developing highly sensitive sensors
10. Biomedical applications
11. Mechanical applications

CHALLENGES OF CARBON NANOTUBES

1. Impurities such as residual metal particles in carbon nanotubes.
2. Processing & manufacturing of carbon nanotubes is challenging.

►LIQUID NANO UREA

IFFCO has entered a MoU with PSU fertiliser manufacturers National Fertilisers Limited (NFL) and Rashtriya Chemicals and Fertilisers Ltd (RCF) for 'transfer of technology' aimed at increasing production Liquid Nano Urea.

ABOUT LIQUID NANO UREA

- Developed by IFFCO. India will be first country to start commercial production of Liquid Nano Urea.
- A nanotechnology-based fertilizer. It contains Nano scale nitrogen particles which have more surface area & number of particles, which make it more impactful.

BENEFITS OF NANO UREA

As compared to conventional urea, uptake of Nano Urea is more than 80%. It is thus required in lesser amounts as compared to conventional urea fertiliser to fulfil plant's nitrogen requirement.

- Cheaper than conventional urea
- Reduced input costs to farmer.
- Easy to apply as when Nano urea is sprayed on leaves Nano Urea
- Reduced transportation cost
- Easy to store
- Reduced import of conventional urea saving precious foreign exchange.
- Increased income for farmers.

BIOTECHNOLOGY & HEALTH

Previous Year Questions

YEAR	UPSC MAINS QUESTIONS
2021	What are the research and developmental achievements in applied biotechnology/? How will these achievements help to uplift the poorer sections of the society?
2020	How is science interwoven deeply with our lives? What are the striking changes in agriculture triggered off by science-based technologies?
2020	COVID-19 pandemic has caused unprecedented devastation worldwide. However, technological advancements are being availed readily to win over the crisis. Give an account of how technology was sought to aid management of the pandemic.
2019	How can biotechnology improve the living standards of farmers?
2018	Why is there so much activity in the field of biotechnology in our country? How has this activity benefitted the field of biopharma?
2017	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?
2014	Can overuse and the availability of antibiotics without doctor's prescription, the contributors to the emergence of drug-resistant diseases in **India**? What are the available mechanisms for monitoring and control? Critically discuss the various issues involved.
2013	What do you understand by fixed dose drug combinations (FDCs)? Discuss their merits and demerits.

►T-CELL IMMUNITY

A recent study has claimed that natural exposure or infection with the novel coronavirus may "prevent recurrent episodes of severe COVID-19". This is because, once infected with SARS-CoV-2, the immune system elicits "robust, broad and highly functional memory T cell responses".

WHAT IS RESEARCH ABOUT?

The study published by a team led by Marcus Bugger from Karolinska Institute, Stockholm, Sweden, found SARS-CoV-2-specific T cells even in family members who have been exposed to the virus but have tested negative on antibody blood tests.

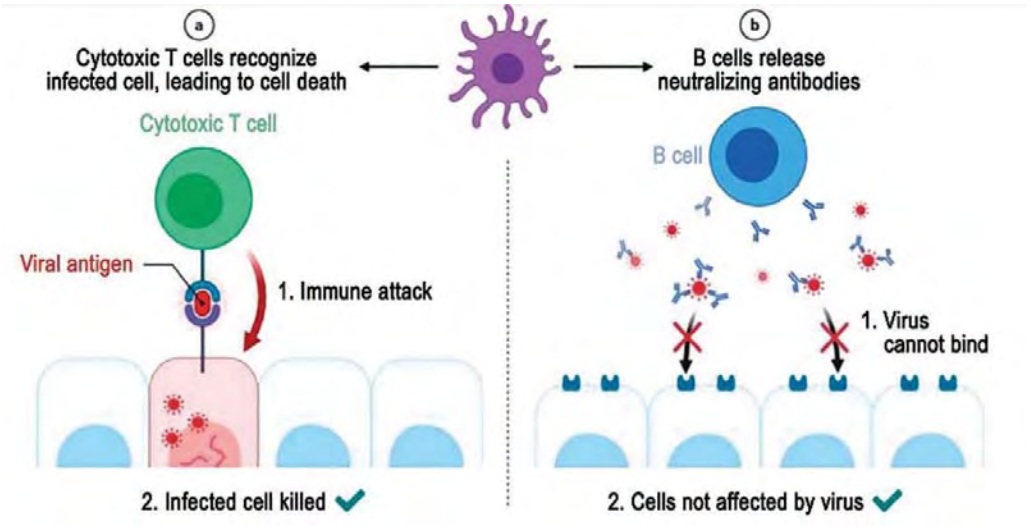
SARS-CoV-2-specific T cells were also seen in convalescent individuals with a history of asymptomatic infection and mild COVID-19 disease.

SOMETHINGS ABOUT T CELLS

A T cell is a type of lymphocyte, which develops in the thymus gland (hence the name) and plays a central role in the immune response.

T cells can be distinguished from other lymphocytes by the presence of a T-cell receptor on the cell surface.

These immune cells originate as precursor cells, derived from bone marrow, and develop into several distinct types of T cells once they have migrated to the thymus gland.



DO ALL INFECTED PEOPLE DEVELOP T CELLS IMMUNITY?

All categories of people — recovered from moderate or severe COVID-19 disease, or in the convalescent phase (recovering) after mild or severe disease or exposed family members or healthy people — exhibited "robust memory T cell responses months after infection, even in the absence of detectable circulating antibodies specific for SARS-CoV-2".

They were able to detect similar memory T cell responses directed against the internal and surface proteins (membrane and/or spike) of the virus in some people in whom SARS-CoV-2-specific antibodies could not be detected.

CAN T CELLS PROTECT US FROM RE INFECTION?

Studies undertaken in rhesus macaques had found that once infected, the animals were fully protected from reinfection.

Till date, no documented case of reinfection has been found in people anywhere in the world, whether they had recovered from mild or severe COVID-19 disease or even been asymptomatically infected.

So even as antibodies wane with time, robust T cell memory formed after SARS-CoV-2 infection suggests that "potent adaptive immunity is maintained to provide protection against severe re-infection".

►VACCINATION

Immunization is the process whereby a person is made immune or resistant to an infectious disease, typically by the administration of a vaccine (antigens or weakened pathogens).

The principle of vaccination is based on the property of 'memory' of the immune system.

When the vaccinated person is attacked by the same pathogens, the existing memory cells recognize the antigen quickly and overcome the invaders with production of antibodies.

Since the body saves copies of the antibodies, it is protected if the threat reappears later in life.

Table of Differences

Active immunization	Passive Immunization
Host develop immunity in response to direct contact of an antigen	Ready-made antibodies are directly given against foreign agents.
Produces an immunological memory	N/A
Slow and takes time to develop	develops immediately with no time lag
Antibodies are produced in the host body	outside the body

Permanent immunity	Short-term immunity
No side-effects	May cause reactions
Vaccine-induced	transferred from mother to foetus through placenta

Being the pharmacy of the world, India can also lead the world towards the development of vaccines.

►VACCINE PRODUCTION INDIA

- India accounts for 60% of global vaccine production.
- India is the largest supplier of DPT, BCG and Measles vaccines globally.
- WHO sources 70% of its essential immunisation vaccines from India.
- Twenty-seven million infants are immunized against 12 diseases annually.
- India's Pulse polio immunisation drive has set a global standard.
- India achieves feat of 2 billion COVID vaccine doses.
- Indigenously developed low-cost Rotavirus vaccine and Japanese encephalitis vaccine are now included under the Indian Universal Immunisation Program.
- Indian biopharma now produces new and more complex vaccines (Ex. meningitis, H1N1, Haemophilus influenzae type b, and pneumococcal conjugate vaccines).
- Percentage share of Biopharma is 62% in the overall biotechnology segment.
- BIRAC has initiated an Ind-CEPI project to strengthen development of vaccines for diseases of epidemic potential in India.

INDIA'S STRENGTH IN VACCINES PRODUCTION

- Robust pharmaceutical industry**:** Indian pharmaceutical industry is the world's 3rd largest by volume and 14th largest in terms of value. The percentage share of Biopharma is 62% in the overall biotechnology segment.
- Vaccine manufacturing companies: Bharat Biotech, Serum Institute of India, Zydus Cadila, Panacea Biotec, Indian Immunological
- Efficient manufacturing: skilled and cheap labour, large scale manufacturing
- Low-cost generic drug: Most of pharmaceuticals made in India are low-cost generic drug which comprise most of pharmaceutical export of India.
- Effective clinical trials due to presence of diverse genetic pool.

CHALLENGES IN VACCINE DEVELOPMENT

- Technological challenge**:** m-RNA vaccines are very fragile.
- Absence of robust research ecosystem
  - knowledge base in immunology; lifecycle immunisation.
  - The Nature Index that measures high-quality research outputs from various countries shows that publications from India are quite unimpressive and just one-tenth of China's.
  - Low biopharma-clusters.
  - According to a UNESCO estimate, the number of researchers in R&D per million people in India is just 253 — the equivalent figures for the developed Western nations range between 4,000 and 7,000.
  - Only about 20 per cent of Indian publications have international collaboration against over 40 per cent of the US publications.
- Economic challenge
  - Lack of funding. The India Innovation Index 2021 has found that the overall spending on R&D as a percentage of GDP is about 0.7%.
  - Cold storage facility
- Governance related challenge
- No finance/fund for promising drug-discovery projects.
- Absence of public-backed platforms like Israel Innovation Authority which brings together entrepreneurs in frontier technologies, enterprises, venture capitalists, academia, and government agencies to bridge the broken links in the ecosystem.
- IPR issues - The Indian Patent Act was amended in 2005 and the product patents have been allowed in the country, which has significant impact on the cost of health care products in India. There is need for improving the institutional capacity for intellectual property (IP) management and technology transfer.
- Strengthening Indian patent office, reducing the time to examine and grant a patent, and creation of more comprehensive IP databases in India
- India should develop/use expertise to study the flexibilities enshrined in the Trade Related Aspects of Intellectual Property rights (TRIPS) agreement to reduce the negative impact of the patents.
  - Collective management of IPR and open access agreements should be resorted to improve innovation and access. A body to acquire and hold

IPR must be created for technologies beneficial for use in public health.

- Cultural challenge: Vaccine misinformation, vaccine hesitance,

SIGNIFICANCE OF VACCINE PRODUCTION

- Technological development /innovation diffusion
- Research on new techniques increases. Ex. cell fusion, DNA-recombinant technologies, gene therapy,
- Biofortified crops for fighting malnutrition
- Biofertilizers for ecologically safe enrichment of soil. Ex. algal biofertilizers for rice cultivation.
- Biotechnology techniques has led to High yielding varieties of crops, drought resistant plants, etc., have overall
- contributed to food security of vast population of India
    - Blockchain, IoT to prevent vaccine fraud.
    - Biotechnology – High yielding varieties of crops, drought resistant plants, etc., have overall contributed to food security of vast population of India; fighting malnutrition by use of biofortified crops, e.g. Dhanashakti-first iron rich pearl millet in India; biofertilizers for ecologically safe enrichment of soil, e.g. algal biofertilizers for rice cultivation.
- Human resource development: Checking brain-drain, and talent-mapping for brain-gain
- Development of ancillary industries: cold storage, transportation, packing, syringes etc
- Utilisation of vaccine supply chain in other industries like agriculture and food processing industry.
- Development of other industries: harnessing pharmaceutical industry's true potential, development of MSME industries etc
- Development of health policy: preventive care, improving detection of non-communicable disease etc.

►TYPES OF VACCINES

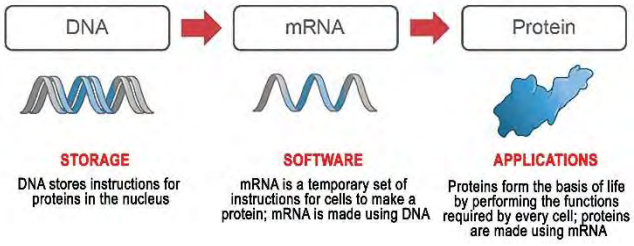
Type of vaccine	Description	Diseases covered
Live attenuated vaccines	• It contains a version of the living microbe that has been weakened in the lab so it cannot cause disease. • These vaccines will replicate in a vaccinated individual and produce an immune response but usually can cause mild or no disease. • Immune response is excellent.	Measles, mumps, rubella (MMR combined vaccine) Varicella (chickenpox) Influenza (nasal spray) Rotavirus
Inactivated vaccines	• The virus is first killed with chemicals, heat, or radiation and then used to make the vaccine. No threat of disease. Do not require refrigeration; are easy to store and transport. • May not always induce an immune response and response may not live longer. Several doses of whole cell vaccines may be required to evoke sufficient immune response.	Hepatitis A, Influenza, Polio, Rabies
Sub-unit vaccine	A piece of the virus (antigen) that is important for immunity, like the spike protein of COVID-19, is used to make the vaccine.	Human papillomavirus vaccines
Toxoid vaccines	It contains a toxin or chemical made by the bacteria or virus. They make a person immune to the harmful effects of the infection, instead of to the infection itself.	Diphtheria and tetanus
Biosynthetic vaccines	It contains manmade substances that are very similar to pieces of the virus or bacteria.	HIV

►M-RNA VACCINE

India's very own m-RNA (messenger-RNA) vaccine could be ready by March.

What are Conventional vaccines? They usually contain inactivated disease-causing organisms or proteins made by the pathogen (antigens), which work by mimicking the infectious agent. They stimulate the body's immune response, so it is primed to respond more rapidly and effectively if exposed to the infectious agent in the future.

HOW DOES RNA VACCINES WORK?



- RNA vaccines use a different approach that takes advantage of the process that cells use to make proteins: cells use DNA as template to make messenger RNA (mRNA) molecules, which are then translated to build proteins.
- An RNA vaccine consists of an mRNA strand that codes for a disease-specific antigen. Once the mRNA strand in the vaccine is inside the body's cells, the cells use the genetic information to produce the antigen. This antigen is then displayed on the cell surface, where it is recognized by the immune system.
- Unlike a normal vaccine, RNA vaccines work by introducing an mRNA sequence (the molecule which tells cells what to build) which is coded for a disease specific antigen, once produced within the body, the antigen is recognized by the immune system, preparing it to fight the real thing.
- RNA vaccines can be delivered using a number of methods: via needle-syringe injections or needle-free into the skin; via injection into the blood, muscle, lymph node or directly into organs; or via a nasal spray. The optimal route for vaccine delivery is not yet known. The exact manufacturing and delivery process of RNA vaccines can vary depending on the type.

HOW ARE THEY BENEFICIAL?

- As RNA vaccines are not developed from an active pathogen or an inactivated pathogen, they are non-infectious.
- RNA vaccines can be produced faster and its cheaper.
- It can be produced with fewer error rates.
- Replication mechanism can amplify antigen translation, decreasing the amount of starting material needed.
- According to preliminary trial results, these vaccines produce a reliable immune response and are tolerated by healthy individuals with few side effects.

CHALLENGES IN FLOATING THIS VACCINE IN INDIA

- There are still no commercially available m-RNA based vaccines.
- They need to be refrigerated to nearly (-) 70°C and India, with its limited cold chain infrastructure, lacks efficient vaccine storage capacity.
- Some mRNA-based vaccine are associated not only with inflammation but also potentially with autoimmunity.
- mRNA vaccines are new. Thus there is the risk of unknown effects, both short and longer-term.
- mRNA is very fragile, and thus the vaccine has to be kept at very low temperatures to avoid degrading.

COMPARISON OF M-RNA AND DNA VACCINE

The principle of mRNA vaccines and DNA vaccine are same. Both DNA and RNA vaccines deliver the message to the cell to create the desired protein so the immune system creates a response against this protein.

Both just produces a specific portion of the virus - spike protein in case of corona virus.

Both are laboratory-made structures and not obtained from the actual virus.

DNA and RNA vaccines are being touted for their cost effectiveness and ability to be developed more quickly than traditional, protein vaccines. Traditional vaccines often rely on actual viruses or viral proteins grown in eggs or cells, and can take years and years to develop. DNA and RNA vaccines, on the other hand, can theoretically be made more readily available because they rely on genetic code–not a live virus or bacteria. This also makes them cheaper to produce.

The COVID-19 vaccine from Pfizer-BioNTech and another developed by Moderna are mRNA vaccines.

However there are some differences:

1. DNA is much easy to prepare in laboratory. DNA based vaccine will be around 10 times cheaper.
2. DNA has to enter the nucleus of the cell to produce the spike protein. m-RNA based vaccine uses Ribosome in the cytoplasm to produce the spike protein. So since in case of DNA vaccine, entry into nucleus is required, safety concerns are more.

WAY FORWARD

- Vaccination is a major achievement of modern medicine, greatly reducing incidence of infectious diseases such as measles and eradicating others, such as smallpox.
- Conventional vaccine approaches have not been as effective against rapidly evolving pathogens like influenza or emerging disease threats such as the Ebola or Zika viruses. RNA based vaccines could have an impact in these areas due to their shorter

manufacturing times and greater effectiveness. Beyond infectious diseases, RNA vaccines have potential as novel therapeutic options for major diseases such as cancer.

►VACCINE NATIONALISM

Even before the end of final stage human trials or regulatory approval, several developed countries like Britain, France, Germany and the US have entered into pre-purchase agreements with COVID-19 vaccine manufacturers. This development is known as vaccine nationalism.

When a country manages to secure doses of vaccines for its own citizens or residents and prioritises its own domestic markets before they are made available in other countries it is known as 'vaccine nationalism'. This is done through pre-purchase agreements between a government and a vaccine manufacturer.

CONCERNS

1. Such advance agreements will make initial supply of vaccines unaffordable and inaccessible to people in poorer countries.
2. This hoarding of vaccine will lead to deepening of the pandemic, WHO has warned.
3. There are no international laws and rules to prevent pre-purchase agreements.
4. Stringent patent protection to vaccines prevents access to the neediest.
5. While the richer nations are thinking of booster doses, many in the developing world have still not gotten their first doses.
6. Number of vaccines delivered to COVAX facility is far below what has been pledged by developed countries.
7. There is on-going hoarding of vaccines.
8. Lack of trust for vaccines supplied by India.

EFFORTS TO BROAD BASE SUPPLY OF VACCINE

1. WHO in partnership with CEPI and GAVI has launched COVAX facility which aims to procure at least two billion doses of COVID-19 vaccines by the end of next year for deployment in middle- and low-income countries. Countries will get assured supplies to protect at least 20% of their populations.
2. Need for an international treaty to deal with supply of critical medicines, testing supplies in case of pandemic should be negotiated under the WHO.
3. Patent regulations should be weakened for wider access to vaccines. Patent pooling should be encouraged.

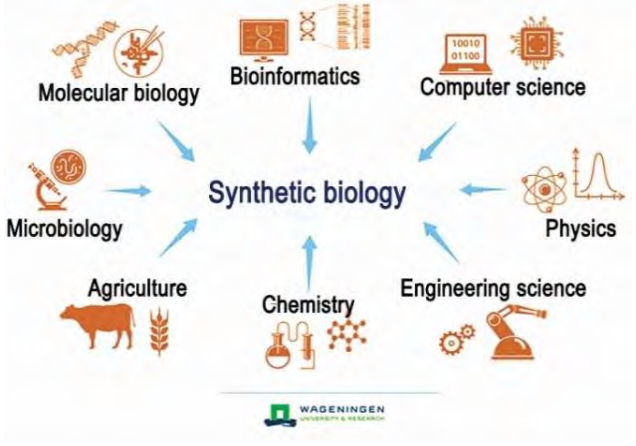
CONCLUSION

We should prevent vaccine nationalism. Sharing finite supplies strategically and globally is in each country's national interest.

►BIOWEAPONS

Traditional notion of security is undergoing a change. The growth of exponential technologies such as synthetic biology, artificial intelligence and nanotechnology is bound to change the theory and practice of national security. The rapid rise of synthetic biology and the danger of Bioweapons need to focus upon.

SYNTHETIC BIOLOGY - "A DOUBLE-EDGED SWORD"



- Synthetic biology is a revolutionary technology which can help us manipulate biological organisms and processes for human betterment, especially in treating diseases, by re-engineering cells.
- The reality is that there has been very little focus on threats emanating from biological sources. There is the possibility of deliberate misuse of technologies such as synthetic biology.
- With increasing access to such technologies, there is a need to review the biosecurity systems in place where such technologies are in use. Accidental leaks of experimental pathogens are another concern. Example - Recent focus on study of origin of COVID-19.
- Insufficiently trained staff, inadequately safeguarded facilities, and lack of proper protocols could all be behind such leaks. A well-planned attack using highly infectious pathogens synthetically engineered in a lab could be disastrous.

LACK OF REGULATORY REGIME FOR BIO - WEAPONS

- Unlike the nuclear domain, the fields of biotechnology or synthetic biology are not regulated internationally despite growing military interest in synthetic biology applications and their potential misuse.
- The Biological and Toxin Weapons Convention (BTWC) of 1972 does not have a verification clause, nor does it have clearly laid down rules and procedures to guide research in this field.
- Biotechnology is dual use; same technology can be used to develop vaccine and medicines and offensive bioweapons. Newer technologies such AI, 3D printing, CRISPR-CAS-9 etc. can make it easier to weaponise biotechnology.

ABOUT BIOLOGICAL AND TOXIN WEAPONS CONVENTION (BTWC) OF 1972

The BTWC was the first multilateral disarmament treaty banning the production of an entire category of weapons.

Terms of the Treaty:

The BWC bans:

- The development, stockpiling, acquisition, retention, and production of:

1. Biological agents and toxins "of types and in quantities that have no justification for prophylactic, protective or other peaceful purposes;"
2. Weapons, equipment, and delivery vehicles "designed to use such agents or toxins for hostile purposes or in armed conflict."

- The transfer of or assistance with acquiring the agents, toxins, weapons, equipment, and delivery vehicles described above. All State parties must destroy all such bioweapons upon becoming a member of BTWC.
- The convention further requires states-parties to destroy or divert to peaceful purposes the "agents, toxins, weapons, equipment, and means of delivery" described above within nine months of the convention's entry into force.
- The treaty regime mandates that states-parties consult with one another and cooperate, bilaterally or multilaterally, to solve compliance concerns. It also allows states-parties to lodge a complaint with the UN Security Council if they believe other member states are violating the convention. The Security Council can investigate complaints, but this power has never been invoked.
- The treaty stands for indefinite period.

CHALLENGES TO THE BTWC REGIME

1. Universality Gap:
   - BTWC has currently been signed by 183 countries. However, some countries such as Israel, Egypt and some others have not ratified the treaty. Thus, nothing prevents them from developing biological weapons. Steps must be taken to bring them on board.
   - BTWC mainly prevents states from developing biological weapons. However, most biological technologies are dual use with increase ease can also be available to non-state actors and terrorist organizations. The BTWC is silent on how to tackle this threat.
2. Implementation Gap: Verification of compliance of the treaty by BTWC states requires implementation at the national level. There is no elaborate international monitoring and inspection regime which is present in most-arms control treaties.
3. Response Gap: The BTWC is silent on how should state parties react in case of a biological attack. In response to a perceived violation, member states can lodge a complaint with the UNSC. However, the power veto means that no action may be taken.
4. Institutional Gap: The meetings of the BTWC are infrequent. There is no permanent agency to ensure implementation of BTWC. Since 2007, a small Implementation Support Unit has been formed. But its mandate and funding are limited.

SUGGESTIONS FOR STRENGTHENING BTWC

1. In the absence of a standing international body to oversee implementation of the BWC, the option of placing biological weapons under the jurisdiction of the existing Hague-based Organization for the Prohibition of Chemical Weapons (OPCW) should be explored.
2. The idea of equipping the BTWC with a verification or investigation mechanism should be revisited.
3. Countries not party to BTWC should be encouraged to become parties to BTWC.
4. Next BTWC review conference in 2021 provides an opportunity for strengthening the BTWC loopholes.

INDIA'S PREPAREDNESS

- India is under prepared compared to the more developed countries in this area given poor disease surveillance, insufficient coordination among various government departments dealing with biosecurity issues.
- Multiple institutions are dealing with biosafety and biosecurity threats but there is no coordination among them.

Example - implementation of biosafety guidelines is the responsibility of the Science and Technology Ministry and the Environment Ministry. However, labs dealing with biological research are set up under the Indian Council of Medical Research and the Indian Council of Agricultural Research, which are under the Ministries of Health and Agriculture, respectively.

- This highlights two issues pertaining directly to biosecurity.

1. One, the multiplicity of bodies and ministers makes coordination difficult, especially in the absence of an empowered coordinating body.
2. Two, given the rising risk of diseases of zoonotic origin, the traditional ministry-wise separation might not be useful.

- Another important question is whether India, with its porous borders and ill-trained border control institutions, is prepared for defending against pathogens or dangerous biological organisms or agents arriving from abroad. COVID-19 should serve as a wake-up call.

►DISEASE X

Over the past few decades, humanity has faced the threat posed by emergence of many infectious pathogens with pandemic potential.

Examples:

- Severe Acute Respiratory Syndrome (SARS)
- Middle East Respiratory Syndrome (MERS)
- Ebola
- Marburg
- Lassa
- Nipah
- Zika
- SARS Coronavirus (COVID-19)
- Human health, animal health and the state of ecosystems are inextricably linked with 70-80% of emerging and re-emerging infectious diseases known to be of zoonotic origin.
- Disease X is a name of an unknown disease which can develop into a pandemic like situation. There is a need to develop mechanisms to make our health systems better prepared in tackling a future pandemic.

Steps taken to reduce risk of Disease X or future pandemics:

1. WHO has formed Scientific Advisory Group on the Origins of Novel Pathogens (SAGO). Functions of SAGO:
   - To advise WHO on the development of a global framework to define and guide studies into the origins of emerging and re-emerging pathogens of epidemic and pandemic potential, including SARS CoV-2.
   - To advise WHO on prioritizing studies and field investigations into the origins of emerging and re-emerging pathogens of epidemic and pandemic potential.
2. One health approach with an integrated focus on animal health, human health and environmental health should be mainstreamed.
3. Greater international collaboration and strengthening of global surveillance.
4. Building of Universal Healthcare Coverage across the globe.

►NATIONAL BIOTECHNOLOGY DEVELOPMENT STRATEGY 2021-25

FOCUS AREAS

1. Building capabilities - a skilled workforce and strengthened state of the art infrastructure.
2. UNATI Biotech Missions - aligned with national and global priorities.
3. Building a self-reliant India through biotech interventions - affordable and accessible products and technologies
4. Leveraging the strength of strategic partnerships - national and international
5. Preparing for the future - building the knowledge base.
6. Taking science to society - empowering the rural sector.
7. Effective outreach and communication - building the public trust.
8. Global benchmarking

INDIA'S KEY STRENGTHS IN BIOTECHNOLOGY SECTOR

1. Large reservoir of scientific human resource including scientists and engineers.
2. Cost-effective manufacturing capabilities.
3. Budding start-ups in the biotechnology related areas.
4. Large number of national research laboratories, centres of academic excellence in biosciences.

5. Several universities offering degrees and diplomas in biotechnology, bioinformatics and biological sciences.
6. Presence of a large and vibrant drugs and pharmaceutical industry.
7. Rich biodiversity: India's human gene pools offer an exciting opportunity for genomics.
8. Fast developing clinical capabilities making India a popular destination for clinical trials and contract research.

►GENOME SEQUENCING

Genome sequencing means revealing the order of bases present in the entire genome of an organism. DNA nucleotides, or bases —Adenine, Cytosine, Guanines, and Thymine make up an organism's DNA. A genome is an organism's complete set of genetic instructions.

Our bodies are made up of millions of cells, each with their own complete set of instructions for making us, like a recipe book for the body. This set of instructions is known as our genome and is made up of DNA. Each cell in the body, for example, a skin cell or a liver cell, contains this same set of instructions.

- The instructions in our genome are made up of DNA.
- Within DNA is a unique chemical code that guides our growth, development, and health.
- This code is determined by the order of the four nucleotide bases that make up DNA, adenine, cytosine, guanine and thymine, A, C, G and T for short.
- DNA has twisted structure (double helix structure).
- Single strands of DNA are coiled up into structures called chromosomes.
- Chromosomes are in the nucleus within each cell.
- Within our chromosomes, sections of DNA are "read" together to form genes.
- Genes control different characteristics such as eye color and height.
- All living things have a unique genome.
- Human genome is made up of 23 chromosome pairs with a total of about 3 billion DNA base pairs. Some parts of genome are outside these chromosomes and are stored in the Mitochondria.

IMPORTANCE OF GENOME SEQUENCING

Sequencing the genome is an important step towards understanding it. It will help us:

- Find genes much more easily and quickly. A genome sequence does contain some clues about where genes are, even though scientists are just learning to interpret these clues.
- Understand how the genome as a whole works—how genes work together to direct the growth, development, and maintenance of an entire organism.
- Study the parts of the genome outside the genes. This includes the regulatory regions that control how genes are turned on and off.
- Understand diseases including genotyping of specific viruses to direct appropriate treatment
- In the identification of mutations linked to different forms of cancer
- Understand the design of medication & more accurate prediction of their effects, in the advancement of forensic applied sciences, biofuels, animal husbandry, etc.
- Understand evolution much more accurately.
- Forensics and crime investigation, paternity disputes, new technologies such as DNA Barcoding, DNA Computing etc.

WHOLE GENOME SEQUENCING

- Exome, part of gene responsible for making proteins occupies just about 1% of actual gene. Rather than sequencing whole gene, many geneticists rely on "exome maps." However, non-exome portions also affect functioning of genes.
- Hence to know which genes of a person's DNA are "mutated" the whole genome sequencing is required.
- Whole genome sequencing is the process of determining the complete DNA sequence of an organism's genome at a single time.
- This entails sequencing all an organism's chromosomal DNA as well as DNA contained in the mitochondria and, for plants, in the chloroplast.
- In practice, genome sequences that are nearly complete are also called whole genome sequences.

PROGRAMS FOR GENOME SEQUENCING

1. IndiGen program

- Aims to undertake whole genome sequencing of a thousand Indian individuals representing diverse ethnic groups from India.
- Funded by the CSIR under the Ministry of Science and Technology.

- Objective: Create a pilot dataset to enable genetic epidemiology of carrier genetic diseases towards enabling affordable screening approaches in India.
- Found that there are 32% genetic variations in Indian genome sequences, unique as compared to global genomes.

2. Human Genome Project (HGP)

- It was the international research effort to determine the DNA sequence of the entire human genome.
- The HGP gave us the ability, for the first time, to read nature's complete genetic blueprint for building a human being.
- It was coordinated by the National Institutes of Health, USA and the Department of Energy, USA.
- It revealed that there were about 20,000 human genes. According to the HGP, humans share 99.9% genes with each other.

3. Genome India Project

- India's gene-mapping project that aims to form a grid after collecting 10,000 samples in the first phase from across India, to arrive at a representative Indian genome
- Department of Biotechnology, Ministry of Science and Technology will lead the project.
- It will enable new efficiencies in healthcare, medicine, and life sciences. However, GIP also raises concerns pertaining to medical ethics, political misuse, etc.

4. Genome mapping in Indian Ocean

- National Institute of Oceanography is going to launch a project for Genome Mapping in the Indian Ocean.
- Aim of the project:
  - To gather samples for genome mapping of microorganisms in the Indian Ocean
  - To understand the biochemistry and the response of the ocean to climate change, nutrient stress and increasing pollution
- Significance of the project
  - Mapping of DNA and RNA will show the nutrients present in them, and those lacking in different parts of the ocean.
  - Give holistic understanding about nutrient cycling and productivity of the oceans.
  - Generate new information about trace metals from underexplored regions of the Indian Ocean.
  - Show the presence of which these microbes have adapted to, in addition to their reaction to atmospheric carbon dioxide.

►NATIONAL GUIDELINES FOR GENE THERAPY

These guidelines lay guidelines for development of gene and cell therapies.

NEED FOR THESE GUIDELINES

- Huge burden of genetic diseases in India
- These guidelines will spur innovation and accelerate research in gene therapy in India.
- There remain many hurdles that the scientific and clinical community working in the rare diseases fields have yet to overcome, primarily the appropriate and timely diagnosis including genetic testing and genetic counselling, prohibitive costs of such gene therapies, adequate insurance coverage and management practices among treating physicians.
- New Drugs and Clinical Trials Rules, 2019 by CDSCO considers gene therapy product as a 'new drug'.

SALIENT FEATURES

Gene Therapy Products (GTPs) are defined as any entity which includes a nucleic acid component being delivered by various means for therapeutic benefit to patients.

All GTP research pertaining to human applications must be conducted within the principles of these guidelines in a scientific and ethical manner following all regulatory requirements as laid down for all forms of GTP.

All GTP development activities will be steered by Gene Therapy Advisory and Evaluation Committee (GTAEC) with the secretariat at ICMR, which shall be notified by DHR.

The guidelines detail all the requirements for enrolling patients in GTP human trials, their risk and safety assessments and trial designs which must be approved by the GTAEC, RCGM and CDSCO prior to patient administration.

The guidelines cover all considerations for Chemistry, Manufacturing and Control, Quality Assurance, Product Attributes for GTP, including personnel training and infrastructure requirements.

GENE EDITING TECHNIQUES

- Prime editing is a 'search-and-replace' genome editing technology in molecular biology, by which the genome of the living organisms may be modified. The technology directly writes new genetic information into a targeted DNA site.
- CRISPR-Cas9 is a technology that cut-and-paste DNA, raising hope of genetic fixes for disease. CRISPR allows targeting nearly any genomic location and potentially repairing the broken genes. This technique

is based on the natural defence mechanism found in some bacteria. It uses a specific enzyme — Cas9 — to identify and eliminate predetermined genes and DNA sequences.

- Applications of this technology: Gene-editing to cure diseases, developing CRISPR based COVID-19 test (FELUDA), Development of vaccines against mosquitos.
- Mega nucleases are "molecular DNA scissors", that can be used to replace eliminate or modify the sequences in a highly targeted way.

►ANTIMICROBIAL RESISTANCE

- Antimicrobial resistance (AMR) is a global health and development threat. It requires urgent multisectoral action to achieve the Sustainable Development Goals (SDGs).
- Misuse and overuse of antimicrobials are the main drivers in the development of drug-resistant pathogens.
- Lack of clean water and sanitation and inadequate infection prevention and control promotes the spread of microbes, some of which can be resistant to antimicrobial treatment.
- The cost of AMR to the economy is significant. In addition to death and disability, prolonged illness results in longer hospital stays, the need for more expensive medicines and financial challenges for those impacted.
- Without effective antimicrobials, the success of modern medicine in treating infections, including during major surgery and cancer chemotherapy, would be at increased risk.
- WHO has declared that AMR is one among top ten global public health threats facing humanity.

WHAT ARE ANTIMICROBIALS?

Antimicrobials – including antibiotics, antivirals, antifungals and ant parasitic – are medicines used to prevent and treat infections in humans, animals, and plants.

WHAT IS ANTIMICROBIAL RESISTANCE?

- Antimicrobial Resistance (AMR) 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, severe illness and death.
- As a result of drug resistance, antibiotics and other antimicrobial medicines become ineffective and infections become increasingly difficult or impossible to treat.

MAJOR CAUSES OF ANTIBIOTICS RESISTANCE:

- Over-prescription of antibiotics
- Patients not finishing the entire antibiotic course
- Overuse of antibiotics in livestock and fish farming
- Poor infection control in health care settings
- Poor hygiene and sanitation
- Absence of new antibiotics being discovered
- Patients taking antibiotics without consulting doctors & practitioners.
- Environmental pathways of AMR:
  - Antimicrobial manufacturing waste disposal
  - Antimicrobial discharge and determinants of AMR in food systems
  - Antimicrobial discharge and determinants of AMR in hospitals and other health facilities.
- Socio-economic factors
  - Limited access to WASH (Water, Sanitation and Hygiene) facilities.
  - Density and informality of population especially in slum areas, rural shanties and peri-urban areas. (Often unplanned).

GLOBAL ANTIBIOTIC RESISTANCE IMPLICATION

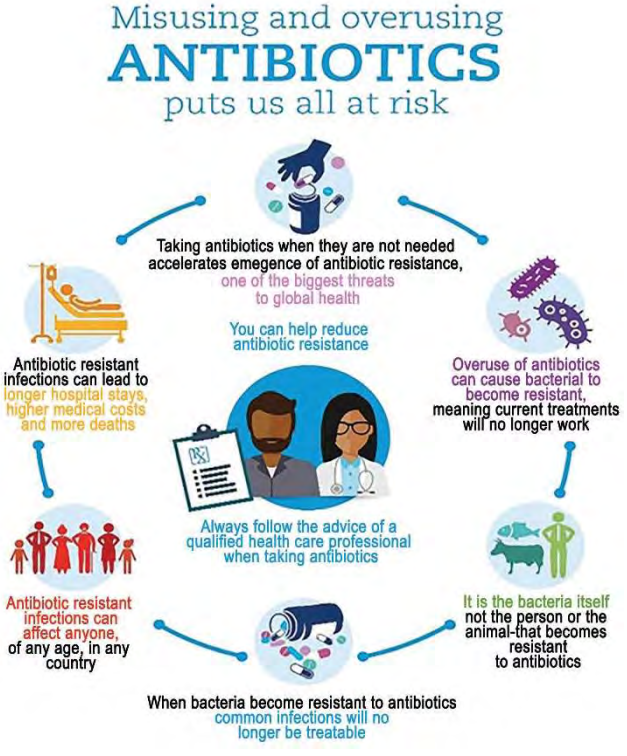
The consequences of Antibiotic resistance are highly problematic because of its severity.

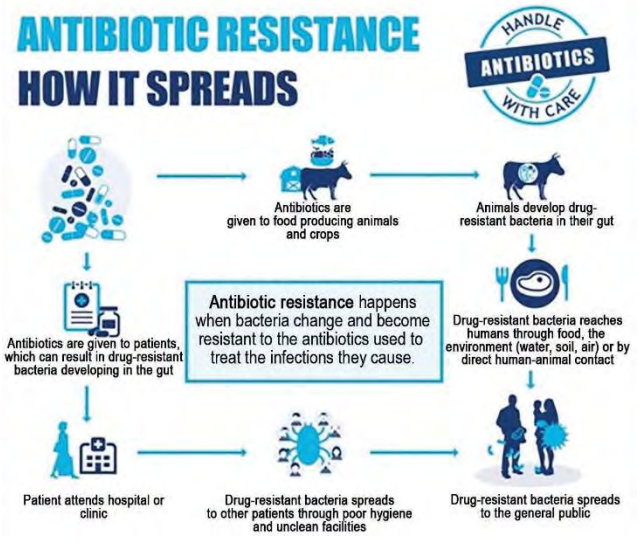
- Leads to higher medical costs.
- Prolonged hospital stays.
- Increased mortality.
- Longer periods of infectivity, with increased risk of transmission in the community.
- Multidrug resistance microbes are more life threatening.
- Old, researched antibiotics not working effectively/at all on diseases, hence new antibiotics need to be found.
- The cost of AMR to national economies and their health systems is significant as it affects productivity of patients or their caretakers through prolonged hospital stays and the need for more expensive and intensive care.
- Without effective tools for the prevention and adequate treatment of drug-resistant infections and improved access to existing and new quality-assured antimicrobials, the number of people for whom treatment is failing or who die of infections will increase.

- Medical procedures, such as surgery, including caesarean sections or hip replacements, cancer chemotherapy, and organ transplantation, will become riskier.

STEPS TAKEN BY GOVERNMENT

- National Action Plan to tackle AMR has been released by Ministry of Health and Family Welfare.
- AMR Surveillance has been strengthened by creation of two AMR surveillance networks
  - ICMR AMR Surveillance Network: Operational in 30 hospitals
  - NCDC AMR Surveillance Network: Operational in 20 hospitals





WAY FORWARD

- Improving surveillance and monitoring of microbial use and resistance across all sectors
- Reducing incidence of infections through effective infection prevention and control (IPC)
- Optimising use of antimicrobials through antimicrobial stewardship programs
- Infectious diseases blocks should be created in district hospitals.
- Paucity of good microbiology laboratories in secondary hospitals makes it challenging to collect data about AMR from lower levels of healthcare ecosystem.
- Expanded wastewater treatment and access to WASH facilities.
- Regulatory and incentive measures encouraging responsible manufacturing, disposal and use of anti-microbial.

DO'S AND DONT'S OF ANTIBIOTICS

- Do not use antibiotics to treat viral infections, such as influenza, the common cold, a runny nose, or a sore throat. Ask your doctor for other ways to feel better.
- Use antibiotics only when a doctor prescribes them.
- When you are prescribed antibiotics, take the full prescription even if you are feeling better. Ensure that members of your family do the same.
- Never share antibiotics with others or use leftover prescriptions.

►DNA TECHNOLOGY REGULATION BILL

Currently, use of DNA technology for identification of individuals is not regulated. In the past, several expert groups including the Law Commission have looked at the use and regulation of DNA technology. The Commission submitted its report as well as a draft Bill in 2017.

In this context, DNA Technology (Use and Application) Regulation Bill, 2018 regulates use of DNA technology for identification of persons in criminal and civil matters.

HIGHLIGHTS OF THE BILL

- Regulates use of DNA technology for establishing the identity of persons. These include criminal matters (such as offences under the Indian Penal Code, 1860), and civil matters such as parentage disputes, emigration or immigration, and transplantation of human organs.

- Establishes a National DNA Data Bank and Regional DNA Data Banks. Each Data Bank will maintain the following indices: (i) crime scene index, (ii) suspects' or undertrials' index, (iii) offenders' index, (iv) missing persons' index, and (v) unknown deceased persons' index.
- Establishes a DNA Regulatory Board. Every DNA laboratory that analyses a DNA sample to establish the identity of an individual must be accredited by the Board.
- Written consent by individuals is required to collect DNA samples from them. Consent is not required for offences with punishment of more than seven years of imprisonment or death.
- Provides for the removal of DNA profiles of suspects on filing of a police report or court order, and of under trials based on a court order. Profiles in the crime scene and missing persons' index will be removed on a written request.

ISSUES RAISED

- DNA profiles can reveal extremely sensitive information of an individual such as pedigree, skin color, behavior, illness, health status and susceptibility to diseases.
- Under the provisions of the Bill, access to such intrusive information can be misused to specifically target individuals and their families with their own genetic data. This is particularly worrying as it could even be used to incorrectly link a particular caste/community to criminal activities.
- Proposes to store DNA profiles of suspects, under trials, victims and their relatives for future investigations. "While there is a good case for a DNA database of convicts, so that repeat offenders may be easily identified, there is no legal or moral justification for a database with DNA of the other categories as noted above, given the high potential for misuse."
- Refers to consent in several provisions, but in each of those, a magistrate can easily override consent, thereby in effect, making consent perfunctory. There is also no guidance in the Bill on the grounds and reasons when the magistrate can override consent, which could become a fatal flaw.
- In absence of robust data protection legislation, security of a huge number of DNA profiles that will be placed with National DNA Data bank and its regional centers is questionable.
- Permits retention of DNA found at a crime scene in perpetuity, even if conviction of the offender has been overturned. The committee urged the government to amend the provisions to ensure that if the person has been found innocent his DNA profile must be removed immediately from the data bank.
- Independent scrutiny must be done of the proposals to destroy biological samples and remove DNA profiles from the database.
- Provides that DNA profiles for civil matters will be stored in the data banks, but without a clear and separate index. The committee questioned the necessity for storage of such profiles, pointing out that this violates the fundamental right to privacy and does not serve any public purpose.

►DNA FINGERPRINTING

Conventional fingerprint of an individual comes from fingertip and unique for an individual. This is used for identification of a person in forensic lab, police station etc. However, the major drawback of the conventional fingerprints is that it can be changed by surgery. There is another type of fingerprint unique to an individual called DNA fingerprint. This remains same in all body parts, tissues and cells as well as cannot be altered by any known methods. Thus, DNA fingerprint method is becoming primary method for identifying an individual.

PRODUCTION OF DNA FINGERPRINT

First step of DNA fingerprinting was to extract DNA from a sample of human material, usually blood.

Molecular 'scissors', called restriction enzymes, were used to cut DNA. This resulted in thousands of pieces of DNA with a variety of different lengths.

These pieces of DNA were then separated according to size by a process called gel electrophoresis.

Once DNA had been sorted, pieces of DNA were transferred or 'blotted' out of fragile gel on to a robust piece of nylon membrane and then 'unzipped' to produce single strands of DNA.

Next nylon membrane was incubated with radioactive probes.

Mini satellites that probes have attached to were then visualized by exposing nylon membrane to X-ray film.

To compare two or more different DNA fingerprints the different DNA samples were run side-by-side on the same electrophoresis gel.

APPLICATIONS

- Useful in forensics because only a tiny sample of human material left behind after a crime may be sufficient to identify someone.

- Confirm whether two people are related to one another and are commonly used to provide evidence that someone is, or is not, the biological parent of a child.
- Identify victims of crime or major disasters and help bring separated families back together.
- Identify racial groups, their origin, historical migration and invasions.
- Study breeding pattern of endangered animals.
- Diagnosing inherited disorders in both prenatal and new-born babies. These disorders may include cystic fibrosis, haemophilia, Huntington's disease, familial Alzheimer's, sickle cell anaemia, thalassemia, and many others.

By comparing the band of HIV "RNA" (converted to DNA using RTPCR) with the bands form by the man's blood, person suffering with AIDS can be identified.

Breeders conventionally use the phenotype to evaluate the genotype of a plant or an animal. For example, homozygous dominant genotype AABB is always desirable. As it is difficult to make out homozygous or heterozygous dominance from appearance, the DNA fingerprinting allows a fastidious and precise determination of genotype. Offspring from the discerning mating of superior animals are expected to inherit desirable characters like strong cardiopulmonary capacity and speed. It is basically useful in breeding racehorses and hunting dogs.

►DNA PROFILING

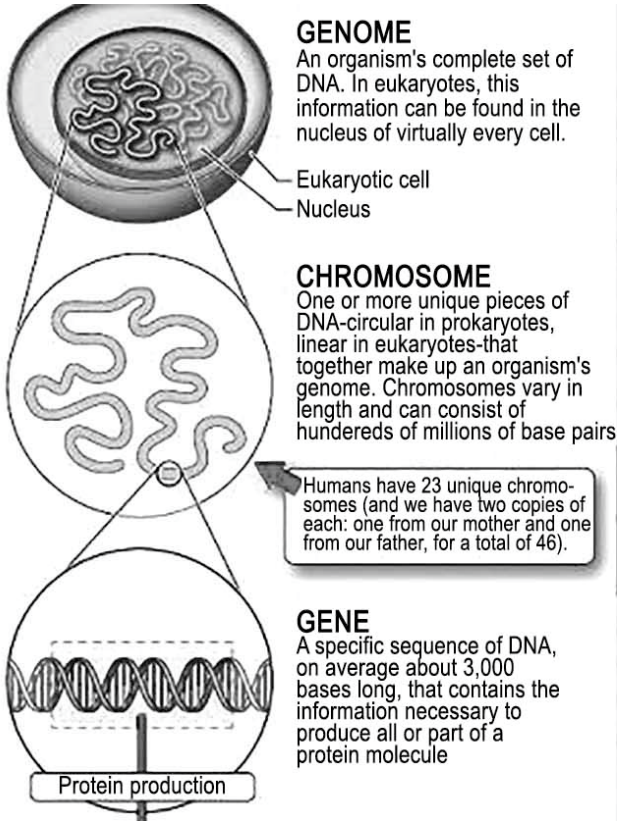
DNA profiling or DNA fingerprinting is creation of a biometric database comprising DNA information of individuals.

ESTABLISHING DNA PROFILES

- While DNA is unique to an individual's genetic makeup, it is 99.9% similar between all individuals within the human species.
- Variable regions (0.1%) also called Variable Number of Tandem Repeats (VNTR) are unique to individual's DNA constitute DNA profile of that individual.
- DNA profile of an individual varies in some regions in terms of number of times a sequence of nucleotide base pairs is repeated.
- Thus, by counting number of times these base-pair sequences are repeated in these variable regions a DNA profile of an individual is established.

APPLICATION

- To establish identity of persons.
- Determining biological relationship to establish parentage, viability of organ transplantation etc.



HOW DO GENES WORK?

- Every cell in an organism contains all the information needed to manufacture every protein in its body.
- The genes in strands of DNA are a storehouse of information, an instruction book.
- The genes that an organism carries for a particular trait is its genotype and the physical manifestation of the instructions are the organism's phenotype.
- A gene (a sequence of bases in a section of DNA) affects the phenotype in two main steps.
- Transcription, in which a copy of a gene's base sequence is made, and
- Translation, in which that copy is used to direct the production of a protein.
- In transcription, gene's base sequence or code is copied into a middleman molecule called messenger RNA (mRNA).
- In translation, the mRNA moves out of the nucleus and into the cytoplasm of the cell, where the messages encoded in the mRNA molecules are used to build proteins

WHAT IS GENOME SEQUENCING?

- Full set of DNA present in an individual organism is called its genome.

- DNA sequencing is a procedure for determining linear order of nucleotide bases in DNA.
- Sequencing a gene is like reading a book, one letter at a time, to look for any spelling mistakes.
- Mapping out a person's entire genetic code, or genome or reading each of the 3 billion base pairs that make up a person's genetic code is called genome sequencing.
- By creating a genome sequence, we will be able to assess specific genes to detect presence of mutations associated with genetic disorders.
- Within next few years, experts expect the turnaround time to improve and the cost to drop so much that analyzing a person's genome will be no more expensive than zeroing in on just one gene.

NEXT-GENERATION SEQUENCING

- Next generation sequencing simply refers to DNA sequencing techniques that decode multiple DNA fragments at the same time in an automated process.
- As a result, next-generation sequencing procedures are fast, accurate, automated and cheap.

►BIOTECHNOLOGY IN AGRICULTURE

Agricultural biotechnology is a range of tools that alter living organisms, or parts of organisms, to make or modify products; improve plants or animals; or develop microorganisms for specific agricultural uses. It includes both traditional breeding techniques and modern tools of genetic engineering.

BENEFITS

For Producers:

- Safe and easier pest control and weed management E.g., BT Brinjal.
- Enhanced crop yields and productivity.
- Withstand weather fluctuations and extremes E.g., Flood-tolerant "Scuba Rice"
- Enhanced quality traits Ex., Golden rice with Vitamin A

For Consumers:

- Foods with long-lasting life E.g., FlavrSavr tomato.
- Enhanced Nutrition via food fortification E.g., Iodine Salt
- Lower levels of toxicants in food.
- Low saturated fats in cooking oils etc.

For Researchers:

- Understanding the basic biology of living organisms.
- Producing newer more potent antibiotics.
- Producing new vaccines for crop diseases.

For Environment:

- Herbicide-tolerant crops, compatible with no-till/reduced tillage systems, helps preserve topsoil from erosion E.g., HT mustard
- Phyto-remediation E.g., Use of Poplar handling heavy metallic pollution.

Risks associated:

- Effects on human health are not well studied. It may trigger:

Emergence of new disease

Allergies

- Impact on other organisms and overall environment is also debatable.
- Anti-microbial resistance – E.g., BT cotton has developed resistance to pink ball worm.
- Patent Rights can lead to monopolization E.g., Terminator seeds.
- GM crops could push farmers to debt.

Biotechnology has the potential to revolutionise agriculture, but it needs appropriate safeguards and awareness programs to meet apprehensions of all stakeholders.

►HTBT COTTON

The illegal cultivation of herbicide-tolerant (HT) BT cotton has seen a huge jump this year. Seed manufacturers have claimed that the sale of illegal seed packets has more than doubled.

Domestic seed industry has demanded that action be taken to stop such sales and punish offenders, noting that cultivation of the genetically modified cotton variant has serious environmental and economic consequences.

ABOUT BT COTTON

- BT cotton is an insect-resistant transgenic crop *(genetically modified by introduction of a gene from a different species)* designed to combat the cotton bollworm, a common pest.
- It was created by genetically altering the cotton genome to express a microbial protein from the bacterium Bacillus thuringiensis.
- The transgene inserted into the plant's genome produces toxin crystals that the plant would not normally produce which, when ingested by a certain population of organisms (Bollworm), dissolves the gut lining, leading to the organism's death.

- BT cotton is the only transgenic crop that has been approved by the Centre for commercial cultivation in India.

HTBt COTTON

- HTBt cotton variant adds another layer of modification, making the plant resistant to the herbicide glyphosate. Fears include glyphosate having a carcinogenic effect, as well as the unchecked spread of herbicide resistance to nearby plants through pollination, creating a variety of super weeds.
- HTBt cotton has not been approved by government for cultivation. Activists from the *Shetkari Sangathan* have stepped up the reach of their civil disobedience movement to demand legalisation of HTBt cotton by encouraging farmers to plant the seeds in violation of government regulations.
- Seed manufacturers have said that the illegal seeds are sold using the brand name of prominent companies. So,
  - Farmers are at risk with such illegal cotton seed sale as there is no accountability of the quality of seed.
  - Pollutes the environment.
  - Industry is losing legitimate seed sale.
  - Government also loses revenue in terms of tax collection.
  - It will not only decimate small cotton seed companies but also threatens the entire legal cotton seed market in India.

NEED FOR USING HTBT COTTON

- Saves Cost: There is a shortage of labour needed to do at least two rounds of weeding for BT cotton. With HTBt, simply one round of glyphosate spraying is needed with no weeding, savings cost for farmers.
- Support of Scientists: Scientists are in favour of this crop, even WHO has said it does not cause cancer.

ISSUES FROM ILLEGAL SALE OF HTBt COTTON

- As it is not approved by the Genetic Engineering Appraisal Committee (GEAC), illegal sale takes place in Indian markets.
- Farmers are at risk with such illegal cotton seed sale as there is no accountability of the quality of seed, it pollutes the environment, the industry is losing legitimate seed sale and the government also loses revenue in terms of tax collection.
- It will not only decimate small cotton seed companies but also threatens the entire legal cotton seed market in India.

GENETIC ENGINEERING APPRAISAL COMMITTEE

- The Genetic Engineering Appraisal Committee (GEAC) functions under the Ministry of Environment, Forest and Climate Change (MoEF&CC).
- It is responsible for the appraisal of activities involving large-scale use of hazardous microorganisms and recombinants in research and industrial production from the environmental angle.
- The committee is also responsible for the appraisal of proposals relating to the release of genetically engineered (GE) organisms and products into the environment including experimental field trials.
- GEAC is chaired by the Special Secretary/Additional Secretary of MoEF&CC and co-chaired by a representative from the Department of Biotechnology (DBT).

WAY FORWARD

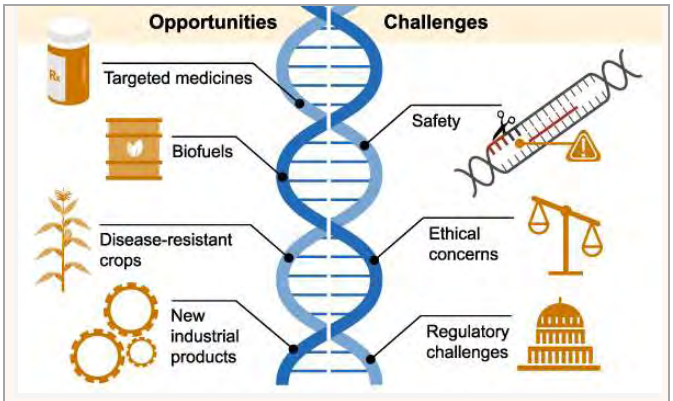
- Regulators only limit their checking/regulation to licensed dealers and seed companies while illegal activity of HT seed sales is carried mostly by unorganised and unreliable operators. Thus, focus must be shifted to catching them and taking exemplary and strong punitive action.
- Collective action of both center and state government is required. The Centre has made the policy to ban this variant. But it is the State governments that must also work in tandem with the central government.
- Environmental impact assessment should be conducted by independent environmentalists, as farmers do not and cannot assess the long-term impact of GM crops on ecology and health.
- Awareness among the farmers about the concerns of HTBt cotton.

►SDN-1 & SDN-2

Proposal of Indian regulators to consider a new gene editing technique has been pending with the Genetic Engineering Appraisal Committee for almost two years.

GENE EDITING

- Genome editing (also called gene editing) is a group of technologies that give scientists the ability to change an organism's Deoxy-Ribonucleic Acid (DNA).
- These technologies allow genetic material to be added, removed, or altered at locations in the genome.



KEY POINTS

- Indian Agricultural Research Institute (IARI) has now moved to newer technologies such as Site Directed Nuclease (SDN) 1 and 2.
- New technique aims to bring precision and efficiency into breeding process using gene editing tools such as CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats), whose developers won Nobel Prize for Chemistry in 2020.
- SDN genome editing involves the use of different DNA-cutting enzymes (nucleases) that are directed to cut DNA at a predetermined location by a range of different DNA binding systems.
- After the cut is made, cell's own DNA repair mechanism recognizes the break and repairs the damage, using one of two pathways that are naturally present in cells.
- It involves use of gene editing tools to directly tweak (improve\change) plant's own genes instead.
- It would allow plants to be genetically modified without the need for conventional transgenic technology.

SDN 1 and 2:

- MOEFCC exempted SDN1 and SDN2 genome-edited plants from Rules 7-11 of Environment Protect Act (EPA), which govern manufacture, use, import, export, and storage of dangerous microorganisms or genetically modified organisms or cells.
- The notification will pave way for government to approve and notify genome-edited plant guidelines.

What are SDN 1 and SDN 2:

- SDN 1 & 2 (Site-Directed Nuclease technology) are Gene-editing technologies which do not involve the introduction of any foreign DNA.
- Site-Directed Nuclease (SDN) genome editing involves the use of different DNA-cutting enzymes (CRISPR-Cas9) that are directed to cut the DNA at a predetermined location. After the cut is made, the cell's own DNA repair mechanism recognizes the break and repairs the damage.
- In the case of SDN1 and SDN2 approaches, the CRISPR components used to edit the selected native genes for a desirable trait can easily be removed by segregation of the plant progeny in the next and subsequent generations. In this way, one can produce transgene-free edited plants (in other words, non-genetically modified or non-GMOs) that are indistinguishable from conventional breeding material. But this method is faster and cheaper than traditional crossing, which results in a host of unwanted traits also getting transferred and, hence, requires several more breeding cycles in order for the offspring to have only the desired traits.

- Current Application:
  - A research coalition under Indian Council of Agricultural Research (ICAR), which includes IARI, is using these techniques to develop rice varieties which are drought-tolerant, salinity-tolerant and high-yielding. They could potentially be ready for commercial cultivation within three years.
    - IARI has previously worked on golden rice, a traditional GM variety which inserted genes from other organisms into the rice plant but ended trials over five years ago due to agronomic issues.
- Significance of New Techniques:
  - Safe:
    - In this case, you are just tweaking a gene that is already there in the plant, without bringing in any gene from outside.
    - When a protein comes from an outside organism, then you need to test for safety. But in this case, this protein is right there in the plant, and is being changed a little bit, just as nature does through mutation.
  - Fast: It is much faster and far more precise than natural mutation or conventional breeding methods which involve trial and error and multiple breeding cycles. It is potentially a new Green Revolution.
- Status of New Techniques Globally:
  - U.S, Canada, Australia and Japan are among countries which have already approved SDN 1 and 2 technologies as not akin to GM, so such varieties

of rice can be exported without any problem.

- European Food Safety Authority has also submitted its opinion that these technologies do not need the same level of safety assessment as conventional gene mutation, though the European Union is yet to accept the recommendation.

- Related Laws in India:
  - In India, several rules, guidelines, and policies backed by "Rules for Manufacture, Use, Import, Export and Storage of Hazardous Microorganisms/Genetically Engineered Organisms or Cells, 1989" notified under Environment Protection Act, 1986, regulate genetically modified organisms.
  - Apart from it, National Ethical Guidelines for Biomedical and Health Research involving human participants, 2017, by Indian Council of Medical Research (ICMR), and Biomedical and Health Research Regulation Bill implies regulation of the gene-editing process.
    - This is especially so in the usage of its language "modification, deletion or removal of parts of heritable material".
    - However, there is no explicit mention of the term gene editing.

►FOOD FORTIFICATION

- Fortification is the addition of key vitamins and minerals such as iron, iodine, zinc, Vitamin A & D to staple foods such as rice, milk and salt to improve their nutritional content. These nutrients may or may not have been originally present in the food before processing.
- Various technologies are available to add micronutrients to regular rice, such as dusting, coating and extrusion.
- Government is promoting fortification in following 5 food items: Rice, wheat, salt, edible oil & milk.

NEED OF FORTIFICATION

- India has very high levels of malnutrition among women and children. As per recent report of NFHS-5: Stunting 35.5%, Wasting 19.3% & Underweight-32.1%.
- Every second woman in the country is anaemic.
- Deficiency of micronutrients or micronutrient malnutrition, also known as "hidden hunger", is a serious health risk.
- India has slipped to 101st position in Global Hunger Index (GHI) 2021 out of 116 countries, compared to 94th rank in 2020.
- Rice is one of India's staple foods, consumed by about two-thirds of the population. Per capita rice consumption in India is 6.8 kg per month. Therefore, fortifying rice with micronutrients is an option to supplement the diet of the poor.

BENEFITS OF FORTIFICATION

- Wider coverage: fortification of widely consumed staple foods is very effective way of health improvement of improvised masses.
- Quick results: the technique of food fortification show results in terms of improvement of health in a relatively shorter duration.
- Cost effective solution: fortification enables a threshold level of nutrition at a very low cost. For instance, it takes just around 10 paisa to fortify a litre of oil.
- Culturally sustainable: Fortification does not require any changes in food habits. Hence it becomes a socio-culturally friendly method to deliver nutrients to people.
- No alteration of food characteristics: It does not alter the characteristics of the food like the taste, aroma or the texture of the food
- Economic growth and development: The Copenhagen Consensus estimates that every 1 Rupee spent on fortification results in 9 Rupees in benefits to the economy. While an initial investment to purchase both the equipment and the vitamin and mineral premix is required, the overall costs of fortification are extremely low.
- Issues with fortification
- Fragmented approach to malnutrition: Malnutrition in India is a multidimensional issue involving calorie deficiency, protein inadequacy apart from micro-nutrient deficiency. Food fortification will be a fragmented approach to these complex problems.
- Hypervitaminosis: To address anemia, haemoglobin production is targeted. Haemoglobin synthesis does not happen with just iron alone; many other elements are required in far larger quantities, especially good quality protein, vitamin B and C, folic acid, etc. Adding more iron will only succeed in increasing ferritin, an iron storage protein, but won't lead to haemoglobin synthesis, or treatment of anemia.
- Research shows that high ferritin is associated with diabetes, especially during pregnancy.

- Too much of Iron intake will create problem for normal physiological function of the body. Iron has oxidative properties and it can react with intestinal mucosa, which could become damaged by existing infections, which are widespread in India.
- Tuberculosis, malaria and other infections become uncontrollable when iron is given at the acute phase of these infections.
- Loss of other essential substances from the food: foods contain protective substances such as phytochemicals and polyunsaturated fat that are adversely affected by the process of blending micronutrients.
- Anaemia does not have 100% correlation with iron deficiency: There is no direct link between anaemia and iron deficiency. Anaemia is high among poor children in the rural areas but iron deficiency is more among the urban and rich across the country.
- High cost on subsidy: fortification will increase the cost of food delivered through the public distribution networks, putting burden on government finances.
- Impact on small industries: Fortification creates a market driven solution for a social problem of malnutrition. In absence of parity of opportunity for small and medium sized industry, their livelihoods can get threatened. We have seen this happening in rice and oil processing industry.
- Although government is ready to give incentives to medium and large rice millers for fortification of rice, the process itself is expensive and prohibitive for small players. An indicative cost of setting up rice fortification infrastructure for a medium-sized mill is Rs 3.2 crore, according to the government data.
- Suggestions/Measures
- A balanced, diverse and quality diet – will be a better option to meet the nutritional requiremts. National Institute of Nutrition has recommended that a diverse natural diet is required to meet the normal population need of micronutrients in its Nutrient Requirements of Indians released 2020.
- Less processed or unpolished rice – must be encouraged specially in the Public Distribution System. Less processed or unpolished rice are rich source of rice bran having many micronutrients.
- Nutrition rich processed food – local farmers can supply the nutritionally rich raw materials to micro, small and medium processors for food-to-food fortificants such as syrups, biscuits, porridge, powders, pudding etc. Food fortificants greatly improve nutrition, while supporting local livelihoods.
- Natural breast feeding with proper latching techniques can improve nutrition deficiency in the critical first 1,000 days.
- Organic farming technique naturally increase the nutritional content of food and also increases the absorption in the body.
- Nutri-gardens – Several studies have highlighted the importance of nutri-gardens or kitchen gardens. Vegetables grown there organically increase nutritional levels in the food.
- Mid-day Meal program and other school meal programs should enhance dietary diversity - adding animal and plant protein like eggs, dairy, pulses along with vegetables and fruit.

►TRANS FAT

- FSSAI has capped the amount of transfat acids (TFA) in oils and fats to 3% for 2021 and 2% by 2022 from the current permissible limit of 5% through an amendment to the Food Safety and Standards (Prohibition and Restriction on Sales) Regulations.
- The revised regulation applies to edible refined oils, vanaspati (partially hydrogenated oils), margarine, bakery shortenings and other mediums of cooking such as vegetable fat spreads and mixed fat spreads.
- It has been suggested that the regulation must not be restricted to oils and fats but must apply to all foods. It is hoped that the FSSAI will address this to eliminate chemical Trans fatty acids from the Indian platter.
- It was in 2011 that India first passed a regulation that set a TFA limit of 10% in oils and fats, which was further reduced to 5% in 2015.

TYPE OF TRANS FAT

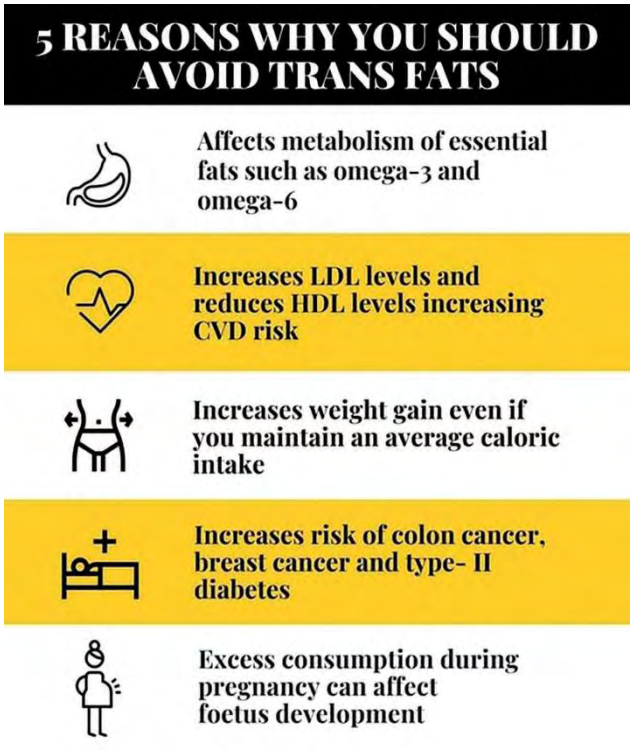
- Naturally occurring Trans fats are produced in the gut of some animals and foods made from these animals (e.g., milk and meat products) may contain small quantities of these fats.
- Artificial Transfats are created in an industrial process that adds hydrogen to liquid vegetable oils to make them more solid. Since they are easy to use, inexpensive to produce and last a long time, and give foods a desirable taste and texture, they are still widely used despite their harmful effects being well-known.

ASSOCIATED RISK WITH TRANS FAT

- Pose a higher risk of heart disease than saturated fats. While saturated fats raise total cholesterol levels, TFAs not only raise total cholesterol levels but also reduce the good cholesterol which protects us against

heart diseases. Trans fats consumption increases the risk of developing heart disease and stroke.

- Lead to compromised fetal development causing harm to the yet to be born baby.
- Some studies have found that Trans fats consumption is related to risk of cancers in individuals.
- Transfats are metabolized differently by the liver than other fats and interfere with normal liver functions.
- The risk of type 2 diabetes increases with trans-fat consumption. A study has found diabetes risk associated with Trans fats and other factors such as total fat intake and BMI.



- Transfat may increase weight gain and abdominal fat, despite a similar caloric intake. TFAs enhance deposition of fat even in the absence of caloric excess.
- Transfats are found to be associated with insulin resistance that poses a great risk to already diabetic patients.
- Transfats as opposed to that from carbohydrates, lead to greater risk of infertility in women.
- Those who ate the most Transfats are at higher risk of depression than those who do not eat Trans fats.
- Consumption of Transfats has been linked to behavioral irritability and increased general aggression.
- Replacing industrially produced TFA with healthier oils and fats is feasible without changing the taste of food or its cost to the consumer.

1. Step Taken by FSSAI

- Heart Attack Rewind: Thirty second public service announcement that will help support FSSAI's global target of eliminating trans-fat in India by 2022, a year ahead of global target by WHO for complete elimination of trans fat. It is a follow-up to an earlier campaign called "Eat Right."
- Eat Right Campaign: Edible oil industries took a pledge to reduce the levels of salt, sugar, saturated fat and trans-fat content by 2% by 2022.
- Swasth Bharat Yatra: An initiative started under "Eat Right" campaign is a Pan-India cyclotron to engage citizens on issues of food safety, combating food adulteration and healthy diets.
- FSSAI has directed that food establishments which use trans-fat free fats/oils and do not have industrial trans-fat more than 0.2 gms per 100 gm of food can display 'Trans Fat Free' logo in their outlets and on their food products.
- In 2018, WHO launched REPLACE action package to support governments to eliminate industrially produced TFA from global food supply by 2023. Approximately 5.4 lakh deaths take place each year globally because of the intake of industrially produced Trans fatty acids. WHO has called for the global elimination of Trans fats by 2023.

As part of SDG, global community has committed to reducing premature death from non-communicable diseases by one-third by 2030. Global elimination of industrially produced Trans fats can help achieve it.

MISCELLANEOUS

Previous Year Questions

YEAR	UPSC MAINS QUESTIONS
2021	How is S-400 air defence system technically superior to any other system presently available in the world?
2021	The Nobel Prize in Physics of 2014 was jointly awarded to Akasaki, Amano and Nakamura for the invention of Blue LEDs in 1990s. How has this invention impacted the everyday life of human beings?
2019	How is the government of India protecting traditional knowledge of medicine from patenting by pharmaceutical companies? (Answer in 250 words)
2015	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.
2014	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.
2013	Bring out the circumstances in 2005 which forced amendment to section 3(d) in the India n Patent Law, 1970. Discuss how it has been utilized by Supreme court in its judgment rejecting Novartis patent application for "Glivec." Discuss briefly the pros and cons of the decision.

►NEW EMERGING DEFENSE TECHNOLOGIES

ARTIFICIAL INTELLIGENCE

- Adoption of AI in defense enhances computational military reasoning for intelligence, surveillance, & reconnaissance (ISR) missions.
- Empowers autonomous weapon systems, thereby reducing soldier casualties.
- Machine learning helps in test new military product iterations & enable predictive maintenance for military assets.
- Deep fake technology could be used to generate false news reports, influence public discourse, erode public trust, and attempt blackmail of government officials. Deploying deep fake detection tools and labelling and authenticating content using AI is required.
- Israeli startup Axon Vision develops an AI-based decision-making engine. It detects, classifies, and estimates the whereabouts of threats in real-time.

- US-based startup Rebellion uses machine learning & data to deter threats & drive mission success.
- Big data analytics: Militaries with capabilities to extract most vital data, accurately and quickly analyze it, and then rapidly disseminate information will have a strategic advantage. To aid this, big data analytics unlocks insights from various data sources.

QUANTUM TECHNOLOGY

- Quantum computing finds applications in *cryptanalysis* & running simulations for informed decision-making.
- Quantum technology could have other military applications, such as quantum sensing, which could theoretically enable significant improvements in submarine detection, rendering oceans "transparent."
- Quantum sensing could provide alternative positioning and navigation options that could in theory allow militaries to continue to operate at full performance in GPS degraded or GPS-denied environments.

BLOCKCHAIN

- Blockchain provides data security while sharing data with all concerned parties.
- Other applications of blockchain technology in the industry include device tracking, streamlining the procurement process, and supply chain security.
- Smart contracts significantly reduce risk of fraud or corruption while dealing with defense contractors.
- US-based startup Taekion develops technology for military data protection. It leverages blockchain to secure defense data in tamper-proof storage.

ADVANCED DEFENSE EQUIPMENT

- Hypersonic flights**:** A number of countries, including the United States, Russia, and China, are developing hypersonic weapons—those that fly at speeds of at least Mach 5, or five times the speed of sound.
- In contrast to ballistic missiles, which also travel at hypersonic speeds, hypersonic weapons do not follow a parabolic ballistic trajectory and can maneuver en route to their destination, making defense against them difficult.
- Weapons to space militarization are underway.
- Investments in battlefield electrification techniques through electric propulsion and hydrogen fuels for military aircraft facilitate this transition.
- Defense organizations are advancing research in biotechnology and nanotechnology for creating self-healing armors and other innovative equipment.

DIRECTED ENERGY (DE) WEAPONS

- Directed energy (DE) weapons as those using concentrated electromagnetic energy, rather than kinetic energy, to "incapacitate, damage, disable, or destroy enemy equipment, facilities, and personnel."
- DE weapons could offer low costs per shot and—assuming access to a sufficient power supply.
- Enable an efficient & effective means of defending against missile salvos/swarms of unmanned systems.
- Theoretically, DE weapons could provide options for missile intercept, *given their* speed-*of-light travel time.*
- High-powered microwave weapons, a subset of DE weapons, could be used as a nonkinetic.
- Means of disabling electronics, communications systems, and improvised explosive devices, or as a nonlethal "heat ray" system for crowd control.

ROBOTICS & AUTONOMOUS SYSTEMS

- Protecting forces, increasing situational awareness, reducing soldiers' physical and cognitive workload as well as facilitating movement in challenging terrains are facilitated by Robots.
- Robots facilitate landmine clearance, search rescue operations, explosive ordnance disposal, and logistics support.
- Use of drones also enhances battlefield situational awareness.
- US-based startup *Anduril* offers an autonomous UAS for intelligent air support. The startup's product, Ghost, is an advanced drone system that uses edge AI algorithms.

INTERNET OF MILITARY THINGS (IOMT)

- Applications of IoT in defense include connecting ships, planes, tanks, drones, soldiers, and operating bases in a cohesive network.
- This enhances perception, understanding in the field, situational awareness, and response time.

EDGE COMPUTING, AI, 5G & BIG DATA ANALYTICS

- Support smooth flow of data across all branches of military, and this strengthens command-and-control structure.
- In IoMT, sensing and computing devices worn by soldiers and embedded in their equipment collect a variety of static and dynamic biometric data.
- US-based startup Geosite aggregates data from different sources for both human and machine analysis. The startup's collaborative military system uses satellites, IoT, and field sensors to build a common operating picture.

CYBERWARFARE

- Connected military equipment security, cyber protection for major institutions as well as in nuclear security are major areas of focus.
- Prescriptive security technology uses cybersecurity, AI, and automation to detect potential threats and stop them before they impact defensive cyber warfare capabilities.
- Militaries are also developing offensive cyber warfare capabilities ranging from malware and ransomware to phishing attacks.

IMMERSIVE TECHNOLOGIES

- Immersive technologies make it easy to build replicable and flexible experiences, such as for flight or combat training.
- Startups use virtual reality (VR) to construct synthetic training environments (STE). These experiences augment conventional training and mission rehearsal, improving the readiness of soldiers and units. Beyond training opportunities, augmented reality (AR) makes on-field soldiers more effective in their missions. Wearable glasses or AR headsets provide soldiers with mapping information, movement markers, and other data. This enhances real-time situational decision-making for ground forces.
- US-based startup ***GOVRED*** builds VR-based training solutions for the military.

ADDITIVE MANUFACTURING

- Reducing weight of defense equipment is crucial for improving performance in speed, capacity, and fuel consumption.

3D PRINTING

- Enables production of components and parts while utilizing significantly less material than traditional manufacturing.
- Reduces production costs
- Enables new design engineering possibilities and
- Localized, on-demand production, reducing the logistical burden.
- Facilitates creation of novel material combinations for armors, self-heating military clothing, and ammunition.
- Biotechnology could be used to create adaptive camouflage, cloaking devices, or lighter, stronger, and—potentially—self-healing body & vehicle armor.

CHANGING NATURE OF WARFARE & SECURITY

- Developments in technology like AI, big data analytics & lethal autonomous weapons could diminish or remove need for a human operator. This could increase combat efficiency and accelerate pace of combat—potentially with destabilizing consequences.
- AI could be paired with 5G communications technologies to enable virtual training environments or with biotechnology in a "brain-computer interface" to enhance human cognition or control prosthetics or robotic systems. Such developments could require new strategies, tactics, and concepts of operation.
- Emerging technologies such as low-cost drones could shift balance between quality—upon which U.S. military forces have traditionally relied—and quantity, as well as between offense and defense. Ex. swarms of coordinated, unmanned vehicles could overwhelm defensive systems, providing a greater advantage to the attacker, while directed energy weapons that provide a low-cost means of neutralizing such attacks, could favor the defender. Thus, emerging technologies could shift the offense-defense balance multiple times over the coming decades.
- Interactions among emerging technologies could improve existing military capabilities or enable new capabilities—with unforeseen consequences for warfighting and strategic stability. Ex, an enabling technology like AI could be paired with quantum computing to produce more powerful methods of machine learning, potentially leading to improvements in image recognition, target identification & enabling more sophisticated autonomous weapons.
- Emerging military technologies—particularly complex systems such as AI & LAWS—could produce unintended consequences if they fail to perform as anticipated. These consequences could range from system failure to violations of law of armed conflict. In most extreme case, an autonomous weapon could continue engaging inappropriate targets until it exhausts its magazine, potentially over a wide area. This could, in turn, result in mass fratricide or civilian casualties—a possibility that has led some analysts to call for a pre-emptive ban on LAWS.
- Emerging military technologies could raise an array of ethical considerations. Ex, Use of LAWS would be inherently immoral— regardless of whether the weapon could be used legally—because a human operator would not make specific target selection and engagement decisions.
- Ethical concerns about applications of biotechnology that involve human testing or modification and weaponization of biotechnology, which could potentially be used for targeted genetic attacks.

►NATIONAL HYDROGEN MISSION

National Hydrogen Mission has been launched by the Prime Ministry with the intention to make India world's largest exporter of green hydrogen.

NATIONAL HYDROGEN MISSION

- It was announced during Budget 2021 by Finance Minister.
- Hydrogen is usually produced using electrolysis method of water, which breaks into Oxygen and Hydrogen, natural gas, and coal. Based on the source of fuel used to produce the electricity used to feed with electrolysis, hydrogen is classified into:
  - Blue Hydrogen: Hydrogen produced using conventional energy sources along with carbon capture and storage.
  - Green Hydrogen: Hydrogen produced using entirely green energy sources. This hydrogen is entirely green and environment friendly.
  - Grey Hydrogen: Hydrogen produced using natural gas using steam reforming process. 96% of Hydrogen today is produced using this method.
  - Brown hydrogen: Hydrogen produced using coal using gasification process. However, it leads to carbon emissions.

WAYS OF USING HYDROGEN AS FUEL

- Hydrogen CNG: Mixture of hydrogen and CNG in a fixed ratio. (Used as transportation fuel). Thus, it enables Hydrogen being used as fuel in conventional engines. HCNG increases the efficiency of combustion of CNG and is less polluting.
- Hydrogen Fuel Cell: Fuel cells based on Hydrogen and Oxygen. Produces Water as by-product.

National Hydrogen Mission

Major Activities envisaged

- Creating volumes and infrastructure
- Demonstrations in niche applications (including for transport, industry)
- Purposeful Research & Development; facilitative policy support
- Putting in place a robust framework for standards and regulations for hydrogen technologies
- Envisages generation of hydrogen from green power sources
- Aims to develop India into a global hub for manufacturing of hydrogen and fuel cells technologies
- GoI will facilitate demand creation in identified segments. Possible areas include suitable mandates for use of green hydrogen in industry such as fertilizer, steel, petrochemicals etc.

USES OF HYDROGEN

- Hydrogen is the fuel of stars and packs amazing energy. It is additionally the most significant element in the universe. On Earth, it is found in compounds like water or hydrocarbons. However, Hydrogen is not present in Free State. Therefore, it must be created and put away before it tends to be utilized.
- By-product of Hydrogen as a fuel is water.
- Presently, hydrogen is used refining industry, ammonia making, methanol manufacturing, steel making industries and other uses.

HYDROGEN'S DISRUPTIVE POTENTIAL

Fuel uses

- Transportation: Fuel cell EVs and heavy-duty fuel cell trucks. Feedstock for synthetic fuels. However, at current technology, it will be a costly mode of transport. HCNG is being used in India where Hydrogen is being used in mixture with CNG for higher efficiency.
- Energy storage: Integration of variable renewables via hydrogen production and long duration storage.
- Engines/turbines: Generation by fuel cell, co-firing of gas turbines or combined heat and power to increase power system flexibility.

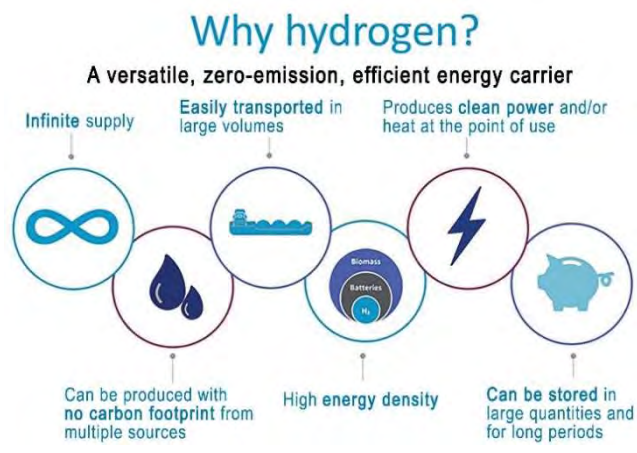
Chemical uses

- Can be used as a decarbonizing agent in industries like synthetic compounds, iron, steel, compost and refining, transport, warmth, and force.
- Petroleum recovery and refining: Enhanced oil recovery, increasing well pressure, hydrocracking and desulfurization of crude and products.
- Electronics: Semiconductors, LED displays, photovoltaic
- Chemical production: Methanol, ammonia, urea for fertilizer production.

Industrial uses

- Industrial heat: High grade heat for metals refining, cement production.
- Building heat: Decarbonization of gas grid through direct hydrogen injection, combined heat and power cells.

- Industrial feedstock: Replacement of fossil hydrogen use with low carbon hydrogen. Direct reduction of iron.



DRIVERS OF INTEREST IN GREEN HYDROGEN

1. Low renewable energy electricity cost: Major cost driver for green hydrogen is cost of electricity. The price of electricity procured from solar PV and wind energy plants has decreased substantially in the last decade making production of green hydrogen economically attractive. India has one of lowest cost of renewable energy production.
2. Technologies ready to scale up: Many technologies in hydrogen value chain have already been shown to work at small scale and are ready for commercialization, requiring investments to scale up. Ex. Capital cost of electrolysis has fallen by 60% since 2010. Cost of fuel cells for vehicles has decreased by 70% since 2006.
3. Benefits for power systems: As share of renewable power sources such as solar and wind increases in overall electricity consumption, power systems will need for flexibility. Electrolysers used to produce green hydrogen can be designed as flexible resources than can quickly ramp up or down to compensate for fluctuations in renewable energy production, by reacting to electricity prices. Green hydrogen can be stored for long period and can be used when renewable energy is not available for power generation with stationary fuel cells or hydrogen-ready gas turbines.
4. Addressing climate change and need for net zero emissions: green hydrogen can play an important role in decarbonizing hard-to-abate sectors such as cement, steel, chemicals such as plastics and heavy-duty transport such as trucking, container shipping and aviation.

KEY CHALLENGES TO HYDROGEN ECONOMY

- Storage capacity requirement: India has insufficient storage capacity for the current state of domestic consumption.
- Infrastructure requirements for Hydrogen Highway: It would also require large investments in underground piping and underground caves and filling stations.
- Safety Issues: Hydrogen is highly flammable and explosive in nature, it is colorless, odorless, and its flames are not visible by naked eyes.
- Purity of Hydrogen: When Hydrogen is used as a part of fuel cells, one requires ultra-high purity hydrogen.
- Environmental concerns: Most hydrogen is currently produced using fossil fuel reformation process. This would lead to higher rate of carbon emissions than if the fossil fuels are used directly. Producing Hydrogen from clean energy sources is costly.

WAY AHEAD

- Development of technology to produce "green" hydrogen is expensive. However, falling prices for renewable energy and fuel cells and stringent climate change regulations have spurred investment in the sector.
- Developing standardized procedures, rules and standards for hydrogen economy which will standardize and scale up production.
- Investing in R&D and promoting private sector participation in hydrogen economy.
- Mandating large users of hydrogen to shift to green hydrogen such as refineries, iron, and steel plants etc. For ex. A minimum green hydrogen mandate can be introduced in such industries.
- Using existing infrastructure such as that of natural gas for hydrogen economy.
- Facilitating international trade in clean & green hydrogen.
- Green hydrogen facilities can be created at sites where cost of producing renewable energy is lowest. Ex. In Thar desert region in Rajasthan and Ladakh etc.

►HYDROGEN COMPRESSED NATURAL GAS

ABOUT H-CNG

- H-CNG is a blend of hydrogen and CNG, (i.e.: hydrogen+ CNG), the ideal hydrogen concentration being between (18-20) %.
- CNG is compressed natural gas. It is composed mainly of methane and emits much less air pollutants than petrol or diesel. The emissions of carbon dioxide,

carbon monoxide, nitrogen oxides and particulate matter are much less thus resulting in less air pollution.

WHY IS IT NEEDED?

Crude oil, petrol and diesel are non-renewable sources of energy and causes pollution. There is release of oxides of carbon, nitrogen and particulate matter (PM 2.5 & 10). This pollutes the air to alarmingly high levels and leads to health hazards. It causes lung cancer, stroke and heart diseases in humans along with environmental hazards like ground level smog and the deteriorating. Air Quality Index in most of the major cities in India.

Recently a study funded by the Indian government and the Bill & Melinda Gates Foundation, it was found that in 2017. 1.24 million people died in India due to air pollution, that is, 1 out of 8 deaths in India were caused by air pollution.

A report of the World Trade Organisation also said that the top 14 most-polluted cities in the world are in India and Delhi ranked six. The Rising levels of pollution have been a major cause of concern in the National Capital Delhi.

There has been a constant pressure on Governments to reduce the Carbon footprints and stopping the effects of climate change. This has forced the research towards alternative fuels.

So, alternative and cleaner fuels like HCNG, CNG, LPG, Alcohol fuels, electricity and biofuels are being explored. Electricity can be generated by sources like nuclear energy, wind power, solar energy, etc., as cleaner options.

Acting as per recent orders of Supreme Court of India to check it, Delhi Government is planning to push Hydrogen-enriched CNG buses on its roads.

Hydrogen for H-CNG fuel is being produced through electrolysis. Electrolysis is the decomposition of water into hydrogen and oxygen. The hydrogen produced is blended with CNG to fuel vehicles. In addition to the electrolyser, the station has a compressor along with a buffer storage facility.

ADVANTAGES OF USING H-CNG

- Use of HCNG reduces emissions of CO up to 70% as compared to CNG.
- First step towards future Hydrogen economy. A hydrogen economy would help us in achieving sustainable development goals and will also reduce India's carbon footprint. H-CNG will give more hydrogen efficiency as compared to CNG.
- CNG Engines can be easily altered to make it H-CNG friendly releasing lower amounts of NO, CO.
- Ideal fuel for high load applications and heavy-duty vehicles.
- Better performance due to higher Octane rating of H2.

DISADVANTAGES OF USING H-CNG

- Determining most optimized H2/NG (Natural Gas) ratio. Even though it is made to be between 18-20%, the optimised levels are yet to be finalised.
- Requires new infrastructures for preparing HCNG. It will require hydrogen reservoirs which is very expensive.
- Many steps need to be taken for commercializing it at a large scale.
- Current cost of Hydrogen is more than the cost of Natural Gas. The new electrolysis methods that are being implemented to split water to hydrogen and oxygen will require more infrastructure and will also require reservoirs. So, HCNG's cost is more than CNG.

►FUEL CELL

WHAT IS A FUEL CELL?

A fuel cell is an electrochemical cell that converts the chemical energy of a fuel (often hydrogen) and an oxidizing agent (often oxygen) into electricity through a pair of redox reactions. Fuel cells are different from most batteries in requiring a continuous source of fuel and oxygen (usually from air) to sustain the chemical reaction, whereas in a battery the chemical energy usually comes from metals and their ions or oxides that are commonly already present in the battery. Fuel cells can produce electricity continuously for as long as fuel and oxygen are supplied.

Fuel Cells don't require electrical recharging. A battery stores all its chemicals inside and coverts the chemicals into electricity.

The products of the reaction in the cell are water, electricity, and heat. This is a big improvement over internal combustion engines, coal burning power plants, and nuclear power plants, all of which produce harmful by-products.

BENEFITS OF FUEL CELLS

Environmental Performance: Hydrogen fuel cells don't produce air pollutants or greenhouse gasses. Hydrogen fuel cells only produce heat and water – no toxins, particles, or greenhouse gasses, which means cleaner air for us to breathe.

Energy Efficiency: Fuel cells are 2 to 3 times more efficient than combustion engines. For co-generation applications, where fuel cells generate both heat and electricity, efficiency is as close as 80%.

Fuel Flexibility: There are many types of fuel cells, and many different materials can be used for energy generation like hydrogen, natural gas, methanol, ethanol, and biogas.

Versatile: Fuel cells are scalable and provide everything from milli-watts to megawatts of power in a variety of uses. It can be used in cell phones, cars, and a variety of devices.

Complementary: Fuel cells can readily be combined with other energy technologies such as batteries, wind turbines, solar panels, and super-capacitors.

Products of the reaction in the cell are water, electricity, and heat. This is a big improvement over internal combustion engines, coal burning power plants, and nuclear power plants, all of which produce harmful by-products

Anode, the negative post of the fuel cell, has several jobs. It conducts the electrons that are freed from the hydrogen molecules so that they can be used in an external circuit. It has channels etched into it that disperse the hydrogen gas equally over the surface of the catalyst.

Cathode, positive post of fuel cell, has channels etched into it that distribute the oxygen to the surface of catalyst. It conducts the electrons back from the external circuit to the catalyst, where they can recombine with the hydrogen ions and oxygen to form water.

Electrolyte is the proton exchange membrane. This specially treated material, which looks something like ordinary kitchen plastic wrap, only conducts positively charged ions. The membrane blocks electrons. For a PEMFC, the membrane must be hydrated to function and remain stable.

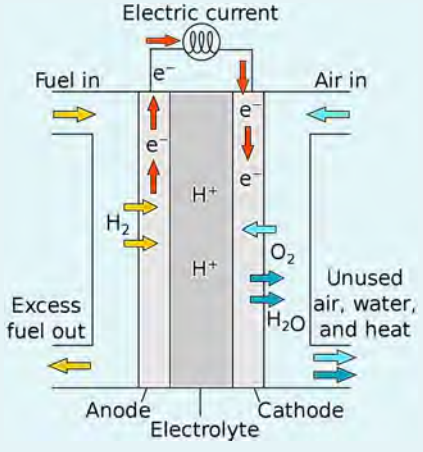
Catalyst is a special material that facilitates the reaction of oxygen and hydrogen. It is usually made of platinum nanoparticles very thinly coated onto carbon paper or cloth. The catalyst is rough and porous so that the maximum surface area of the platinum can be exposed to the hydrogen or oxygen. The platinum-coated side of the catalyst faces the PEM.

►FUEL CELL ELECTRIC VEHICLES

- FCEVs use a propulsion system similar to that of electric vehicles, where energy stored as hydrogen is converted to electricity by the fuel cell.
- The electricity powers the motor while the harmless water vapour is released into the atmosphere.
- Hydrogen fuel cell cars are refuelled with hydrogen at specific service stations that contain pressurised tanks
- FCEVs are equipped with other advanced technologies to increase efficiency, such as regenerative braking systems that capture the energy lost during braking and store it in a battery.

HOW FUEL CELLS WORK

- A fuel cell is a device that produces electric energy, through a chemical reaction.
- The chemical energy of hydrogen or other fuels to cleanly and efficiently produce electricity. If hydrogen is the fuel, the only products are electricity, water, and heat.



- The most common type of fuel cell for vehicle applications is the polymer electrolyte membrane (PEM) fuel cell.
- In a PEM fuel cell, an electrolyte membrane is sandwiched between a positive electrode (cathode) and a negative electrode (anode).
- Hydrogen is introduced to the anode, and oxygen (from air) is introduced to the cathode.
- The hydrogen molecules break apart into protons and electrons due to an electrochemical reaction in the fuel cell catalyst. Protons then travel through the membrane to the cathode.
- The electrons are forced to travel through an external circuit to perform work (providing power to the electric car) then recombine with the protons on the cathode side where the protons, electrons, and oxygen molecules combine to form water.

COMPARISON OF BEV AND FCEV

Parameters	Comparison
Range	Hydrogen fuel cell vehicles offer

	greater ranges and faster refuelling times too. Most models exceed 300 km of range on a full tank.
Cost	Hydrogen-powered cars are not cheap and refuelling prices differ considerably between countries. Electric vehicles are cheaper and the cost of recharging is also less during off-peak grid times, making electric vehicles a good long-term investment.
Infrastructure requirement	The infrastructural requirement for electric vehicles is much higher that for hydrogen-powered vehicles in terms of charging stations at existing petrol stations and motorway rest stops. But present infrastructure hydrogen vehicle is less – only around 400 hydrogen refuelling stations currently in the world
Safety	Safety has been seen as a key concern for hydrogen fuel cells, due to the highly flammable nature of hydrogen gas. Electric batteries also come with their safety concerns and challenges. If lithium-ion batteries are allows to overheat or overcharge they can cause injury. Plus, should there be a fire, the batteries can ignite and are difficult to put out as the fuel for the fire is not vented away as with hydrogen.
Environmental friendliness	Manufacturing lithium-ion batteries is an energy-intensive process also requires efficient recycling of spent batteries. FCEV produces 120g of CO_2 per kilometre, although this can be greatly reduced with green hydrogen.

Both require further research and development, with electric vehicles needing efficient recycling of spent batteries, faster charging times and increased ranges. Hydrogen, meanwhile, needs improved infrastructure and reduced costs for extraction of hydrogen gas for fuelling.

In the meantime, hybrid options could prove to be a workable solution, but ultimately the goal is to replace combustion engines to provide a clean, green and renewable transport future.

SIGNIFICANCE OF FCHV

- Technological advancement
  - Green Hydrogen based ecosystem in the country
  - Promotion of Green Hydrogen based ecosystem in the country.
  - Unique production method of green house gases from renewable energy and abundantly available biomass. IISc has announced the development of *new technology to* produce *green hydrogen from biomass.*
  - Diversification of economy - Fuel cells, semiconductors, controllers, etc.
  - Skilled human resource
- Strengthening of Economy
  - Reducing import dependence on fossil fuels and thereby make India 'Energy Self-reliant' by 2047.
  - Transportation revolution: The transition to electric mobility is a promising global strategy for decarbonising the transport sector.
  - Efficiency in different industries - Hydrogen produced as a by-product from steel plant, waste plastic plant, brine electrolysis etc can be tapped.
- Environmental sustainability
  - Unlike conventional internal combustion engine vehicles, these vehicles produce no harmful tailpipe emissions. It will drive the global climate agenda established under the Paris Agreement to reduce carbon emissions in order to limit global warming.
  - India has the target of producing 40% of electricity from renewable sources.
- Governance - ISRO, CSIR, IISc, ITOL, TATA Labs etc are already working on Hydrogen based researches. They will get further boost.
- International Relation – Lesser dependence on China.

However, in India, so far, the definition of EV only covers BEVs; the government has lowered taxes to 12%. At 43%, hybrid electric vehicles and hydrogen FCEVs attract the same tax as IC vehicles.

►ALGAE BIOFUELS

Microalgae are photosynthetic microorganisms that are seen as the next big sustainable source of clean energy. Biofuel experts have been working to find an economically

viable way to turn algae into bio-crude oil to power various types of vehicles.

Microalgae are found in abundance in marine eco-systems and provide food for higher animal forms.

Marine algae have the power to simultaneously fuel vehicles, recycle carbon dioxide, and provide nutrition to animals and humans.

Algae can also be used to produce hydrogen (for use in fuel cells), and production of methane.

It is a highly clean fuel and emissions are minimal.

It can be grown on brackish or polluted water and does not require freshwater resources either.

Potential for India: There is scope for both small-scale (as cottage industries) and large-scale algal farming here. Algae as biofuel can be an ideal solution for India's impending fuel crisis, as India's long coastal region and tropical climate can facilitate the cultivation of algae in India in mass scale. This calls for strong and dedicated action by the government. Pilot projects are being undertaken in Bhavnagar, Gujarat.

►LITHIUM-ION BATTERIES

Lithium-ion batteries are rechargeable, lightweight batteries having revolutionized safe energy-storage. Their high efficiency compared to internal combustion engines makes them an ideal choice for Electric Vehicles. Batteries constitutes major constituent of electric vehicles, developing manufacturing capabilities of Li-ion batteries is a must for electric vehicle revolution in India.

ADVANTAGES OF LI-ION BATTERIES

Light weight: Li-ion batteries are the lightest batteries because lithium is the lightest metal available.

High Energy Density: Lithium being a highly reactive element, it has high energy density. Compared to a lead-acid battery, Li-ion battery weighs 6 times less to store the same amount of energy.

Low Maintenance: Low self-discharge capability of Li-ion batteries enables it to be recharged before it completely discharges, making it easily rechargeable just like any other fuel.

CHALLENGES TO LI-ION BATTERY MANUFACTURING

Nascent industry: Li-ion battery manufacturing is a nascent industry in India. Currently Li-ion batteries are imported mostly from China, South Korea and Taiwan.

High manufacturing cost: Li-ion batteries are around 40% more costly to manufacture than Lead-acid batteries.

Resource crunch: Li-ion battery use lithium, cobalt, nickel and manganese which are in short supply in the world (restricted to Bolivia, Chile).

Difficult switch: Given that internal combustion engine has more than 2000-odd moving parts, the survival of MSME landscape in India currently depends on manufacturing of these auto part. This has hindered the switch to EVs which have significantly a smaller number of auto components (20-odd) in turn hindering the growth of Li-ion battery manufacturing in India.

To give a push to Li-ion battery manufacturing in India, ISRO recently announced a technology transfer package to competent Indian industries for setting up local production units.

BATTERY SWAPPING

Battery swapping is proposed as a method to facilitate the proliferation of electric vehicles in India. An alternative battery recharging method that is receiving global attention is battery swapping, in which a depleted EV battery is removed from the vehicle and replaced with a fully charged one. The technology is being tried out for various EV segments, including e-2Ws, e-3Ws, e-cars and even e-buses.

Advantages of Battery Swapping:

1. EV recharging is completed in minutes.
2. Batteries can be charged away from swapping point, allowing more freedom in setting up swap facilities.
3. Reduction in upfront cost of EV, as battery ownership is replaced by battery leasing.
4. Increased predictability of battery life due to controlled charging conditions.

Challenges for mass-adoption of Battery Swapping:

1. Lack of standardization among EV batteries.
2. Unsuitable battery pack design to enable ease of swapping (weight, dimensions and ergonomics)
3. Greater number of batteries needed to power same number of EVs
4. Shorter commercial life of battery packs due to customer preference for new batteries with higher range.
5. Slow adoption of charging method by OEMs
6. Higher costs of battery leasing over the life of EVs.

7. Higher GST on separate battery (18%) vs. battery sold with EVs (5%).

►AUTONOMOUS VEHICLES

Autonomous vehicles are light motor vehicles with highest level of automation such that they can drive without a human driver and thus are also called self-driving cars.

Autonomous vehicles primarily use sensors (cameras, radars, lidar etc.), navigation and communication systems to collect data from the environment including roads, other vehicles, traffic signals, sign boards etc.

AI-based processing systems & electronic control systems process and send data to electro-mechanical systems that run car based on the data so obtained.

CHALLENGES

- Reliability: Autonomous vehicles are effective in homogenous and predictable driving conditions. Unpredictable driving conditions of Indian roads characterized by narrow lanes; difficult terrains make AI-based systems unreliable.
- Infrastructure: Autonomous vehicles sense cues from environment via communication with objects like traffic signal, parking lots, sign boards etc. Thus, infrastructure needs to be upgraded, which is both cost and time intensive.
- Legal and regulatory standards: Before we migrate into autonomous vehicles, strict legal and regulatory standards should be in place. Designing appropriate legislations is a challenge particularly with respect to licensing, driver liability, insurance, traffic violations etc. Besides given use of elaborate communication technologies, privacy and data protection risks may arise.
- Safety: Failure of any AI-system may lead to fatal accidents.
- While autonomous cars are said to revolutionize sustainable mobility in urban areas, the above challenges should be overcome for their widespread use.
- An autonomous vehicle, or a driverless vehicle, is one that can operate itself and perform necessary functions without any human intervention, through ability to sense its surroundings.

ADVANTAGES

Autonomous vehicles may be able to provide certain advantages compared to human-driven vehicles. One such potential advantage is that they could provide increased safety on the road – vehicle crashes cause many deaths every year, and automated vehicles could potentially decrease the number of casualties as the software used in them is likely to make fewer errors in comparison to humans. A decrease in the number of accidents could also reduce traffic congestion, which is a further potential advantage posed by autonomous vehicles. Autonomous driving can also achieve this by the removal of human behaviours that cause blockages on the road, specifically stop-and-go traffic.

Another possible advantage of automated driving is that people who are not able to drive – due to factors like age and disabilities – could be able to use automated cars as more convenient transport systems.

Additional advantages that come with an autonomous car are elimination of driving fatigue and being able to sleep during overnight journeys.

DRAWBACKS

Expensive: This technology is currently expensive. For now, however, most companies have not released a price for their driverless cars.

Potential for Technology to Go Wrong: Even if a self-driving car performs flawlessly at first, it is possible for programming that runs the cars to be updated with a fault. Errors like this cause annoyance for computers and mobile devices but could potentially cause car accidents with self-driving cars.

Licensing Infrastructure Not Yet in Place: The companies claim these cars are safe, yet it is up to public institutions to keep drivers safe. Not only do our local car licensing offices need to make sure these cars perform as advertised, but they also need to come up with a way to license and control them quickly and efficiently. Should our technology and hunger for these cars outpace our ability to investigate and approve them, public safety may be at risk.

Potential for Greater Pollution: While many companies are looking at self-driving cars that use fuel-efficient or hybrid models, should our access to self-driving cars outpace our commitment to clean energy, we may be looking at much more pollution. Getting out of your car at the front of the movie theatre without needing to park sounds good in theory, but if the car you're driving isn't

electric, emissions would be worse than leaving your car idling while you watch the movie.

Potential Loss of Privacy: Using a self-driving car means a third party would have the opportunity to track your movements. This can lead to a massive loss of privacy. Because your car would be receiving or communicating with data centres, your location would be potentially accessible to people or organizations who could hack into the network.

Driver Accountability: Currently, regulations on road transport assume that the driver is responsible for actions of the car. Thus, in case of an accident, the driver is held accountable and punished. Drivers are required

All in all, self-driving cars have the potential to be an incredible new wave in the future of humanity. Increased productivity, rest time, and possibly eliminating risk while driving, have the potential to greatly improve all our lives.

►DEEP OCEAN MISSION

It is a mission under Ministry of Earth Sciences, which aims to explore Deep Ocean for resources and develop the deep-sea technologies for sustainable use of ocean resources.

MAJOR COMPONENTS OF DEEP OCEAN MISSION

1. Development of Technologies for Deep Sea Mining and Manned Submersible: A manned submersible will be developed to carry 3 people to a depth of 6,000 m in ocean with suite of scientific sensors & tools. Only a few countries have this capability. An Integrated Mining System will be developed for mining Polymetallic Nodules from 6,000 m depth in Central Indian Ocean. Exploration studies of minerals will pave way for commercial exploitation in near future, as and when commercial exploitation code is evolved by International Seabed Authority, a UN organization. This component will help Blue Economy priority area of exploring and harnessing of the deep-sea minerals and energy.
2. Development of Ocean Climate Change Advisory Services: A suite of observations and models will be developed to understand and provide future projections of important climate variables on seasonal to decadal time scales under this proof-of-concept component. This component will support the Blue Economy priority area of coastal tourism.
3. Technological Innovations for Exploration and Conservation of Deep-Sea Biodiversity: Bioprospecting of deep-sea flora and fauna, including microbes and studies on sustainable utilization of deep-sea bio-resources, will be focus. This component will support Blue Economy priority area of marine fisheries and allied services.
4. Deep Ocean Survey and Exploration: The primary objective of this component is to explore and identify the potential sites of multi-metal Hydrothermal Sulphides mineralization along the Indian Ocean mid-oceanic ridges. This component will additionally support the Blue Economy priority area of deep-sea exploration of the ocean resources.
5. Energy and Freshwater from the Ocean: Studies and detailed engineering design for offshore Ocean Thermal Energy Conversion (OTEC) powered desalination plant are envisaged in this proof-of-concept proposal. This component will support the Blue Economy priority area of offshore energy development.
6. Advanced Marine Station for Ocean Biology: This component is aimed as development of human capacity, enterprise in ocean biology and engineering. This component will translate research into industrial application and product development through on-site business incubator facilities. This component will support the Blue Economy priority area of marine biology, blue trade and blue manufacturing.

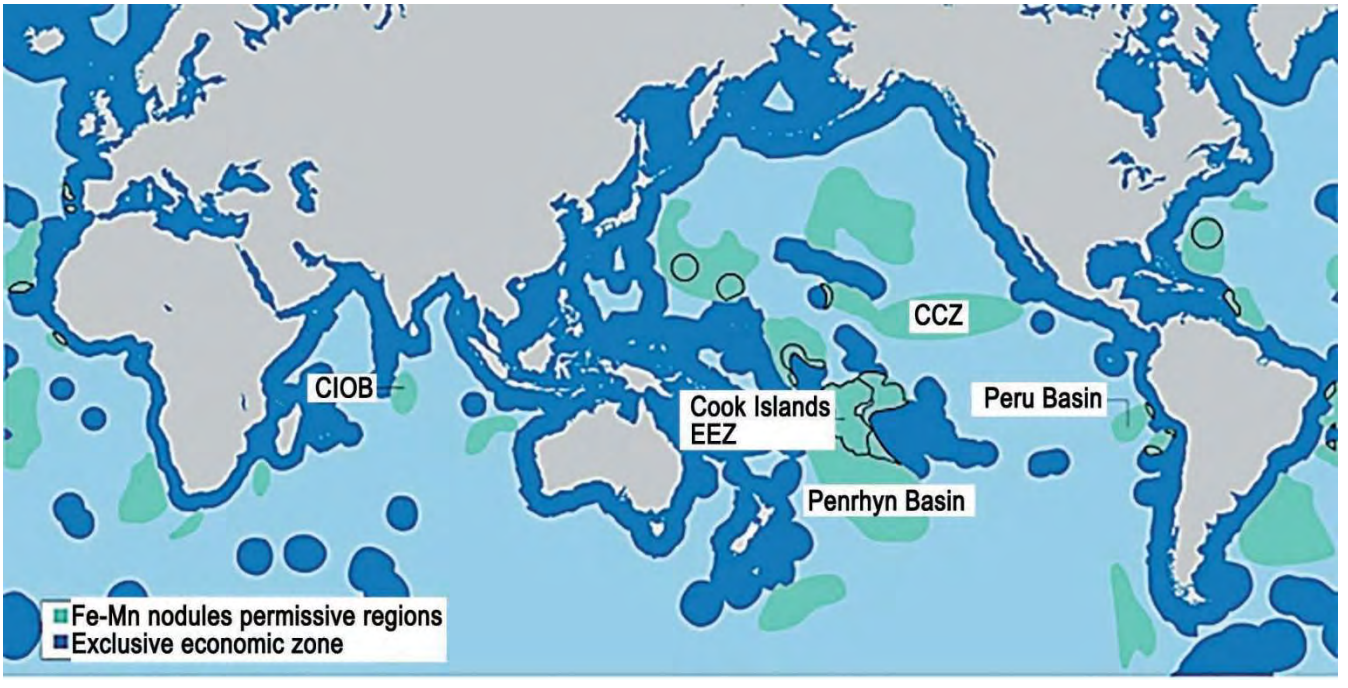
ABOUT POLYMETALLIC NODULES

Polymetallic nodules are found in abundance at Central Indian Ocean Basin (CIOB) in depths of 5,000 m – 6,000 m. An area of 75,000 sq. km. in CIOB was allocated by the preparatory commission, the International Seabed Authority (ISA), UN, to the Government of India as pioneer investor for exploration and development of technology to mine these Polymetallic nodules from a depth of 5,000-6,000m. This region lies outside of India's Exclusive Economic Zone.

IMPORTANT REGIONS FOR POLYMETTALLIC NODULES

1. Clarion-Clipperton Zone (CCZ) in the Central Pacific Ocean.
2. Peru Basin in the Southern Eastern Pacific Ocean.
3. Penrhyn Basin in the South-Western Pacific Ocean.
4. Central Indian Ocean Basic in the Indian Ocean.

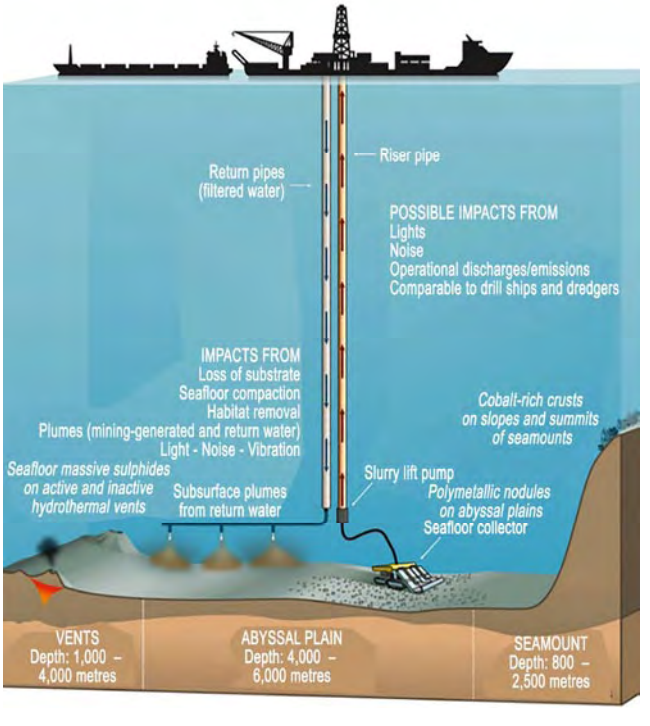
The nodules contain nickel, copper and cobalt (around 2% - 3% of the nodule weight), as well as traces of other metals such as molybdenum, Rare Earth Elements and lithium, which are important to high-tech industries. The amount of copper contained in the CCZ nodules is estimated to be about 20% of that held in the global land-based reserves.



Map showing regions rich in Polymetallic nodules.

SIGNIFICANCE

1. About 95% of Deep Ocean remains unexplored. Oceans are storehouse of food, energy, minerals, medicines, modulator of weather and climate and underpin life on Earth.
2. Increasing depletion of land resources.
3. Ever-increasing demand for metals and minerals due to increasing population, transition to green technologies etc. have led to global interest in marine mineral resources. Metals such as nickel, cobalt and rare-earth metals play a crucial role in promoting renewable energy technologies needed to curtail global warming and environmental and social costs often linked to existing terrestrial mining practices.
4. Gas hydrates deposits may contain roughly twice the carbon contained in all reserves of coal, oil and conventional natural gas combined.
5. The availability of these minerals on land is reducing.
6. Mining of polymetallic nodules gives us access to 3-4 minerals. This
7. In the context of global movement towards green technologies, metals such as nickel and cobalt have a central place. These minerals are not available in India. Also, there is a global shortage for these minerals at the global level as well. Thus, Thus, exploring and harnessing
8. Deep ocean technology is of strategic importance and is not commercially available. Hence, attempts will be made to indigenize technologies by collaborating with leading institutes and private sector.
9. Ocean mineral resources: Polymetallic nodules are source of critical minerals, deep sea fishing and mining of methane hydrates.



CHALLENGES

1. These technologies are often not shared by countries. Neither can they be bought on commercial basis from private companies.
2. Environmental consequences for deep ocean mining:

(a) Disturb the ocean floor destroying deep-sea habitats, leading to loss of species and fragmentation or loss of ecosystem.

(b) Deep ocean mining can stir up fine sediments on the seafloor consisting of clay, silt and remains of microorganisms creating plumes of suspended particles. These sediment plumes may affect ecosystems and species such as filter feeders that depend on clean, clear water to feed such as krill and whale sharks.

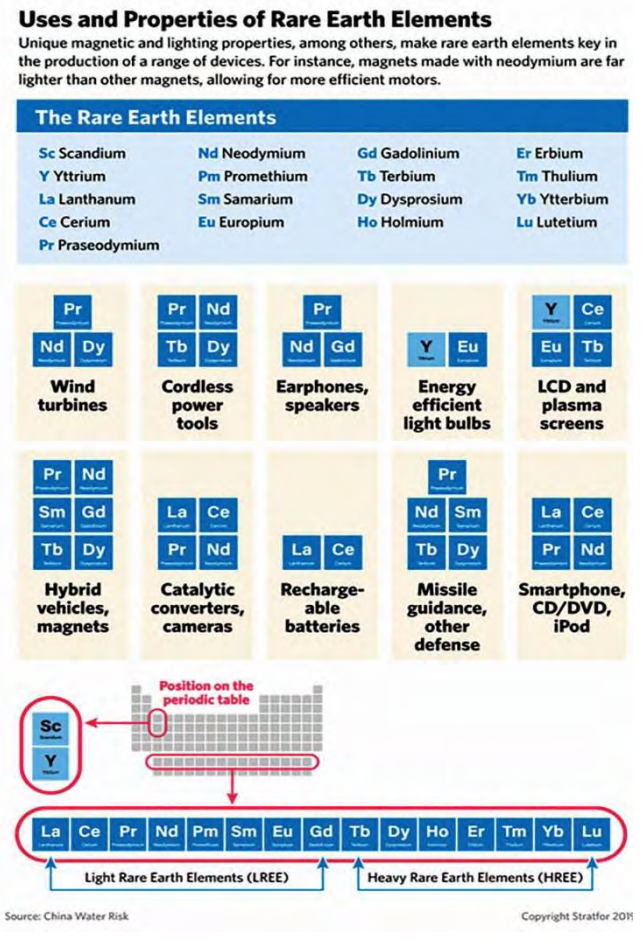
(c) Noise, vibrations and light pollution caused by mining equipment and potential leaks and spills of fuel can adversely affect marine biodiversity.

WAY FORWARD

1. International technology collaboration for development of critical technologies.
2. Adequate budgetary support for the program.
3. India should expedite and apply for more area for mining of deep ocean resources from the International Seabed Authority.
4. Effective coordination and program of action should be chalked out for the program.
5. Adequate steps should be taken to limit the adverse effects of deep ocean mining on environment.

►RARE EARTH METALS

- They are a collection of 17 metal elements, including 15 lanthanides in the periodic table, plus scandium and yttrium, their physical and chemical properties are like lanthanides.
- *17 kinds of rare earth elements: cerium (Ce), dysprosium (Dy), erbium (Er), europium (Eu), gadolinium (Gd), holmium (Ho), lanthanum (La), lutetium (Lu), neodymium (Nd), Pr (Pr), promethium (Pm), samarium (Sm), scandium (Sc), terbium (Tb), thulium (Tm), ytterbium (Yb) and yttrium (Y).*
- These minerals have unique magnetic, luminescent, and electrochemical properties, so they are used in many modern technologies, including consumer electronics, computers and networks, communications, medical care, national defense, etc.
- These REEs are even used by future technologies (such as temperature superconductivity, safe storage) and transportation of hydrogen after hydrocarbon economy, global warming, and energy efficiency).
- Rare earth elements are called so because they are available in trace amounts on Earth. Also, it is technically difficult to extract them from their oxides.
- China dominates the global rare-earth production. As tensions rise between the West and China, there is a fear of disruption on rare earth metal supply chains. China produces 60% of world's production.



INDIA'S CURRENT POLICY ON RARE EARTHS

- India has world's fifth largest reserves of rare-earth elements, despite that India's imports its requirement of rare earth metals from China. Most of India's Rare Earth resources are found in Monazite sands found in coastal areas.
- Geological surveys in India are conducted by Bureau of Mines and Ministry of Atomic Energy is nodal ministry for their production.
- Mining and processing of rare earths are concentrated in the hands of IREL (India) Limited

(formerly India Rare Earth Limited), a company owned by the Ministry of Atomic Energy.

- IREL's primary focus has been on exploitation of monazite sands from which thorium is extracted.
- India has granted government companies such as IREL the right to monopolize the main REE mineral monazite beach sand.
- IREL mainly produces rare earth oxides low cost, low-reward upstream process. It sells rare earth oxides to foreign firms that extract metals and manufacture high end products (high-cost, technology intensive, high return downstream process) elsewhere.

WAY FORWARD

1. India must open its rare earth mining and processing industry for private sector. This will increase competition and innovation.
2. A Dedicated Cell focusing of Rare Earths should be created. This cell can focus on policy formulation, attracting investment and promoting R&D and allow private sector companies to process beach and minerals within appropriate environmental safeguards.
3. India could secure access to rare earth of strategic importance by offering viability gap funding to companies to set up facilities in the upstream sector.
4. Focus should be on developing downstream industry rare earth metals processing industry in India. For ex those manufacturing magnets and batteries.
5. Coordinate with other agencies to partner directly with groupings such as QUAD, building up a strategic reserve as a buffer against global supply crisis.
6. India has entered into an agreement with Japan for development of Rare Earth Metals. This needs to materialize in actual production and processing

►DESALINATION PLANTS

Desalination is being proposed as an innovative solution to meet India's water challenges especially in coastal areas surrounded by salty sea water. Chennai is already using desalinated water.

Desalination has largely been limited to affluent countries in the Middle East and has recently started making inroads in parts of the United States and Australia. In India, Tamil Nadu has been the pioneer in using this technology.

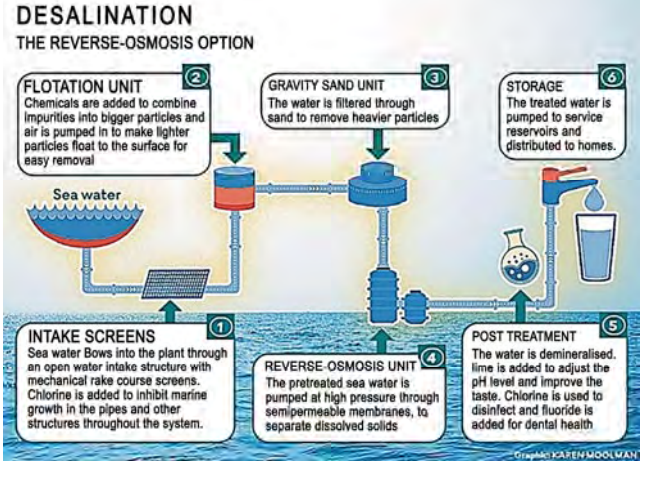
Worldwide, desalination is seen as one possible answer to stave off water crisis. Maharashtra announced the setting up of a desalination plant in Mumbai, becoming the fourth state in the country to experiment with the idea.

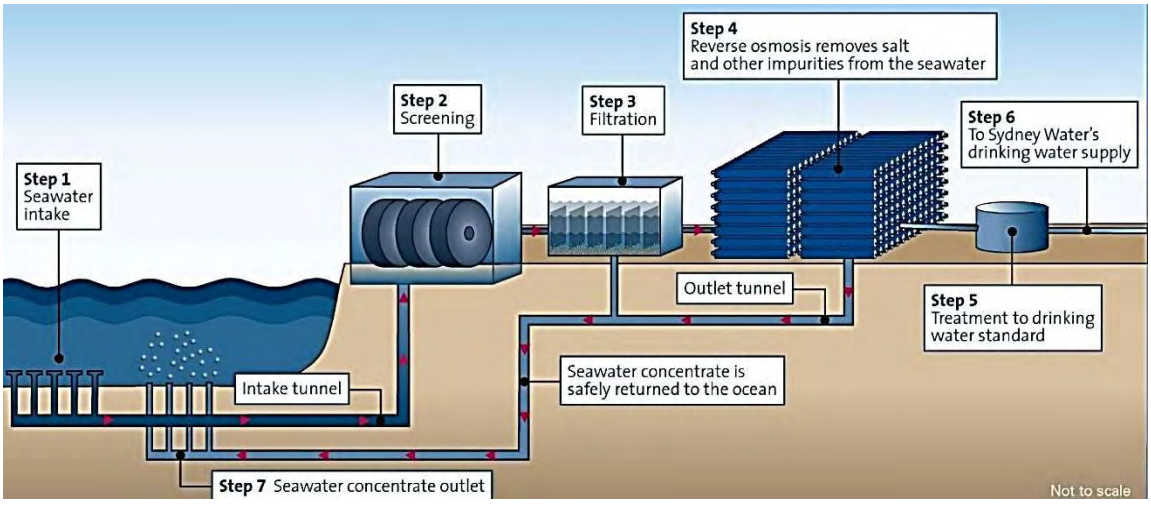
Desalination Plants

- A desalination plant transforms salt water into drinking water.
- Most common technology for interaction is reverse assimilation where an external stress is applied to push solvents from a high solute concentration space to a low solute binding space through a layer.
- Layers allow water particles to pass through but release salt and pollutants, allowing the water to dry out on the opposite side.
- Mainly installed in regions close to seawater.
- Most used technique is reverse osmosis.

1. How widely is this technology used in India?

- Desalination has largely been limited to affluent countries in Middle East and has recently started making inroads in parts of USA and Australia.
- In India, Tamil Nadu has been pioneer by setting up two desalination plants near Chennai. The two plants supply 100 million liters a day each to Chennai. Two more plants are expected to be set up in Chennai.
- Gujarat has announced to set up a 100 MLD RO plant at the Jodiya coast in Jamnagar district.
- There are proposals to set up desalination plants in Dwarka, Kutch, Dahej, Somnath, Bhavnagar and Pipavav, which are all coastal areas in Gujarat. Andhra Pradesh, too, has plans of setting up a plant.

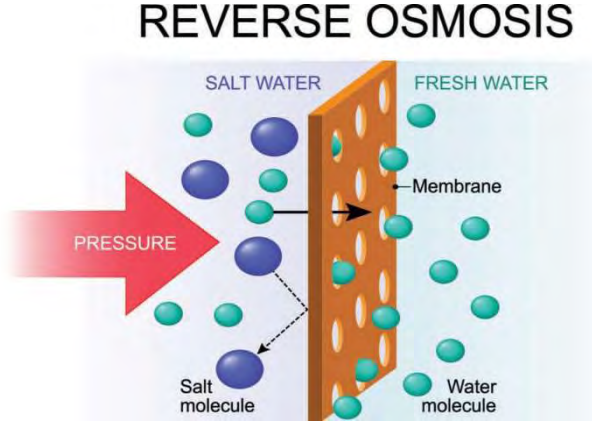




Limitations of desalination in harnessing potable water from the sea

Design of such plants must consider several limitations, for example, salt levels in the source water that will be treated, energy required for the treatment and the removal of the salt back into the ocean.

- Energy intensive: To get rid of necessary salt, there must be a power source, whether it is a power plant or a diesel or battery source. Estimates put this at about 4 units of power per 1000 liters of water.
- Hyper-salinity: Reverse osmosis plants release highly saline water along the coast adversely affecting coastal biodiversity especially fisheries such as shrimp, sardines and mackerel. Hyper salt along shore affects minnows, which are the main food for a long time of these species of fish.
- Danger to sea life: Additionally, high-voltage motors supposed to draw seawater end up sucking up small fish and living things, pounding and killing them, again a dearth of marine heritage.
- Wastage of land and freshwater: Development of reverse osmosis plants requires groundwater reserves. It was fresh water that was sucked in and has since been supplanted by salt water, making it unsuitable for residents around desalination plants.
- Expensive: Desalination is expensive and water supplied is just as exorbitant. Given India's poor population, desalination may not work. Speculation is needed to set up the installation, energy requirements and waste disposal.
- Waste Disposal: Desalination requires pre-treatment and cleaning of synthetic compounds, which are added to water before desalination. These synthetics are used only for a limited time. These synthetics when discarded, become a significant concern. These synthetic compounds regularly discover their direction towards sea, where they poison life of plants and creatures.
- Health Concerns: Desalination is certainly not a culminating innovation, and desalinated water can also be harmful to human well-being. The results of synthetic compounds used in desalination can pass through "unaltered" water and endanger those who drink it. Desalinated water can also be acidic for both lines and structures related to the stomach.



2. Reverse Osmosis (RO)

- Reverse osmosis (RO) is a water purification technology that uses a semi-permeable membrane to eliminate larger particles of drinking water.
- In reverse osmosis, an applied pressure is used to overcome osmotic pressure so that pure water flows from a region of high solute concentration (hypertonic) through a semi-permeable membrane to a region of low solute concentration (hypotonic).

3. Applications of Reverse Osmosis (RO)

- Sea Water Desalination
- Pharmaceutical Water Purification
- Bottled Water Production
- Wastewater Recycling
- Car washes 'Spot Free' rinse

- Medical Device Manufacturing
- Rural Water Purification
- Brackish Well Water Desalination
- Laboratory Water Purification
- Food Products and Cosmetic Products
- Industrial Water Purification

Excessive spending, energy consumption and danger to fishing and the sea should cause the nets to think about desalination in response. Conservation and reuse programs are generally significantly cheaper and safer options than building desalination plants. By using efficient decisions about water items, without any penance for the quality of workmanship of the items, we can help ration our most precious commodity.

►NATIONAL SCIENCE TECHNOLOGY & INNOVATION POLICY

Draft 5th National Science Technology and Innovation Policy has been finalized and is now available for public consultation. The aim of the scientific policy is to "encourage individual initiative for the acquisition and dissemination of knowledge, and for the discovery of new knowledge, in an atmosphere of academic freedom."

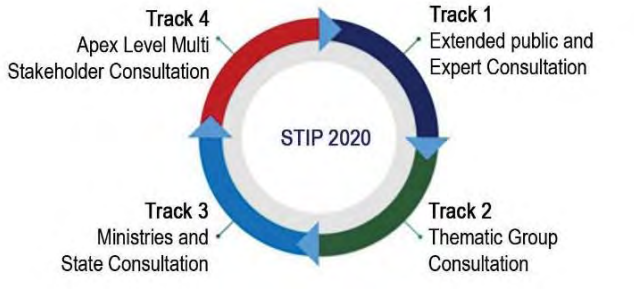
PHILOSOPHY OF DRAFT STIP

- Unlike previous STI policies which were largely top-driven, fifth national STI policy (STIP) follows core principles of being decentralized, evidence-informed, bottom-up, experts-driven, and inclusive.
- It aims to be dynamic, with a robust policy governance mechanism that includes periodic review, evaluation, feedback, adaptation and a timely exit strategy for policy instruments.

VISION OF STI POLICY

- STIP will be guided by the vision of positioning India among the top three scientific superpowers in the decade to come with technological self-reliance.
- Attract, nurture, strengthen, and retain critical human capital through a people centric STI ecosystem.
- Double number of full-time equivalent (FTE) researchers, gross domestic expenditure on R&D (GERD) and private-sector contribution to GERD every five years.
- Build individual and institutional excellence in STI with the aim of reaching the highest levels of global recognition and awards in the coming decade.
- Policy outlines strategies for strengthening India's STI ecosystem to achieve larger goal of Atmanirbhar Bharat.

Policy Process



HIGHLIGHTS OF STIP

- Open Science Framework to provide access to scientific data, information, knowledge, and resources to everyone in the country.
- Bulk subscriptions and free access for all: Keeping in mind 'One Nation, One Subscription,' the STIP envisions free access to all journals, Indian and foreign, for every Indian against a centrally negotiated payment mechanism.
- Participation of women and the LGBTQ community in science and education: To address the issue of inclusion and equity in a holistic way, an Indian version of the Athena SWAN Charter (a global framework to support gender equality in higher education and research, especially in science, technology, engineering, mathematics, and medicine) is needed. STIP has made recommendations such as
  - Mandatory positions for excluded groups in academics.
  - 30% representation of women in selection/evaluation committees and decision-making groups.
  - Addressing issues related to career breaks for women by considering academic age rather than biological/physical age.
  - A dual recruitment policy for couples; and o institutionalization of equity and inclusion by establishing an Office of Equity and Inclusion, etc.

FUNDING IN R&D

STIP has made some recommendations, such as

- Expansion of the STI funding landscape at the central and state levels.
- Enhanced incentivization mechanisms for leveraging the private sector's R&D participation through boosting financial support and fiscal incentives for

industry and flexible mechanisms for public procurement; and

- Creative avenues for collaborative STI funding through a portfolio-based funding mechanism called the Advanced Missions in Innovative Research Ecosystem (ADMIRE) program to support distributed and localized collaborative mission-oriented projects through a long-term investment strategy.
- A national STI Financing Authority, along with an STI Development Bank, needs to be set up to direct long-term investments in select strategic areas.

LESSONS LEARNT FROM THE COVID-19 PANDEMIC

- There is a growing realization that science can address pressing problems of society, in sectors such as health, energy, and water. Science brought quick and effective solutions against challenge of Covid-19, by producing protective and diagnostic kits, and developing vaccines.
- STIP draft focuses on need to adopt such learnings for greater efficiency and synergy in future.

ISSUES WITH STIP

- 2013 STIP policy had similar aims but the 2020 draft policy fails to discuss what we have achieved on these fronts since then. For example, the 2013 policy aimed R&D investment in science to be 2% of GDP but it still hovers between 0.5% and 0.6% of the GDP.
- 2020 draft policy blames this on "inadequate private sector investment" and adds that "a robust cohesive financial landscape remains at the core of creating an STI-driven Atmanirbhar Bharat." This way, Government is trying to shift the responsibility of financing R&D to different agencies such as the States, private enterprises, and foreign multinational companies.
- Visualizes a 'decentralized institutional mechanism' balancing top-down and bottom-up approaches, but this intention is defeated, where new authorities, observatories and centers have been proposed in science administration. Decentralization of administrative architecture is essential, but we need to explore practical option of providing more autonomy to research and academic centers for financial management.
- As part of inculcating an inclusive culture in academia, the document promises to tackle discriminations "based on gender, caste, religion, geography, language, disability and other exclusions and inequalities." It mentions more representation of women and LGBTQ community but is silent on how we are to achieve their proportionate representation.
- Harks back to our constitutional obligation to "develop a scientific temper, humanism and the spirit of inquiry and reform." But it is silent on how this can be achieved when pseudoscience is deliberately propagated in the name of traditional science with the help of government. Ex. proposal by Rashtriya Kamdhenu Aayog to conduct a national examination under the garb of 'cow science.'

WAY FORWARD

Along with the problems that we are encountering today, we should focus on the kind of problems that we may encounter in future and be ready for that.

- Science needs to be promoted at the grass root level; science communication in regional languages should be promoted.
- Catering the export market and making India a hub for new technologies like Artificial Intelligence, 5G etc.
- To change the life of millions of people, the government needs to collaborate with various stakeholders to focus on inculcating scientific temperament in everyone. The goal of the policy is to make India self-reliant (Atmanirbhar) in all respects.

►SCIENTIFIC SOCIAL RESPONSIBILITY GUIDELINES

Ministry of Science & Technology notified Scientific Society Responsibility Guidelines to create a scientific ecosystem with interconnections to create two-way engagement among science and society for driven scientific community building a self-reliant India.

ABOUT SCIENTIFIC SOCIAL RESPONSIBILITY

The ethical obligation of knowledge workers in all fields of science and technology to voluntarily contribute their knowledge and resources to the widest spectrum of stakeholders in society, in a spirit of service and conscious reciprocity.

NEED FOR SCIENTIFIC SOCIAL RESPONSIBILITY GUIDELINES

- India made significant progress in science and technology since independence.
- Recent achievements in scientific field:
  1. India is ranked third among countries in scientific publication as per National Science Foundation.
  2. As per Global Innovation Index, India is ranked 46th among most innovative economies.
  3. Third position in number of PhDs in science and engineering, size of higher education system and startups.

4. Considerable progress in quality of research output, number of patents and women participation in S&T.

- However, despite the progress, transfer of scientific knowledge and its benefits to society remains a concern. Thus, building a strong connection between science and society assumes significance.

OBJECTIVES

To harness the potential that is latent in the country's scientific community to strengthen science and society linkages, on a voluntary basis, to make the S&T ecosystem vibrant.

This primarily involves bridging society-science, science-science and science-society gaps, thereby bringing trust, partnership and responsibility of science at an accelerate pace towards achieving social goals.

Aimed at creating effective ecosystem for optimum use of existing assets to empower less endowed, marginalised and exploited sections of society by enhancing their capability, capacity and latent potential.

- Science-Society connect: Facilitating inclusive and sustainable development by transferring benefits of scientific work to meet existing and emerging societal needs.
- Science-science connect: Creating an enabling environment for sharing of ideas and resources within the knowledge ecosystem.
- Society-science connect: Collaborating with communities to identify their needs and problems and develop scientific and technological solutions. Age old Lab to Land approach would be replaced by a new age of Land (Experience) to Lab(Expertise) to Land (Applications) (L3).
- Cultural change: Inculcating social responsibility among individuals and institutions practicing science, creating awareness about SSR within society and infusing scientific temperament into day-to-day social existence and interaction.

STRATEGIES FOR IMPLEMENTING SSR:

- All Central and State Ministries would plan and strategize their SSR in accordance with their mandates.
- Every knowledge institution would prepare its implementation plan in consultation with an identified knowledge-based institution called 'Anchor Scientific Institution (ASI)' for achieving its SSR goals and prepare its SSR code of conduct that ensures transparency, diversity and equity.
- All knowledge workers would be sensitised by their institutions and Anchor Scientific Institution about their ethical responsibility to contribute towards betterment of society and achieving national development and environmental goals.
- Every knowledge to contribute at least 10 person days in year towards SSR.
- SSR assessment cell in each institution including Anchor Scientific Institution based on appropriate indicators.
- SSR activities to be incentivised at individual and institutional level.
- SSR activities to be given weightage in performance evaluation of knowledge workers.

ACTIVITIES

1. Lectures by scientists in schools/college
2. Engagement and training
3. Interactive exhibits
4. Skills workshops
5. Sharing infrastructure and technology
6. Working with innovators

BENEFITS OF SSR

- Expanding domain of science and its benefits to the community.
- Encouraging students into science through handholding and nurturing their interest.
- Creating an opportunity of cooperation and sharing of S&T resources in laboratories with other researchers/universities.
- Providing training for skill development and upgrading scientific knowledge.
- Helping MSMEs, Start-ups and informal sector enterprises in increasing their overall productivity.
- Facilitating scientific intervention in rural innovation.
- Empowering women disadvantaged and weaker sections through scientific intervention.
- Facilitating action towards addressing Technology Vision 2035 & SDG such as water, ecology, health and livelihood.

►DRAFT NATIONAL DATA GOVERNANCE FRAMEWORK POLICY

This policy has been launched by Ministry of Electronics and IT (MEITY) to ensure that non-personal data and anonymised data from both Government and Private

entities are safely accessible by research and innovation eco-system.

CONTEXT OF THE POLICY

- Digitisation of government, governance and economy are progressing at rapid pace in India.
- India's unique platformisation strategy has helped to transform public service delivery and governance at scale through public digital platforms. These public digital platforms are
  - empowering citizens
  - enhancing government-citizen engagement
  - driving data-driven governance
  - leading to inclusive development.
- This accelerated digitisation is leading to exponential increase in volume and velocity of data generated. This data can be used to improve citizen's experience and engagement with the government and governance.
- However, Digital Government data is currently managed, stored and accessed by fragmented and inconsistent ways leading to sub-optimal efficacy of data-driven governance, preventing an innovative ecosystem of data science, analytics and AI from emerging.
- Data generated must be harnessed for more effective Digital Government, public good and innovation. This policy aims to realise the full potential of Digital Government for maximising data-led governance and catalysing data-based innovation transforming government services and their delivery especially in socially important areas of agriculture, healthcare, law & justice, education etc.
- The policy launches non-personal data-based Datasets program and addresses methods and rules to ensure that non-personal data and anonymised data from both Government and Private entities are safely accessible by Research & Innovation ecosystem.

OBJECTIVES OF THE POLICY

- Transform and modernise Government data collection and management processes and systems for improving governance through a whole of government approach towards data-led governance.
- Enable vibrant AI and Data led research and start-up ecosystem by creating a large repository of India Datasets.
- Applicability:
  a. Applicable to all Government departments. Rules and Standards prescribed will cover all data collected and managed by Government entities.
  b. Applicable to all non-personal datasets, data and platform, rules, standards governing its access and use by researchers and startups.
  c. State governments will be encouraged to adopt this policy.
- Improve framework for government data sharing, promoting principles around privacy and security by design, encouraging use of anonymisation tools and ensuring equitable access to non-personal data for both public and private sector.

INTENDED BENEFITS

1. Accelerate Digital Governance.
2. Standardised data management and security standards across whole of government.
3. Accelerate creation of common standard based public digital platforms while ensuring privacy, safety and trust.
4. Standard APIs and other tech standards for Whole of Government Data management and access.
5. Promote transparency, accountability and ownership in Non-personal data and datasets access. For purposes of safety and trust, any non-personal data sharing by any entity can be only via platforms designated and authorised by IDMO.
6. Build a platform that will allow Dataset requests to be received and processed.
7. Build Digital Government goals and capacity, knowledge and competency in Government departments.
8. Set quality standards; promote expansion of India Datasets program and overall non-personal Datasets ecosystem.
9. Greater citizen awareness, participation and engagement.

INSTITUTIONAL FRAMEWORK

An India Data Management Office (IDMO) shall be set under Digital India Corporation under Meity.

Functions of IDMO:

- Framing, managing and periodically reviewing and revising the policy.
- Developing rules and standards under this policy.
- Formulate all data/datasets/metadata rules, standards in consultation with ministries, States and industry.

- Design and manage the India Datasets platform that will process requests and provide access to non-personal and anonymised datasets to researchers and startups.
- Standardise data management by building up capacity in each ministry.
- Accelerate inclusion of non-personal datasets housed with ministries and private companies into India Datasets Program.
- Encourage data and AI based Research, startup ecosystems by working with Digital India Start-up hub.
- Every department/ministry to have Data Management Units headed by Chief Data Officer (CDO) who will work in coordination with IDMO.
- IDMO shall be staffed at DIC by a dedicated government data management and analytics unit.

CONCERNS

- Inadequate emphasis of the policy on ensuring privacy of citizens.
- Creation of datasets can lead to profiling of citizens.
- IDMO should be given a statutory basis.
- Statutory challenges such as Aadhar Act prohibits use of Aadhar data for other purposes.
- A comprehensive data protection law on the recommendations of B N Sri Krishna Committee and Global best practices should be enacted.
- Government may lack the human resource and technical capacity to implement the policy.

CONCLUSION

NDGFP is the first building block of digital government architecture that will maximize data-driven governance. This will lead to greater scope for better, informed decision making, enhanced program evaluation and more efficient delivery of public services.

►INTELLECTUAL PROPERTY RIGHTS

- Intellectual property refers to creations of the mind: inventions; literary and artistic works; and symbols, names and images used in commerce. Intellectual property is divided into two categories:
- Industrial Property includes patents for inventions, trademarks, industrial designs and geographical indications. Copyright covers literary works (such as novels, poems and plays), films, music, artistic works (e.g., drawings, paintings, photographs and sculptures) and architectural design.
- Rights related to copyright include those of performing artists in their performances, producers of phonograms in their recordings, and broadcasters in their radio and television programs.

PROMOTE AND PROTECT THE INTELLECTUAL PROPERTY

The reasons are:

- Progress and well-being of humanity rest on its capacity to create and invent new works in the areas of technology and culture.
- Legal protection of new creations encourages the commitment of additional resources for further innovation.
- Intellectual property system helps strike a balance between the interests of innovators and the public interest, providing an environment in which creativity and invention can flourish for the benefit of all.
- Promotion and protection of intellectual property spurs economic growth, creates new jobs and industries.
- Strong protection of IPR leads to more inflow of FDI in developing countries.

CHALLENGES IN INDIA'S IPR REGIME

- Considerably low number of patents granted in India as compared to China or USA.
- Major share (64%) of patents filed in India is by non-residents or foreign entities.
- R&D expenditure in India is a meager 0.7% of GDP. This R&D expenditure is mostly concentrated in public and educational sector. Businesses and private companies' expenditure on R&D is dismal.
- IP crimes including counterfeiting & piracy are rising threats to IPRs which should be deftly handled by appropriate measures.
- Vacancies in Patent Office.
- IP Appellate Board (IPAB) has been abolished by the Tribunals Reforms (Rationalisation & Conditions of Service) Ordinance, 2021.
- IP financing ecosystem has not been given adequate importance.
- Lack of awareness which leads to frequent violation and disregard for IPR laws.

TYPES OF INTELLECTUAL PROPERTY RIGHTS

Patents (Patents Act, 1970)	A patent protects an invention. It gives the holder an exclusive right to prevent others from selling, making and using the patented invention for a certain period (typically 20 years from filing

	date).
Copyright (Copyright Act, 1957)	Copyright protects the expression of literary or artistic work. Protection arises automatically giving the holder the exclusive right to control reproduction or adaptation.
Trademarks (Trademarks Act, 1999)	A trademark is a distinctive sign which is used to distinguish the products or services of one business from others. Trademarks are often closely linked to brands.
Design (Designs Act, 2000)	Protects the form of outward appearance or aesthetic style of an object Does not protect functionality or unseen (internal) design elements.
Database	Database right prevents copying of substantial parts of a database. The protection is not over the form of expression of information but of the information itself, but in many other aspects database right is like copyright
Trade secrets	A trade secret is a formula, practice, process, design or compilation of information used by a business to obtain an advantage over competitors. Trade secrets are not disclosed to the world at large.

STEPS THAT NEED TO BE TAKEN

Recently, Parliament Standing Committee on commerce recommended the following measures for strengthening India's IPR ecosystem.

1. Comprehensive study on benefits of improvement of IPRs ecosystem on the economy.
2. Focus on R&D: Increasing spending on R&D activities in both public and private sector. Specific allocation for R&D should be done by each ministry. Incentives should be provided to private sector for undertaking R&D. Every industry with certain specified turnover may be directed to put funds under CSR for R&D activities.
3. Industry-Academia partnership for research and innovation: Catapult system of UK needs to be emulated.
4. An exclusive apex level institution for IPR development should be established.
5. Introduction of 'Patent Pending' status for innovations which have been filed with patent offices but have not been conferred patent.
6. IP backed financing: Commercialisation of IPRs needs to be promoted.
7. IP Crimes, focus on enforcement and adjudication: (a) Capacity building of IP enforcement agencies including strengthening of IPR cells in Police. Establishment of a Central Coordination Body on IP Enforcement for enforcement of IP laws to check IP crimes. (b) Specific legislation to curb counterfeiting and piracy should be enacted. (c) Dedicated benches in High Courts for IP matters.
8. IP audit should be conducted for assessing IPR potential in specific sectors which would help in formulating targeted IPR programs.
9. Holistic review of National IPR Policy needs to be undertaken in view of new and emerging trends of innovation, research and root out existing challenges.

CONCLUSION

An inclusive and balanced IPR ecosystem needs emphasis on both formal and informal innovation, instilling a culture of IPR along with improvisation and streamlining of legislative, administrative, adjudicative and enforcement mechanisms.

A strong IPR regime consistent with larger public interest would play an instrumental role in spurring economic, technological, and industrial growth of the country.

►NATIONAL IPR POLICY

A comprehensive National IPR policy was adopted in 2016 to stimulate innovation and creativity across sectors and providing a clear vision regarding IPR issues.

OBJECTIVES

1. IPR Awareness, Outreach & Promotion: To create public awareness about the economic, social and cultural benefits of IPRs among all sections of society.
2. To stimulate generation of IPRs.
3. Legal and legislative framework: To have strong and effective IPR laws, which balance interests of rights' owners with larger public interest.
4. Administration and Management: To modernise and strengthen service oriented IPR administration.
5. Commercialisation of IPRs: Get value for IPRs
6. Strengthen enforcement and adjudication for combating IPR infringements.

7. Strengthen and expand human resources, institutions and capacities for teaching, training, research and skill building in IPRs.

►BIOPIRACY

NEED TO PROTECT TRADITIONAL KNOWLEDGE

- Traditional knowledge is a valuable yet vulnerable asset to indigenous and local communities who depend on it for livelihood and healthcare needs.
- Globally too there has been renewed interest in the use of traditional medicine increasing its vulnerability to exploitation.
- Traditional knowledge related to treatment of various diseases has provided leads for development of biologically active molecules.
- Indian traditional knowledge exists in languages such as Sanskrit, Hindi, Arabia, Urdu, Tamil etc. and that too in ancient local dialects that are no more in practice. Thus, public Indian TK literature is neither accessible nor understood by patent examiners at international patent offices.
- Formulations used for treatment of diseases in TK systems are time-tested and have been practice for centuries. Reliability of traditional medicine systems coupled with absence of such information with patent offices, provides an easy opportunity for interlopers for getting patents on these therapeutic formulations derived from traditional medicine systems.
- Examples (i) Grant of Patent for healing properties of Turmeric in US. (ii) Grant of patent to basmati rice. These incidents flagged the danger of complacence in proactively guarding traditional knowledge.
- Revocation of patents once granted may not be feasible since it involves huge costs and time.
- Time, effort and money spent on revocation of turmeric patent at US Patent Office highlighted need for a proactive mechanism for TK protection.

TRADITIONAL KNOWLEDGE DIGITAL LIBRARY (TKDL)

- TKDL is an initiative of India to protect Indian traditional knowledge and prevent its misappropriation at International Patent Offices.
- An initiative of CSIR and AYUSH Ministry.
- Aims to make it easier for international patent offices to access non-patent literature databases on traditional knowledge of India.
- It has overcome language and format barrier by systematically and scientifically converting and structuring available content of the ancient texts on Indian medicinal systems into 5 international languages, namely, English, Japanese, French, German and Spanish with help of information technology and an innovative classification system – Traditional Knowledge Resource Classification (TKRC). Currently, 3.6 lakh formulations have been documented into TKDL database.
- TKRC has structured and classified the Indian Traditional Medicinal System into several thousand subgroups of Ayurveda, Unani, Siddha and Yoga.
- TKRC enabled incorporation of traditional knowledge into International Patent Classification has enhanced the quality of search and examination of prior art with respect to patent applications in the field of TK.
- TKDL has also set international specifications and standards for setting up of TK databases based on TKDL specifications. This has been adopted by WIPO.
- It acts as a bridge between books of Indian Systems of Medicine (prior art) & international patent examiners.
- Access to TKDL is available to 13 Patent Offices internationally under TKDL Access (Non-disclosure) Agreement.
- Pre-patent grant oppositions are being filed by TKDL at various International Patent Offices, along with prior art evidence from TKDL. So far more than 230 patent applications have either been set aside/withdrawn based on prior art evidence present in the TKDL database without any cost.
- Thus, TKDL is proving to be an effective deterrent against bio-piracy and has been recognized internationally as a unique effort.
- It has set a benchmark in TK protection globally, particularly in TK rich countries, by demonstrating advantages of proactive action & power of deterrence. Preventing grant of wrong patents by ensuring access to TK related prior art for patent examiners without restricting use of traditional knowledge.

►UTILITY MODEL OF PATENTS

India spends only around 0.7% of its GDP on Research and Development (R&D). The Economic Survey 2019-20 has highlighted the need for increasing the investment in R&D to boost innovation and become $ 5 trillion economy. Accordingly, there is a need for introduction of Utility Model (on the lines of Patents).

UNDERSTANDING PATENT

- A Patent is a statutory right for an invention granted for a limited period. Upon being granted the patent,

the patent holder enjoys exclusive monopoly with respect to making, using, or selling the patented product/process for certain period.

- The patents have been given protection under the WTO's Trade Related aspects of Intellectual Rights (TRIPS). Under this agreement, member countries must provide protection to Patents for a minimum period of 20 years. Once a patent expires, the invention enters the public domain and anyone can commercially exploit the invention without infringing the patent.
- 3 Criteria for issuing Patents in India under Indian Patents Act, 1970
    - It should be new or novel(that is, not be published in India or elsewhere + no prior Public KnowledgePublic Use in India)
    - It must involve an inventive step(Technical advanced in comparison to existing knowledge +
    - non-obvious to a person skilled in the relevant field of technology)
    - It should be capable of Industrial application.

UNDERSTANDING UTILITY MODEL

Some countries have adopted Utility Model to promote and protect "minor inventions" which may not fulfil the criteria for patent. In general, compared with patents, utility model systems require compliance with less stringent requirements (for example, lower level of inventive step), have simpler procedures and offer shorter term of protection. Hence, like patents, utility models protect new technical inventions through granting a limited exclusive right to prevent others from commercially exploiting the protected inventions without consents of the right holders.

DIFFERENCE BETWEEN PATENT AND UTILITY MODEL

1. Requirement for acquiring Utility Model is less stringent than Patent. Both Patent and Utility model may have to fulfil the criteria of novelty, the criteria for inventive step may be lower or absent in case of Utility Model.
2. The term of protection for utility models (which varies from 6 to 15 years in different countries) is lower than that of Patents (minimum protection for 20 years)
3. The registration process for Utility models is simpler and faster in comparison to patents
4. In some countries, utility model protection can only be obtained for certain fields of technology, such as mechanical devices and apparatus, and only for products but not for processes.
5. Unlike Patents, there is no reference of Utility Models in the Trade related aspects of Intellectual property rights (TRIPS)

WAY FORWARD

India should consider adopting Utility Model regime to promote incremental and minor innovations by the MSMEs. This would help us foster and promote the innovation ecosystem in India.

NUCLEAR TECHNOLOGY

Previous Year Questions

YEAR	UPSC MAINS QUESTION
2017	Give an account of the growth and development of nuclear science and technology in **India.** What is the advantage of fast breeder reactor program in India?

►BASICS OF NUCLEAR

NUCLEAR FISSION

- Nucleus of an atom splits into two daughter nuclei.
- This decay can be natural spontaneous splitting by radioactive decay or can be simulated in a lab by achieving necessary conditions (bombarding with neutrons, alpha particles, etc.).
- The resulting fragments tend to have a combined mass which is less than the original. The missing mass is usually converted into nuclear energy.
- Currently, all commercial nuclear reactors are based on nuclear fission.

NUCLEAR FUSION

- Nuclear Fusion is defined as the combining of two lighter nuclei into a heavier one.
- Such nuclear fusion reactions are the source of energy in the Sun and other stars.
- It takes considerable energy to force the nuclei to fuse. The conditions needed for this process are extreme – millions of degrees of temperature and millions of Pascals of pressure.
    - Nuclear fusion is arguably the best way for humans to generate energy.
    - The required raw materials — deuterium and tritium — are easily available in the oceans.
    - It creates huge amounts of energy—several times greater than fission.
    - Nuclear fusion also does not produce any harmful radioactive waste and hence, is extremely environment friendly.
- The hydrogen bomb is based on a thermonuclear fusion reaction. However, a nuclear bomb based on the fission of uranium or plutonium is placed at the core of the hydrogen bomb to provide initial energy.

►GENERAL APPLICATIONS OF NUCLEAR TECHNOLOGY

1. Nuclear Medicine:
    a. Nuclear technology is applied to various branches of medicine: Oncology, cardiology, neurology, pneumology or pediatrics.
    b. Medical professionals use diagnostic techniques such as radio pharmaceuticals, scans or radioisotopes and apply radiotherapy treatments that include X-rays as well as radiations from radio-active elements or radiation producing equipment's such as

accelerators.

c. Used in sterilisation of medical equipment, learn about biological processes with use of tracers or study of properties of tumorous cells. BARC is planning to develop a Research Reactor for production of radioisotopes for nuclear medicines.

2. Applications in Hydrology: Isotope hydrology is a nuclear technique that uses both stable and radioactive isotopes to follow the movements of the water in the hydrologic cycle. These techniques help research subterraneous freshwater resources and determine their origin, their charge, whether there is a risk of intrusion or contamination by salt water.
3. Sewage treatment: Nuclear technology is also employed in sustainable waste management. BARC has set up a Technology Demonstration project "Sewage Sludge Hygienisation Plant" in Ahmedabad, Gujarat. The plant is loaded with Cobalt-60 and is in continuous operation since then.
4. Food and agriculture: Radioisotope and radiation techniques are used to improve the quality of food by inducing mutations in plants and seeds to obtain desired crop varieties. Nuclear technology is also employed for pest control, increasing food production and reducing fertiliser usage. Direct irradiation of food reduces losses after harvest and improves shelf life of food products. This technique consumes less energy than conventional methods and can replace or radically reduce the use of additives and fumigants. (Ex. Employed to increase shelf life of onions at Lasalgaon, Nashik, Maharashtra).
5. Applications in Industry: Use of isotopes and radiations in modern industry is highly important to the development and improvement of processes, measurement, automatization and quality control. Use cases: Used to obtain information that makes it possible to extend its operative life and obtaining X-rays of the internal structure of certain pieces to check their quality.
6. Art: X-ray radiography makes it possible to get a deep look at a work of art to determine artists technique, change of composition, authenticity and age of art works.
7. Space Exploration: Nuclear batteries are used in space exploration as they can remain functional and active to power space missions over centuries.
8. Strategic uses: Nuclear power submarines which allow them to remain operational for long periods of time without having to come to surface to energy supplies.

►NUCLEAR ENERGY IN INDIA

India is fourth largest energy consumer in the world (After USA, China and Russia). Still, India continues to remain energy-poor.

As per Central Electricity Authority, India's per capita electricity consumption, computed as the ratio of the estimated total electricity consumption during the year 2014-15, stood at just over 1,000 kilowatt hours as compared to developed countries which average around 15,000 kWh.

Recently India has committed to the Nationally Determined Contribution (NDC) of the United Nations Framework Convention on Climate Change (UNFCCC). This outlines its intent to scale up the country's clean-energy capacity.

There are three important reasons to use nuclear energy: It is clean, cheap and can provide electricity 24x7 (base load).

India said nuclear power remains an important option to meet the challenges of increased energy demand, address concerns about climate change and ensure energy supply security.

To increase the nuclear energy production and expand the nuclear energy programs, IAEA along with the support of the member states is needed. India has low reserves of uranium and high reserves of thorium.

India has also participated actively and exchanged information on new developments and experience in the field of fast reactors and related technologies during the International Conference on Fast Reactors and Related Fuel Cycles held in the Russian Federation in 2017.

India currently has 21 operating nuclear reactors at six locations across the country, their combined capacity totalling 5.8 GW. Its civil nuclear strategy has proceeded largely without fuel or technological assistance from other countries for more than 30 years.

This was a result of its Peaceful Nuclear Explosion (PNE) in 1974 and its voluntary exclusion from the Non-Proliferation Treaty (NPT), which led to India's isolation from trade in nuclear power plant materials. However, following the Nuclear Suppliers Group (NSG) India-specific agreement, civil nuclear cooperation agreements have since been signed with the US,

Russia, France, Australia and Kazakhstan, among other countries.

INDIA'S NUCLEAR PROGRAM

India developed a three-stage nuclear power program formulated by Homi Bhabha in 1950s to secure the country's long term energy independence, using uranium and thorium reserves found in the monazite sands of coastal regions of South India.

The recent Indo-US Nuclear Deal increases the scope for civilian nuclear trade which increased significantly, and the NSG waiver which was procured by India in 2005 ended more than three decades of international isolation of the Indian civil nuclear program. It also created many unexplored alternatives for the success of the three-stage nuclear power program.

The three-stage nuclear program laid out what needs to be done to eventually use the country's almost inexhaustible Thorium resources.

THREE-STAGE NUCLEAR PROGRAM

First stage: Creation of a fleet of 'pressurised heavy water reactors', which use scarce Uranium to produce some Plutonium.

Second stage: Setting up of several 'fast breeder reactors' (FBRs). These FBRs would use a mixture of Plutonium and reprocessed 'spent Uranium from the first stage, to produce energy and more Plutonium (hence 'breeder'), because the Uranium would transmute into Plutonium. Alongside, the reactors would convert some of the Thorium into Uranium-233, which can also be used to produce energy.

Third Stage: After 3-4 decades of operation, the FBRs would have produced enough Plutonium for use in the 'third stage'. In this stage, Uranium-233 would be used in specially-designed reactors to produce energy and convert more Thorium into Uranium-233—you can keep adding Thorium endlessly.

PRESENT STATE OF INDIA'S ENERGY PROGRAMME

After almost five decades of operating pressurized heavy-water reactors (PHWR), India is now ready to start the second stage.

A 500 MW Prototype Fast Breeder Reactor (PFBR) at Kalpakkam has been set up.

Experts, however, estimate that it would take India many more FBRs and at least another four decades before it has built up a sufficient fissile material inventory to launch the third stage.

According to a report by the Central Electrical Agency, India's 6,780 MW of nuclear power plants contributed to less than 3% of the country's electricity generation.

Some of the latest nuclear power plants in India are the Kudankulam Nuclear Power plant and the Tarapur Nuclear Power Plant.

KUNDAKULAM NUCLEAR POWER PLANT

Largest nuclear power station in India, situated in Kudankulam in Tirunelveli district of Tamil Nadu.

It is scheduled to have six VVER-1000 reactors with an installed capacity of 6,000 MW of electricity.

It has been built in collaboration with Atomstroy export, the Russian state company and NPCIL.

WHAT ARE THE FACTORS THAT ARE INFLUENCING NUCLEAR POWER GROWTH?

Land requirements:

Nuclear power projects require significant areas of land for operation.

According to the Atomic Energy Regulatory Board (AERB) code, an area in the radius of 1.5 km, called exclusion zone, around the reactors is established where no human habitation is permitted. This area forms the part of the project and included in the land acquired.

Fuel Requirements:

India operates a closed fuel cycle designed to make maximum use of its limited uranium resources. Having low reserves of uranium and high reserves of thorium, this strategy of reprocessing and recycling of uranium and plutonium would also lead to optimum resource utilisation. Uranium is one of the most important materials required for production of nuclear energy.

Spent fuel, that is, residue left after the production of nuclear energy is a crucial resource and should not be treated as waste for disposal.

The closed fuel cycle requires reprocessing of the spent fuel to separate uranium and plutonium for reuse.

India's first reprocessing plant was established in 1964 at Trombay. Currently India has three operating reprocessing plants based on the Plutonium Uranium Redox Extraction (PUREX) technology at Trombay, Tarapur and Kalpakkam. They are operated by the Bhabha Atomic Research Centre (BARC).

Manufacturing needs:

A domestic manufacturing base is required for energy production in India. It has covered most of all the supply chain of materials required for building a nuclear power plant.

The cost as well as the capability of these materials needs to be scaled up.

Manpower needs:

To scale up nuclear energy in India, human resource for nuclear engineering is paramount.

As per a DAE projection exercise done in 2006, it was estimated that to replace retiring personnel and provide manpower for expansion of the programme in the coming decade, it would be necessary to train and recruit about 700 scientists and engineers every year in R&D units and about 650 engineers every year in public sector and industrial units.

India currently faces a shortfall in nuclear scientists and engineers.

ISSUES RELATED WITH NUCLEAR ENERGY

All nuclear reactors produce radioactive waste materials because each fission event involving nuclei of uranium or plutonium gives rise to radioactive elements called fission products. Some of these remain radioactive for hundreds of thousands of years. Despite decades of research, nuclear waste remains an unavoidable long-term problem for the environment.

Nuclear reactors are also capable of catastrophic accidents, as witnessed in Fukushima and Chernobyl. A single nuclear disaster can contaminate large tracts of land with radioactive materials, rendering these areas uninhabitable for decades. As per recent reports by the UN, more than 30 years after the accident at Chernobyl, about 650,000 acres are still excluded from inhabitation.

The cost of nuclear energy is such that it cannot be sold commercially below at least ₹7 a unit. Nuclear power is thus very high priced as compared to solar energy and other clean forms of energy.

ALTERNATIVE ENERGY SOURCES AVAILABLE

Solar Power: Solar power is abundant, inexhaustible, and arguably best known of alternative energy sources. Most common method of harnessing this energy is through solar panels that convert sunlight to electricity that is then distributed to the end user. It can be used in areas in India which cannot be covered by the electricity grid and is also being incentivised by the government.

Natural Gas: Natural gas can also be used as an alternative source of transport fuel and has several advantages over oil, which is the typical fossil fuel that is currently refined into gasoline. Natural gas emits less carbon and other harmful pollutants. Example: CNG, HCNG.

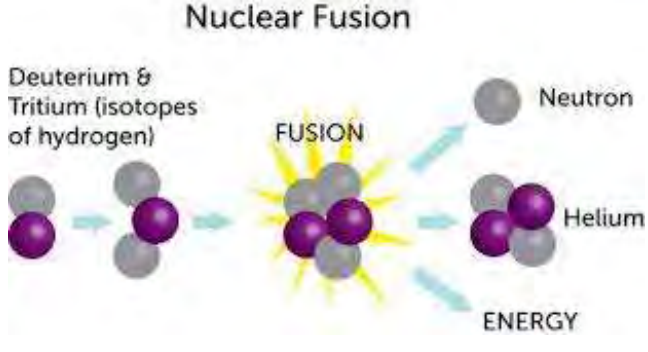
►NUCLEAR FUSION

A team at the Joint European Torus (JET) facility near Oxford in central England generated 59 megajoules of sustained energy using nuclear fusion.

- The energy was produced in a machine called a tokamak, a doughnut-shaped apparatus.
  - A tokamak is a machine that confines a plasma using magnetic fields in a donut shape that scientists call a torus.
- Deuterium and tritium, which are isotopes of hydrogen, were heated to temperatures 10 times hotter than the centre of the sun to create plasma.
- This was held in place using *superconductor electromagnets* as it spins around, fuses and releases tremendous energy as heat.

NUCLEAR FUSION REACTION

- Nuclear fusion is a kind of nuclear reaction in which there is combining of several small nuclei into one large nucleus.
- The process results in release of enormous amount of energy.
- In a sense it is the opposite of nuclear fission, where heavy a isotope is split into smaller ones.
- Nuclear fusion is the mode of energy generation in the sun. The extreme pressure produced by its immense gravity and very high temperature creates the conditions for fusion to take place.
- Fusion reactions take place in the plasma state – the 5th state of matter. Plasma is a hot, charged fluid made of fast moving positive ions and free-moving electrons.
- Plasma state make it possible for two nuclei to come closer together and get fused.



SIGNIFICANCE OF NUCLEAR FUSION

- Enormous amount of energy: It releases nearly 10 million times more energy than a chemical reaction such as the burning of coal, oil or gas and four times as much as nuclear fission reactions, at equal mass.
- Environmentally friendly: as the technology does not lead to any greenhouse gas emission. Its major by-product is helium: an inert, non-toxic gas.
- Sustainable supply of fuel: Fusion fuels are widely available and nearly inexhaustible. Deuterium can be distilled from all forms of water, while tritium will be produced during the fusion reaction as fusion neutrons interact with lithium.
- No radioactive waste: Nuclear fusion reactors produce no high activity, long-lived nuclear waste.
- Encourage space exploration – eg: mineral mining and prospecting for He-3.
- Diffusion of Innovation – in terms of better material design, control systems, encouragement to semi-conductor manufacturing, cooling design, development of nano-technology etc
- Social justice – nuclear fusion will bring abundant supply of electricity resulting, rural electrification, minimising rural-urban divide and balanced region growth.
- No security issue:
  - Limited risk of proliferation: Fusion doesn't employ fissile materials like uranium and plutonium (Radioactive tritium is neither a fissile nor a fissionable material).
  - No risk of meltdown: It is difficult enough to reach and maintain the precise conditions necessary for fusion—if any disturbance occurs, the plasma cools within seconds and the reaction stops.
- International relation: of India with other countries will be strengthened. India is part of International Thermonuclear Experimental Reactor (ITER) Assembly. The ITER members include China, the European Union, India, Japan, South Korea, Russia and the United States.

INITIATIVES BY GOVERNMENT TO PROMOTE FUSION TECHNOLOGY

- In the first 'Atoms for Peace' meeting in Geneva in 1955, Homi J. Bhabha showed his conviction on thermonuclear fusion and the energy source of future.
- The Institute for Plasma Research (IPR) in Gandhinagar and the Hot Plasma Project at Saha Institute of Nuclear Physics (SINP), Kolkata, took the lead in nuclear fusion research in India.
- The IPR owns two operational tokamaks – ADITYA and Steady-State Tokamak (SST)-1.
  - ADITYA Tokamak: It is the first indigenously designed and built tokamak of the country. In 1989 it was able to sustain a plasma temperature for 0.4 seconds. In 2016, the tokamak was upgraded, and it has been in the experimental phase since then.
  - SST-1: IPR is in the process of design and fabrication of SST-1. Its objectives are:
    - Studying the physics of the plasma processes in tokamak under steady-state conditions
    - Learning technologies related to the steady-state operation of the tokamak.

ITER PROJECT

- ITER project was initiated in 1988. India became a member of the ITER project in 2005.
- Institute for Plasma Research, under Department of Atomic Energy, is the institution representing India in the project.
- ITER's stated mission is to demonstrate feasibility of fusion power as a large-scale, carbon-free source of energy. More specifically, project has aims to: Momentarily produce a fusion plasma with thermal power ten times greater than injected thermal power.
- India is building many components of ITER reactor as a member country, as well as conducting several experiments and R&D activities relevant to project.
- Until date, country has delivered the project with cryostats, in-wall shielding, cooling water systems, cryogenic systems, ion-cyclotron RF heating systems, electron cyclotron RF heating systems, diagnostic neutral beam systems, and power supply.

►NUCLEAR TRIAD

INTRODUCTION

India's 1999 Draft Nuclear Doctrine had stated that its nuclear forces would be based on a triad of aircraft, mobile land-based missiles and sea-based assets. The summary of the official Nuclear Doctrine of 2003 also mentioned about maintaining a credible minimum deterrence, a posture of 'No First Use'. Hence India has worked for development of Nuclear Triad.

ABOUT NUCLEAR TRIAD

Nuclear Triad essentially has three major components- the strategic bombers, Inter Continental Ballistic Missiles (ICBMs) and Submarine Launched Ballistic Missiles

(SLBMs) for the purpose of delivering a nuclear weapon. The reason for having such three branched capability is to significantly reduce the possibility of the destruction of the entire nuclear architecture of the state in the first nuclear strike by the enemy itself. The triad provides the potency to the country which has been under the nuclear attack to respond swiftly by nuclear means. Such system essentially increases the deterrence potential of the state's nuclear forces.

This triad fundamentally represents the three basic deliveries platform for nuclear weapons, such as system like Vertical Launch Systems (VLS), Transporter Erector Launcher (TEL), Rail-mobile launcher etc. for land-based fighters and strategic bombers for air-based and under water submarines for sea based.

SIGNIFICANCE

India earlier had the capabilities to launch nuclear weapons from the Air, mounted largely on its Mirage 2000 and Jaguar Aircraft, and by land-based missiles, ranging from its Agni 1 missile, with a range 700-900 km, to Agni 5 Missiles, with a range of 5500 km. Its aim has been to develop a "credible nuclear deterrent", with capabilities to deliver nuclear weapons from multiple locations on land, air and sea, to all strategic areas and centres, in its two nuclear-armed neighbours —China and Pakistan.

With a SSBN (Ship Submersible Ballistic Nuclear ARIHANT) in place, it means that a fully functional ballistic missile becomes a strategic weapon which can fire missiles from ocean at very long ranges. Its advantage over land and air missile delivery platforms is that it can remain undetected for a long time. SSBN can strike a deadly blow to an adversary, firing ballistic missiles deep into his territory from afar.

By strengthening the second-strike capability, it also shows that with the completion of India's nuclear triad, massive retaliation to inflict unacceptable damage in event of a nuclear attack is now real.

GOVERNANCE ISSUES

India has a well-organised, streamlined nuclear command structure headed by Prime Minister & Cabinet Committee on Security; it needs to address serious issues on archaic structure of its Ministry of Defence. Most importantly, the key military figure in the Nuclear Command structure is the Chairman of the Joint Chiefs of Staff Committee, who generally holds office for less than a year. This is hardly the time adequate for him to become fully familiar the complexities of our Strategic Nuclear Command.

High level Defence Committees and Task Forces has recommended appointment of a full time "Chief or Defence Staff", or "Chairman Chiefs of Staff Committee", who will hold charge of the Nuclear "Strategic Forces Command" and report to the political authority, but still it has not been implemented.

WAY FORWARD

Successful completion of nuclear triad has enhanced India's strategic position.

To become a full-fledged nuclear triad power, India will have to be more diligent and efficient to master complex technological advancements needed to construct bigger SSBNs with longer range missiles.

Strengthen its command-and-control system, duly supported with continuous budgetary allocations.

Shorten timelines wherever possible, including retaining key personnel having requisite expertise.

Learn from experience of some of the fully operational nuclear triad powers.

PPP should continue, and private companies should be encouraged to join in this nuclear project.

NO FIRST USE POLICY OF INDIA

India's nuclear doctrine can be summarized as follows:

- Building and maintaining a credible minimum deterrent which refers to the quantity of nuclear forces that India needs to deter potential nuclear adversaries.
- A posture of "No First Use" nuclear weapons will only be used in retaliation against a nuclear attack on Indian territory or on Indian forces anywhere.
- Nuclear retaliation to a first strike will be massive and designed to inflict unacceptable damage.
- Nuclear retaliatory attacks can only be authorised by the civilian political leadership through the Nuclear Command Authority. The Nuclear Command Authority comprises a Political Council and an Executive Council. The Political Council is chaired by the Prime Minister. It is the sole body which can authorize the use of nuclear weapons.
- Non-use of nuclear weapons against non-nuclear weapon states. However, in the event of a major attack against India, or Indian forces anywhere, by biological or chemical weapons, India will retain the option of retaliating with nuclear weapons.
- A continuance of strict controls on export of nuclear and missile related materials and technologies, participation in the Fissile Material Cut-off Treaty negotiations, and continued observance of the

moratorium on nuclear tests.

- Continued commitment to the goal of a nuclear weapon free world, through global, verifiable and non-discriminatory nuclear disarmament.

ADVANTAGES OF NO FIRST USE

- It obviates the need for the expensive nuclear weapons infrastructure that is associated with a first-use doctrine.
- The onus of escalation to a nuclear War is on the adversary, without preventing India from defending itself. This prevents India from shouldering the moral responsibility of initiating a nuclear War.
- India to keep its weapons disassembled, thus averting the need for systems such as Permissive Action Links, which are necessary to maintain control over nuclear weapons if they are stored ready to fire.
- NFU will prevent India from acting against an imminent nuclear attack; however, pre-emptive strike would not prevent retaliation. Also, it is always possible that an adversary might decide not to launch a nuclear attack at the very last moment but that a pre-emptive strike will force them to retaliate.

CRITIQUE OF NO FIRST USE

- NFU posture is only possible for a country that has extreme confidence not only in the survivability of its national nuclear forces sufficient to muster a devastating retaliatory strike, but also in the efficacy of its crisis management system. Crisis management is not India's forte as seen during 26/11 attacks. The Indian bureaucratic system is yet to show capability of handling any emergency as dire as a nuclear strike.
- India's NFU policy frees Pakistan from fearing an Indian nuclear attack to either terrorism or limited war. Pakistan could deploy Tactical nuclear weapons in limited theatres without fear that India might attack them with nuclear weapons. NFU is a confidence building measure among States; however, no country practically believes those that pledge NFU. China has pledged NFU, yet India will not trust China's pledge and similarly, Pakistan does not believe in India's NFU pledge.
- Countries that have pledged NFU such as India and China, while countries that haven't such as Pakistan have the same deployment pattern of weapons during peace time and War time.
- India is a responsible nuclear power. A NFU means that India is not capable of deciding when to use nuclear weapons.

CONTRIBUTIONS OF INDIAN SCIENTISTS

Previous Year Questions

YEAR	UPSC MAINS QUESTIONS
2019	How was India benefitted from the contributions of Sir M. Visvesvaraya and Dr. M. S. Swaminathan in the fields of water engineering and agricultural science respectively?
2018	Discuss the work of 'Bose-Einstein Statistics' done by Prof. Satyendra Nath Bose and show how it revolutionized the field of Physics.

►C N R RAO

- Rao is an Indian chemist who has worked mainly in solid-state and structural chemistry.
- Rao is one of the world's foremost solid state and materials chemists.
- He has contributed to the development of the field over five decades.
- CNR Rao has been conferred with India's highest civilian award, the Bharat Ratna. He recently received that Energy Frontiers Award which is the Noble Prize of Energy Transition Research.

HIS SCIENTIFIC CONTRIBUTIONS

- His work on transition metal oxides has led to a basic understanding of novel phenomena and the relationship between materials properties and the structural chemistry of these materials.
- Rao was one of the earliest to synthesize two-dimensional oxide materials such as La2CuO4.
- He was one of the first to synthesize 123 cuprates, the first liquid nitrogen-temperature superconductor in 1987.
- He was also the first to synthesis Y junction carbon nanotubes in the mid-1990s.
- His work has led to a systematic study of compositionally controlled metal-insulator transitions.
- Such studies have had a profound impact in application fields such as colossal magnetoresistance and high-temperature superconductivity.
- He has made immense contributions to nanomaterials over the last two decades, besides his work on hybrid materials.

CITATIONS FOR THE ENERGY FRONTIERS AWARD

- Professor Rao has been working on hydrogen energy as the only source of energy for the benefit of all mankind.
- Hydrogen storage, photochemical and electrochemical production of hydrogen, solar

production of hydrogen, and non-metallic catalysis were the highlights of his work.

- The EF award has been conferred for his work on metal oxides, carbon nanotubes, and other materials and two-dimensional systems, including graphene, boron-nitrogen-carbon hybrid materials, and molybdenum sulfide (Molybdenite – MoS2) for energy applications and green hydrogen production.
- Green hydrogen production can be achieved through various processes, including the photo dissociation of water, thermal dissociation, and electrolysis activated by electricity produced from solar or wind energy.

►A P J ABDUL KALAM

A P J Abdul Kalam has been lovingly called the People's President. But before being a statesman, Dr. Kalam played a very important role in the development of India's science and technology fields. He was involved with ISRO, DRDO and India's nuclear tests.

1. India's first indigenous satellite launch vehicle: In the 1980s, India did not have its own satellite launch vehicle and was dependent on foreign countries to launch its satellites. Dr. Kalam was program director for the development of the indigenous satellite launch vehicle at ISRO played a very important role in India's SLV-III (Satellite Launch Vehicle) deploying Rohini satellite in the near-earth orbit. Thus, India became a member of the exclusive club of countries having capabilities to deploy satellites in space.
2. Missile Man of India:

Development of the Integrated Guided Missile Development Program (IGMDP): Dr Kalam conceived and played a central role in the implementation of IGDMP. This program consisted of development of 5 missiles:

a. PRITHVI which is a surface-to-surface missile.
b. AKASH which is a medium range surface to air missile.
c. NAG which is a third-generation Anti-tank Missile (ATM).
d. AGNI which is an intermediate and ballistic missile series.
e. TRISHUL which is a quick reaction surface to air missile.

3. India's nuclear test: He played a central role in India's nuclear tests in Pokhran in 1998. He was serving as the Chief Scientific Adviser to then Defence Minister. These tests made India a nuclear armed state and played an important role in augmenting India's security.
4. LCA Tejas: He was deeply involved with the development of India's Light Combat Aircraft (LCA Tejas) and became first Indian Head of State to fly a fighter plane.
5. Kalam-Raju stent: Dr Kalam collaborated with B. Soma Raju for the development of 'Kalam-Raju stent' for coronary heart disease. This indigenously developed stent helped reduce import dependence of Indians suffering from coronary heart disease on imported stents. These stents were also cheaper and made healthcare more accessible for many Indians.
6. Kalam-Raju Tablet: Dr Kalam and Dr Soma Raju again collaborated to design a rugged tablet for better health care administration in the rural pockets of the country.

►C V RAMAN

C V Raman was an Indian scientist who worked in the field of light scattering.

He was the first Asian to receive a Nobel Prize in any branch of science. (1930 Nobel Prize for Physics).

His contribution is even more exemplary as he conducted all his research in India in utterly primary laboratories, with meager finance. Most of India's later Nobel laureates have been employed with foreign laboratories.

RAMAN EFFECT

He developed a spectrograph which helped him discover that when light passes a transparent material, the deflected light changes its wavelength and frequency. This effect was termed as Raman effect or Raman scattering.

National Science Day is celebrated on the day of discovery of Raman effect.

APPLICATIONS OF RAMAN EFFECT

Raman did not realize then the major impact that Raman effect would make. Today, it is used in variety of ways and its applications are immense.

Raman analysis is one of the techniques which can provide key information, easily and quickly, detailing the chemical composition and the structure of the investigated materials.

Applications:

1. In Cancer Diagnosis
2. In Material Science: Raman scattering is widely used in material science as a characterization technology.

OTHER SCIENTIFIC CONTRIBUTIONS

- Studied the scientific basis of musical sounds and instruments.
- Explanation of blue color of sea water: Prior to Raman, it was believed that sea water was blue because it reflected the color of the sky which is blue due to the Rayleigh scattering. Raman's experiments disproved this hypothesis.

INSTITUTION BUILDING

- Raman Research Institute: Raman used his savings and donations to build a new institute devoted to physics research called Raman Research Institute.
- He founded Indian Journal of Physics and served as first Indian director of Indian Institute of Science.
- He also founded the Indian Academy of Sciences.

►RAMANUJAN

ABOUT RAMANUJAN

- The Man Who Knew Infinity (2015) was a biopic on the mathematician.
- His mathematics, done over a hundred years ago, finds applications today in areas other than pure mathematics. Two among these are signal processing and black hole physics.

SIGNAL PROCESSING

- Examples of signals that are processed digitally include obvious ones like speech and music to more research-oriented ones such as DNA and protein sequences.
- These all have certain patterns that repeat repeatedly and are called periodic patterns.
- Complex repeating patterns may need to be identified as they bear significance to health conditions. So, in signal processing, one thing we are interested in is extracting and identifying such periodic information.

PARTITIONS OF A NUMBER

- Ramanujan was interested in the number of ways one can partition an integer (a whole number).
- For instance, 3 can be written as 1+1+1 or 2+1.
- As the number to be partitioned gets larger and larger, the number of ways to partition it becomes difficult to compute.

The seemingly simple mathematical calculation is related to a very sophisticated method to reveal the properties of black holes.

BLACK HOLE ENTROPY

- A separate concept in physics, entropy, explains why heat flows from a hot body to a cold body and not the other way around.
- The results of Ramanujan and Hardy on partitions and his subsequent work on what are called mock theta functions have come to play an important role in understanding the very quantum structure of space-time – the quantum entropy of a type of Black Hole in string theory.

National Mathematics Day is celebrated every year in India on December 22 to mark the birth anniversary of Indian Mathematician Srinivasa Ramanujan and to recognise his achievements.

►BOSE-EINSTEIN CONDENSATE (BEC)

- In Bose-Einstein condensate (BEC) particles condense to the lowest energy level when temperature is taken to very low values. The particles in any system ordinarily are in different quantum states, exhibiting the state of complete chaos. As the particles condensate into BEC, all particles come to the same quantum state from different quantum states, leading to the state of order.
- In short, during the transition to the BEC there is transition from the state of chaos to the state of order.
- NASA Scientists recently observed the fifth state of matter in space for the first time as part of Bose Einstein Condensates (BEC) Experiments aboard the International Space Station (ISS). Solids, liquids, gases, and plasma are the other four states of matter.
- This state was first predicted in 1924–1925 by Albert Einstein following a pioneering paper by Satyendra Nath Bose on the new field now known as quantum statistics.
- BEC is a super cooled gas that no longer behaves as individual atoms and particles, but an entity in a single quantum state.
- The most intriguing property of BECs is that they can slow down light. Researchers have shown how light traveling through a BEC got its speed reduced from its speed in vacuum of 3 × 108 meters per second to a mere 17 meters per second.
- In 2001, physicists for the first time managed to stop light in a vapor of rubidium gas.

Applications

- Tests of general relativity - *Light can be variable in speed and* frequency.

- *Applying Quantum mechanics at macroscopic level.*
- *Quantum computing as BECs can be used to design qubits which can operate at stably at room temperatures.*
- Searches for dark energy, dark matter, and gravitational waves.
- Spacecraft navigation.
- Prospecting for subsurface minerals on the moon and other planetary bodies.
- Applications of superfluidity and superconductivity
- Precision measurement by the development of sensitive detectors

►SCIENCE AND TECHNOLOGY IN ANCIENT INDIA

- Aryabhatta, a great mathematician and astronomer, wrote the book Aryabhatiyam in 499 A.D dealing with mathematics and astronomy. It explains scientifically occurrence of solar and lunar eclipses.
- Aryabhatta was the first to declare that the earth was spherical in shape and that it rotates on its own axis.
- Aryabhatta was the first to invent "zero" and the use of the decimal system. (A Gupta inscription from Allahabad district *suggests that* decimal system was known in India at the beginning of fifth century A. D.)
- Varahamihira composed Pancha Siddhantika, the five astronomical systems. His work Brihadsamhita is a great work in Sanskrit literature. His Brihadjataka is a standard work on astrology.
- In the fields of astronomy, a book called Romaka Siddhanta was compiled which was influenced by Greek ideas, as can be inferred from its name.
- In the field of medicine, Vagbhata lived during this period. He was the last of the great medical trio of ancient India. (The other two scholars Charaka and Susruta lived before the Gupta age. Charaka is known for authoring the medical treatise, the Charaka Samhita.)
- Metallurgy saw technological advancement in Gupta times. The Gupta craftsmen distinguished themselves by their work in iron and bronze.
- In the case of iron objects, the best example is twenty-three feet high iron pillar at Mehrauli in Delhi.
- The paintings of Ajanta, still intact, indicate besides other things, the art of making colors during the period.

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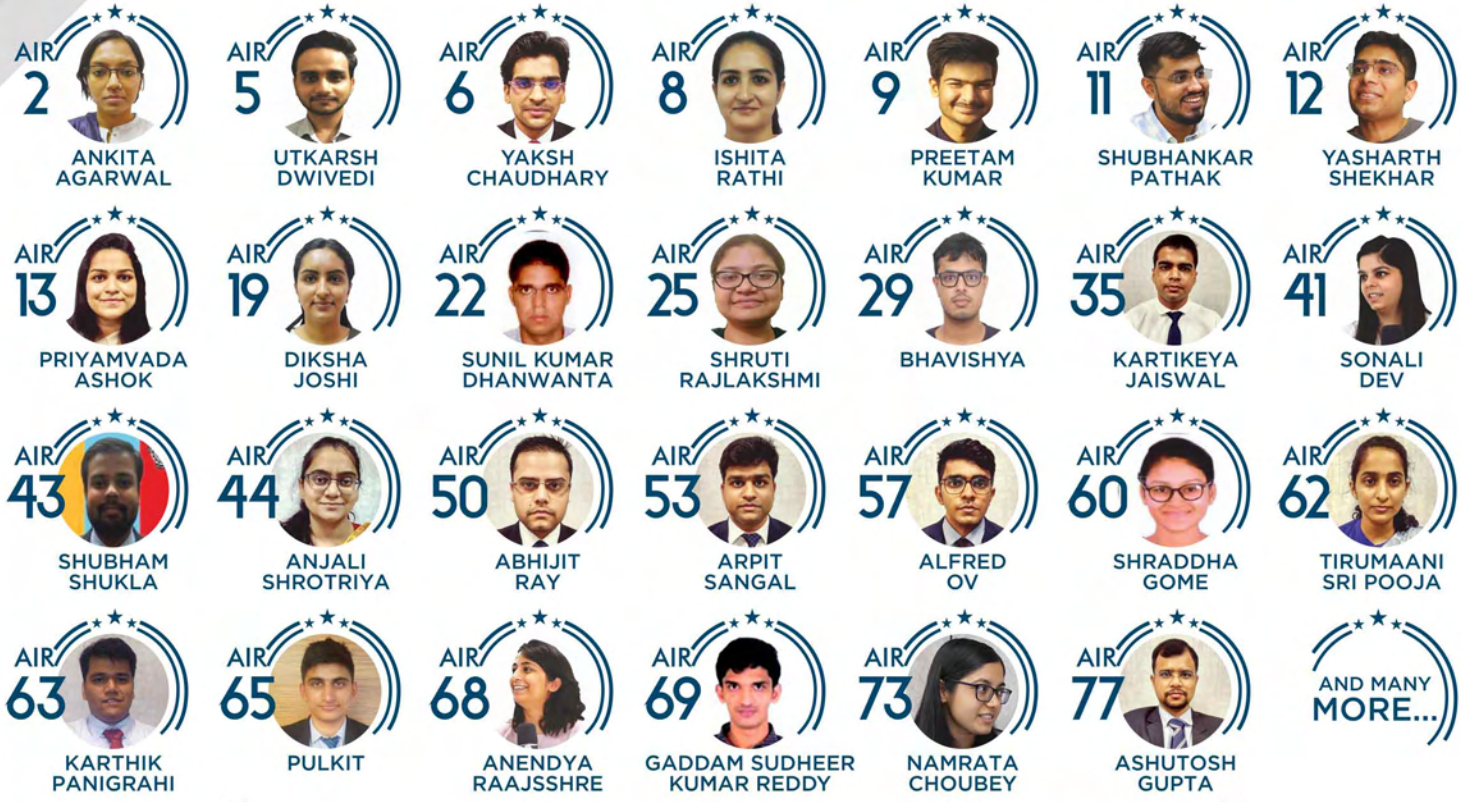

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