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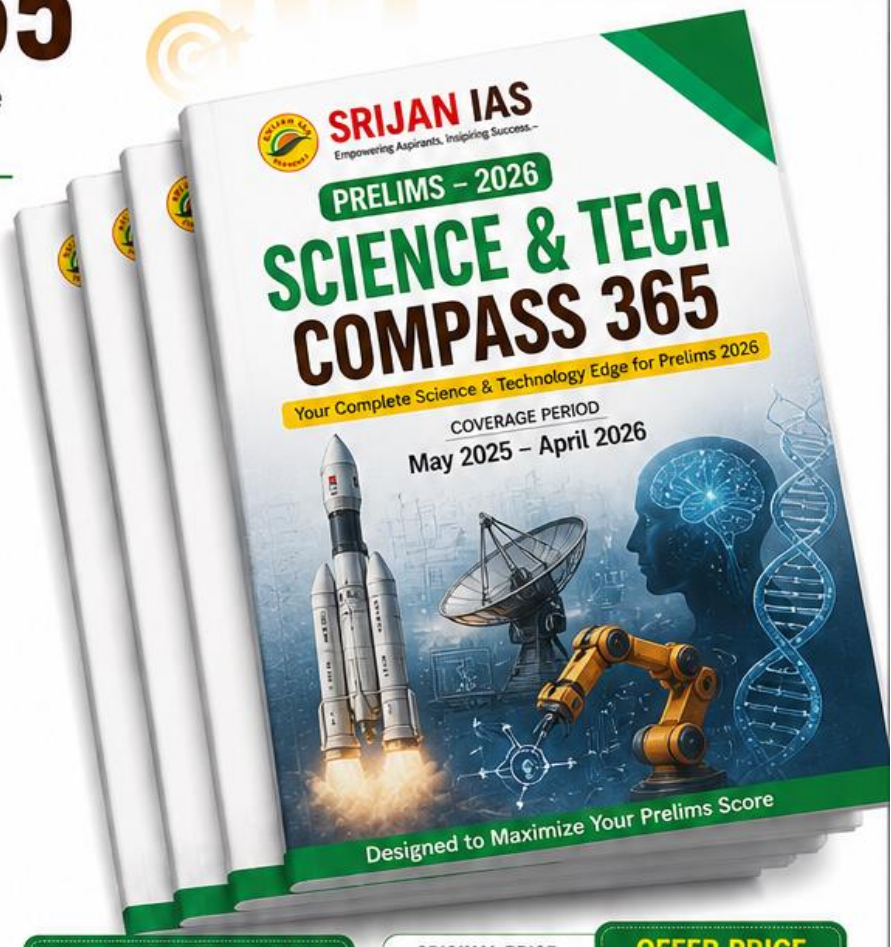
PRELIMS – 2026
SCIENCE & TECH COMPASS 365

Your Complete Science & Technology Edge for Prelims 2026

COVERAGE PERIOD
May 2025 – April 2026



SET OF 6 SUBJECT-WISE BOOKLETS:

1. POLITY
2. ECONOMY
3. SCIENCE & TECHNOLOGY
4. GEOGRAPHY & ENVIRONMENT
5. SOCIETY, CULTURE & PIB
6. IR & INTERNAL SECURITY

KEY HIGHLIGHTS

- Last 1 year Current Affairs contribute ~60–65 questions in UPSC Prelims
- Covers all high-probability current affairs pointers
- Government Schemes, Policies, and Reports are comprehensively covered
- Important Terms & Keywords are highlighted
- Major Supreme Court Judgements and Constitutional developments are included
- Science & Technology is simplified and filtered

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"The future belongs to those who believe in the beauty of their dreams."
– Dr. A. P. J. Abdul Kalam

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SCIENCE & TECH COMPASS 365: CURRENT AFFAIRS FROM MAY 2025 TO APRIL 2026

1. Laser Breakthrough for Long-Range Radioactive Detection

Core Idea

A new laser-based technique using carbon-dioxide lasers enables **remote detection of radioactive materials** by exploiting **avalanche breakdown** in air. Ionization caused by radioactive decay enhances electron acceleration, producing detectable plasma signals (optical backscatter).

- Key advantage: Detect radiation **without physical proximity**, crucial for nuclear safety.

Why in News

US physicists have demonstrated detection of radioactive particles (alpha) from **10 meters**, significantly improving previous capabilities and opening scope for **defense and emergency response applications**.

Key Facts and Figures

- Detection range increased to **10 m (alpha particles)**
- Potential: **100 m (gamma rays)**; future scaling ~**1 km**
- Laser wavelength: **~9.2 micrometers (infrared)**

Definition of Key Terms

- **Avalanche Breakdown**: Rapid multiplication of charged particles due to ionization, leading to plasma formation.
- **Alpha Particles**: Positively charged helium nuclei; low penetration power.
- **Gamma Rays**: High-energy electromagnetic radiation with high penetration.
- **Optical Backscatter**: Reflection of light signals used to detect particles remotely.

Ministry / Institutions / Organizations Involved

Primarily developed by physicists in the United States; relevant globally for agencies dealing with nuclear safety such as the International Atomic Energy Agency, which oversees nuclear security standards and radiation monitoring frameworks.

Government Acts / Policies / Judgements

- **Atomic Energy Act, 1962**
  - Governs nuclear energy use in India; regulates radioactive material handling.
- **Civil Liability for Nuclear Damage Act, 2010**
  - Ensures liability framework for nuclear accidents.
- **IAEA Safety Standards**
  - Provide global norms for radiation detection and safety protocols.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **types of radiation & nuclear physics basics (2012, 2016)**
- UPSC asked on **IAEA & nuclear safety (2017, 2020)**

Possible Prelims Trap Areas

- Confusing **alpha vs gamma penetration ability**
- Assuming **laser detects radiation directly** (it detects plasma effects, not radiation itself)

2. Digital Personal Data Protection (DPDP) Act, 2023 – Key Provisions

Core Idea

India's first comprehensive law regulating **digital personal data processing**, focusing on **consent-based data governance, user rights, and fiduciary accountability**. It operationalizes the Right to Privacy under Article 21.

Why in News

Union Government has **notified major provisions**, moving towards full implementation and setting compliance deadlines (notably **November 2026** for key frameworks like Consent Managers).

Key Facts and Figures

- Penalty up to **₹250 crore per violation**
- Applies to **digital personal data (including digitized offline data)**
- Introduces **Significant Data Fiduciary classification**

Definition of Key Terms

- **Data Principal**: Individual whose data is processed
- **Data Fiduciary**: Entity deciding purpose and means of processing
- **Consent Manager**: Platform to manage user consent
- **Processing**: Any operation on personal data (collection, storage, sharing)

Ministry / Institutions / Organizations Involved

Administered by the **Ministry of Electronics and Information Technology (MeitY)**; enforcement through the proposed Data Protection Board. Judicial foundation stems from Justice K.S. Puttaswamy vs Union of India, which recognized privacy as a Fundamental Right.

Government Acts / Policies / Judgements

- **Digital Personal Data Protection Act, 2023**
  - Consent-based processing, penalties, fiduciary obligations.
- **Right to Information Act, 2005 (Amendment to Sec 8(1)(j))**
  - Restricts disclosure of personal information; reduces public-interest override.
- **Information Technology Act, 2000**
  - Existing cyber law framework; DPDP complements it.
- **K.S. Puttaswamy Judgment (2017)**
  - Established privacy as a Fundamental Right under Article 21.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **Right to Privacy & Fundamental Rights (2017, 2018)**
- UPSC asked on **Data protection & IT Act provisions (2020, 2022)**

Possible Prelims Trap Areas

- Confusing **Data Fiduciary vs Data Processor** (processor not central in DPDP framework)
- Misinterpreting **RTI amendment as complete denial of information**

3. Discovery of New Mosquito Species – 'Pwani Molecular Form'

Core Idea

A newly identified mosquito species in East Africa, genetically distinct but closely related to **malaria vector species**, highlights evolving vector biology and challenges in disease control.

Why in News

Scientists discovered a new mosquito variant ('Pwani molecular form') in **Tanzania and Kenya**, raising concerns over **insecticide resistance and malaria transmission dynamics**.

Key Facts and Figures

- Region: **East Africa (coastal Tanzania & Kenya)**
- Closely related to **Anopheles gambiae**
- Identified using **genomic/molecular tools**

Definition of Key Terms

- **Vector**: Organism that transmits pathogens (e.g., mosquitoes for malaria)
- **Insecticide Resistance**: Ability of insects to survive chemical exposure
- **Molecular Form**: Genetically distinct population within a species complex

Ministry / Institutions / Organizations Involved

Research conducted by institutions including the Wellcome Sanger Institute and Ifakara Health Institute. Globally, malaria control is coordinated by the World Health Organization. In India, vector control falls under National Vector Borne Disease Control Programme (NVBDCP).

Government Acts / Policies / Judgements

- **National Vector Borne Disease Control Programme (NVBDCP)**
    - India's flagship programme for malaria, dengue, etc.
- **National Health Policy, 2017**
    - Emphasizes disease prevention and vector control.
- **WHO Global Technical Strategy for Malaria (2016–2030)**
    - Targets malaria elimination with surveillance and innovation.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **malaria & vectors (2015, 2021)**
- UPSC asked on **biotechnology in disease detection (2019, 2023)**

Possible Prelims Trap Areas

- Confusing **species vs molecular form (sub-population)**
- Assuming **all Anopheles transmit malaria equally** (only specific species are vectors)

4. The Other Space Race – Geopolitics of Satellite Internet

Core Idea

Satellite internet (via Low Earth Orbit satellites) is emerging as a **strategic digital infrastructure**, influencing **geopolitics, sovereignty, and global power balance**. Control over satellite constellations = control over data flow and connectivity.

- Seen as a **new domain of strategic competition** similar to sea routes/oil.

Why in News

India is engaging with **Starlink (SpaceX)** through telecom players like Jio and Airtel, raising debates

on **digital sovereignty vs foreign dependency** and competition with China's satellite network initiatives.

Key Facts and Figures

- Starlink satellites: **7000+ (largest LEO constellation)**
- Competitors: OneWeb, Amazon Kuiper
- Orbit used: **Low Earth Orbit (LEO ~500–2000 km)**

Definition of Key Terms

- **Satellite Internet**: Internet delivered via satellites instead of terrestrial infrastructure.
- **Digital Sovereignty**: Nation's control over its digital data, networks, and infrastructure.
- **LEO Satellites**: Satellites in low orbit enabling low-latency communication.

Ministry / Institutions / Organizations Involved

Key stakeholders include SpaceX (Starlink), ISRO for indigenous capabilities, and telecom operators. Regulatory oversight in India lies with DoT and TRAI, while globally space governance norms are influenced by bodies like the International Telecommunication Union.

Government Acts / Policies / Judgements

- **Indian Space Policy, 2023**
  - Promotes private participation and commercialization in space sector.
- **Telecommunications Act, 2023**
  - Regulates spectrum allocation including satellite communication.
- **Outer Space Treaty, 1967**
  - Establishes space as global commons; restricts sovereignty claims.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **space technology & satellite communication (2013, 2017, 2022)**
- UPSC asked on **ITU & global governance (2014, 2021)**

Possible Prelims Trap Areas

- Confusing **LEO vs GEO satellites (altitude & latency differences)**
- Assuming **space is fully sovereign-controlled (it is governed by treaties)**

5. Prescribe Preventive Medicine for a Healthy India

Core Idea

Preventive healthcare emphasizes **early intervention, disease prevention, and health promotion** rather than treatment. It reduces disease burden, healthcare costs, and improves productivity.

- Focus shifts from **curative → preventive model**.

Why in News

Policy discussions and health strategies increasingly emphasize **preventive healthcare**, especially due to rising burden of **Non-Communicable Diseases (NCDs)** and healthcare costs in India.

Key Facts and Figures

- NCDs account for **~60% of deaths in India**
- Linked to **SDG-3 (Good Health & Well-being)**
- High **out-of-pocket expenditure** in India (~50%+)

Definition of Key Terms

- **Preventive Healthcare**: Measures to prevent disease (vaccination, screening).
- **NCDs**: Chronic diseases (diabetes, cancer, hypertension).
- **Universal Health Coverage (UHC)**: Access to healthcare without financial hardship.

Ministry / Institutions / Organizations Involved

Led by Ministry of Health & Family Welfare; implementation via schemes like Ayushman Bharat and institutions like the World Health Organization guiding global health standards. Grassroots execution through ASHA workers and Panchayati Raj institutions.

Government Acts / Policies / Judgements

- **Ayushman Bharat Programme (2018)**
  - Includes Health & Wellness Centres (HWCs) for preventive care + PM-JAY for insurance.
- **National Health Policy, 2017**
  - Emphasizes preventive and promotive healthcare.
- **National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke (NPCDCS)**
  - Focuses on NCD screening and early detection.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **Ayushman Bharat & health schemes (2018, 2020, 2023)**
- UPSC asked on **NCDs & public health (2017, 2021)**

Possible Prelims Trap Areas

- Confusing **preventive vs promotive vs curative healthcare**
- Assuming **Ayushman Bharat only provides insurance (HWCs focus on prevention)**

6. Iron's Unexpected Opacity Inside the Sun

Core Idea

New experiments show **iron inside the Sun is far more opaque** than previously estimated, affecting how energy is transported within the Sun and altering solar and stellar models.

- Opacity determines **radiation absorption → energy transfer inside stars**.

Why in News

Recent experiments at Sandia National Laboratories confirmed that iron's opacity is **up to 400% higher**, challenging existing solar physics models.

Key Facts and Figures

- Opacity deviation: **up to 400% higher**
- Plasma conditions: **>180 eV temperature**
- Extremely high densities simulated (~10^{30} particles/ml scale)

Definition of Key Terms

- **Opacity**: Measure of how much radiation is absorbed by a material.
- **Plasma**: Ionized gas with free electrons and ions (state of matter in stars).
- **Helioseismology**: Study of solar interior using wave oscillations.

Ministry / Institutions / Organizations Involved

Research conducted by international teams including Sandia Labs; solar physics globally studied by agencies like NASA. In India, solar

studies are supported by ISRO (e.g., Aditya-L1 mission).

Government Acts / Policies / Judgements

- **Aditya-L1 Mission (ISRO)**
    - India's first solar mission studying corona, solar wind, and radiation.
- **Space Policy, 2023**
    - Encourages advanced space research including astrophysics.
- **International Solar Research Collaborations**
    - Promote global data sharing in heliophysics.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **Sun structure & solar phenomena (2012, 2019, 2023)**
- UPSC asked on **plasma state & astrophysics basics (2016, 2022)**

Possible Prelims Trap Areas

- Confusing **opacity with density or temperature**
- Assuming **energy transfer in Sun is only by convection (radiative zone is key)**

7. Eco-Friendly Edible Wrappers – 'Eden Wrap'

Core Idea

A biodegradable, edible packaging alternative developed using **microbial cellulose and plant-based compounds**, aimed at replacing **single-use plastics**. It combines **biotechnology + sustainability** to address plastic pollution.

Why in News

Students from Kerala developed **'Eden Wrap'**, an edible wrapper with antimicrobial properties, gaining attention for its **eco-friendly packaging potential and startup scalability**.

Key Facts and Figures

- Decomposition time: **~1 month**
- Made from: **cellulose-producing bacteria + plant oils**
- Fully **edible & biodegradable**

Definition of Key Terms

- **Biodegradable**: Material that decomposes naturally via microorganisms.
- **Microbial Cellulose**: Cellulose produced by bacteria, used in bio-materials.
- **Antimicrobial Property**: Ability to inhibit microbial growth.

Ministry / Institutions / Organizations Involved

Developed at Kerala Agricultural University; potential scaling with support from Council of Scientific and Industrial Research. Policy alignment with initiatives of Ministry of Environment, Forest and Climate Change and startup ecosystem under DPIIT.

Government Acts / Policies / Judgements

- **Plastic Waste Management Rules, 2016 (amended)**
    - Restricts single-use plastics; promotes alternatives.
- **Startup India Initiative (2016)**
    - Encourages innovation-driven enterprises with funding and incubation.
- **Atmanirbhar Bharat Mission**
    - Promotes indigenous sustainable technologies and local manufacturing.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **biodegradable plastics & waste management (2016, 2021)**
- UPSC asked on **biotechnology applications (2019, 2023)**

Possible Prelims Trap Areas

- Confusing **biodegradable with compostable (conditions differ)**
- Assuming **all eco-friendly materials are edible (not necessarily)**

8. James Webb Space Telescope (JWST) – Detection of Possible Biosignatures

Core Idea

Detection of potential **biosignature gases (DMS, DMDS)** in an exoplanet atmosphere suggests possible biological activity, marking progress in **astrobiology and search for extraterrestrial life**.

Why in News

Scientists using the James Webb Space Telescope detected these gases in **K2-18 b**, raising prospects of life beyond Earth.

Key Facts and Figures

- Distance: **~120 light-years (Leo constellation)**
- Planet type: **Hycean (ocean + hydrogen atmosphere)**
- Mass: **~8.6× Earth**; Size: **~2.6× Earth**

Definition of Key Terms

- **Biosignature**: Substance indicating possible life processes.
- **Exoplanet**: Planet outside the solar system.
- **Hycean Planet**: Hypothetical ocean-covered planet with hydrogen-rich atmosphere.

Ministry / Institutions / Organizations Involved

The discovery involves global collaboration led by agencies like NASA and international astrophysics teams; JWST is a joint mission of NASA, ESA, and CSA.

Government Acts / Policies / Judgements

- **James Webb Space Telescope Mission (2021 launch)**
  - Operates in infrared; successor to Hubble; studies early universe & exoplanets.
- **Outer Space Treaty, 1967**
  - Governs peaceful use of outer space.
- **India Space Policy, 2023**
  - Encourages participation in global space science missions.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **exoplanets & habitable zones (2015, 2019, 2023)**
- UPSC asked on **space telescopes & missions (2016, 2022)**

Possible Prelims Trap Areas

- Assuming **biosignature = confirmed life (it is only an indicator)**
- Confusing **infrared telescope with optical telescope capabilities**

9. Dark Matter Deficiency in Galaxy NGC 1052-DF2

Core Idea

A galaxy observed to have **little or no dark matter**, challenging the standard model where dark matter is essential for **galaxy formation and mass stability**.

Why in News

Indian astronomers from the Indian Institute of Astrophysics studied NGC 1052-DF2 and found **unexpectedly low dark matter content**, raising theoretical questions.

Key Facts and Figures

- Galaxy type: **Ultra-diffuse galaxy**
- Dynamical mass: **<340 million solar masses**
- Stellar mass: **~200 million solar masses**

Definition of Key Terms

- **Dark Matter**: Invisible matter inferred from gravitational effects.
- **Dynamical Mass**: Total mass derived from motion of objects in galaxy.
- **Ultra-Diffuse Galaxy**: Large but faint galaxy with low stellar density.

Ministry / Institutions / Organizations Involved

Research led by Indian Institute of Astrophysics; global cosmology research also involves agencies like European Space Agency and NASA.

Government Acts / Policies / Judgements

- **India Space Policy, 2023**
  - Supports advanced astrophysical research.
- **Aditya-L1 Mission (ISRO)**
  - Enhances solar and space observation capabilities.
- **Global Cosmology Research Collaborations**
  - Enable shared data for dark matter studies.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **dark matter & dark energy (2013, 2020)**
- UPSC asked on **galaxy formation & cosmology basics (2017, 2022)**

Possible Prelims Trap Areas

- Confusing **dark matter with dark energy**
- Assuming **all galaxies must contain significant dark matter**

10. AI and Animal Communication

Core Idea

Artificial Intelligence is being used to **decode animal communication (bioacoustics)** by identifying patterns in sounds and signals. It helps in **biodiversity monitoring, conservation, and behavioral studies**, but still lacks contextual understanding.

Why in News

Google developed **DolphinGemma**, an AI model trained on dolphin vocalizations, showcased on **National Dolphin Day (April 14)**, marking progress in AI-driven wildlife communication research.

Key Facts and Figures

- Model size: **~400 million parameters**
- Species studied: **Dolphins (Bahamas dataset)**
- Uses: **Pattern recognition in whistles, clicks, buzzes**

Definition of Key Terms

- **Bioacoustics**: Study of sound production and perception in animals.
- **AI Model**: Algorithm trained on large datasets to detect patterns.

- **Anthropomorphism**: Attributing human meaning to animal behavior.

Ministry / Institutions / Organizations Involved

Developed by Google in collaboration with Georgia Tech and the Wild Dolphin Project. Conservation applications align with global work by the World Wide Fund for Nature.

Government Acts / Policies / Judgements

- **Wildlife Protection Act, 1972**
    - Provides legal framework for wildlife conservation in India.
- **National Biodiversity Action Plan (2008)**
    - Focuses on biodiversity monitoring and conservation.
- **Convention on Biological Diversity (CBD)**
    - Global treaty promoting conservation and sustainable use of biodiversity.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **AI applications & emerging tech (2020, 2023)**
- UPSC asked on **biodiversity monitoring & conservation (2016, 2021)**

Possible Prelims Trap Areas

- Assuming **AI fully understands animal language (only pattern detection)**
- Confusing **bioacoustics with general AI/ML applications**

11. Axiom-4 (Ax-4) Space Mission

Core Idea

Axiom-4 is a **private human spaceflight mission to the International Space Station (ISS)**, reflecting the growing role of **commercial space missions and international collaboration** in human space exploration.

Why in News

The upcoming Ax-4 mission includes participation from multiple countries including India, marking a **milestone in India's human spaceflight engagement through private partnerships**.

Key Facts and Figures

- Destination: **International Space Station (ISS)**
- Operated by: **Axiom Space (private company)**
- Launch vehicle: **SpaceX Falcon 9**

Definition of Key Terms

- **Commercial Spaceflight**: Space missions operated by private companies.
- **ISS**: A habitable artificial satellite used for research in microgravity.
- **Low Earth Orbit (LEO)**: Orbit range of ~160–2000 km above Earth.

Ministry / Institutions / Organizations Involved

Mission led by Axiom Space in collaboration with NASA and SpaceX. India's involvement is linked to ISRO's broader human spaceflight ambitions (Gaganyaan).

Government Acts / Policies / Judgements

- **Indian Space Policy, 2023**
    - Encourages private sector participation in space missions.
- **Gaganyaan Mission**
    - India's first human spaceflight programme.
- **Outer Space Treaty, 1967**
    - Governs peaceful use of space and international cooperation.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **ISS & space missions (2015, 2018, 2022)**
- UPSC asked on **private sector in space (2020, 2023)**

Possible Prelims Trap Areas

- Confusing **Axiom mission with ISRO mission (it is private-led)**
- Assuming **ISS is owned by a single country (it is multinational)**

12. Solar Climate Intervention Techniques

Core Idea

Solar Climate Intervention (SCI), also called **Solar Radiation Management (SRM)**, involves techniques to **reflect sunlight back into space** to reduce global warming temporarily.

Why in News

Increasing global discussions on **geoengineering solutions** to combat climate change have brought SCI techniques into focus amid rising temperatures and climate risks.

Key Facts and Figures

- Aim: Reduce **incoming solar radiation**
- Examples: **Stratospheric aerosol injection, marine cloud brightening**
- Considered **temporary climate mitigation tool**

Definition of Key Terms

- **Geoengineering**: Deliberate large-scale intervention in Earth's climate system.
- **Albedo**: Reflectivity of Earth's surface.
- **Stratospheric Aerosols**: Particles injected into upper atmosphere to reflect sunlight.

Ministry / Institutions / Organizations Involved

Climate-related research and governance involve the Intergovernmental Panel on Climate Change and UNEP; in India, Ministry of Environment, Forest and Climate Change is the nodal authority.

Government Acts / Policies / Judgements

- **Paris Agreement, 2015**
  - Focuses on emission reduction; does not formally endorse geoengineering.
- **National Action Plan on Climate Change (NAPCC)**
  - India's climate mitigation and adaptation strategy.
- **UNFCCC Framework**
  - Governs global climate negotiations and commitments.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **climate engineering & albedo (2017, 2021)**
- UPSC asked on **IPCC & climate change mitigation (2014, 2022)**

Possible Prelims Trap Areas

- Confusing **mitigation (emission reduction) with geoengineering (radiation control)**
- Assuming **SCI solves root cause of climate change (it does not)**

13. Magnetic Isolation and Concentration (MagIC)

Core Idea

MagIC is a **scientific technique using magnetic fields to isolate and concentrate specific particles or materials**, often applied in **biotechnology, medical diagnostics, and environmental analysis**.

Why in News

Recent advancements highlight MagIC as a promising tool for **efficient separation and detection processes**, especially in biomedical and environmental applications.

Key Facts and Figures

- Works via **magnetic nanoparticles or fields**
- Applications: **disease detection, pollutant separation**
- Improves **precision and efficiency**

Definition of Key Terms

- **Magnetic Separation**: Process of separating materials using magnetic properties.
- **Nanoparticles**: Particles at nanometer scale with unique properties.
- **Isolation Technique**: Method to extract specific components from mixtures.

Ministry / Institutions / Organizations Involved

Research driven by scientific institutions globally; in India, supported by bodies like Department of Biotechnology and CSIR for applied research.

Government Acts / Policies / Judgements

- **National Biotechnology Development Strategy**
    - Promotes biotech innovations and research.
- **Science, Technology and Innovation Policy (STIP)**
    - Encourages advanced research and interdisciplinary technologies.
- **DBT Schemes**
    - Support translational research in diagnostics and health tech.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **nanotechnology & biotechnology applications (2016, 2019, 2023)**
- UPSC asked on **diagnostic technologies (2020, 2022)**

Possible Prelims Trap Areas

- Confusing **MagIC with general magnetism (it is applied technique)**
- Assuming **only industrial use (also biomedical & environmental)**

14. KATRIN Experiment

Core Idea

KATRIN (Karlsruhe Tritium Neutrino Experiment) aims to **measure the mass of neutrinos**, one of the most fundamental yet elusive particles in physics. It studies beta decay of tritium to determine neutrino mass with high precision.

- Important for **particle physics, cosmology, and structure of the universe**.

Why in News

Recent results from the KATRIN experiment have **tightened the upper limit of neutrino mass**, refining our understanding of the Standard Model and cosmic evolution.

Key Facts and Figures

- Location: **Karlsruhe, Germany**
- Particle studied: **Neutrino (electron neutrino)**

- Method: **Tritium beta decay spectroscopy**

Definition of Key Terms

- **Neutrino**: Nearly massless, neutral subatomic particle interacting weakly with matter.
- **Beta Decay**: Radioactive decay where a neutron converts into a proton, emitting an electron and neutrino.
- **Standard Model**: Theory describing fundamental particles and forces (except gravity).

Ministry / Institutions / Organizations Involved

Conducted by an international collaboration led by the Karlsruhe Institute of Technology, with contributions from global physics institutions; relevant to CERN-level particle physics research.

Government Acts / Policies / Judgements

- **International Particle Physics Collaborations**
    - Enable shared infrastructure and research on fundamental particles.
- **India-Based Neutrino Observatory (INO)**
    - Proposed Indian facility to study neutrinos.
- **Science, Technology and Innovation Policy (STIP)**
    - Supports fundamental research in physics.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **neutrinos & particle physics (2015, 2020)**
- UPSC asked on **India-based Neutrino Observatory (2016, 2018)**

Possible Prelims Trap Areas

- Confusing **neutrino with neutron (different particles)**
- Assuming **neutrinos have zero mass (they have very small but non-zero mass)**

15. DNA Identification Techniques

Core Idea

DNA identification uses **unique genetic markers** to identify individuals, widely used in **forensics, criminal investigations, and disaster victim identification**.

Why in News

Growing emphasis on **DNA-based forensic systems and databases** in India has highlighted advancements and regulatory frameworks for DNA identification.

Key Facts and Figures

- Basis: **99.9% DNA similarity among humans; 0.1% variation used for identification**
- Uses: **forensics, paternity testing, missing persons identification**
- Requires: **DNA profiling databases**

Definition of Key Terms

- **DNA Profiling**: Technique to identify individuals using genetic patterns.
- **STR (Short Tandem Repeats)**: Repeating DNA sequences used as markers.
- **Forensic Science**: Application of science in criminal investigation.

Ministry / Institutions / Organizations Involved

In India, overseen by Ministry of Home Affairs and forensic labs; legislative framework linked to

DNA Technology (Use and Application) Regulation Act.

Government Acts / Policies / Judgements

- **DNA Technology (Use and Application) Regulation Act, 2022**
    - Establishes DNA databanks and regulatory boards for forensic use.
- **Indian Evidence Act, 1872 (amended)**
    - Allows scientific evidence including DNA profiling.
- **Criminal Procedure (Identification) Act, 2022**
    - Expands scope of biometric data collection.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **DNA fingerprinting & biotechnology (2014, 2019)**
- UPSC asked on **forensic science applications (2020, 2022)**

Possible Prelims Trap Areas

- Confusing **DNA profiling with genome sequencing (different scope)**
- Assuming **DNA evidence is always conclusive (depends on handling & contamination)**

16. New Species of Jumping Spider

Core Idea

Discovery of a new species of **jumping spider (family Salticidae)** highlights biodiversity richness and importance of **taxonomic research** in ecology and conservation.

Why in News

Scientists have identified a **new jumping spider species**, contributing to expanding knowledge of species diversity and ecosystem dynamics.

Key Facts and Figures

- Family: **Salticidae (jumping spiders)**
- Known for: **excellent vision and jumping ability**
- One of the **largest spider families globally**

Definition of Key Terms

- **Taxonomy**: Science of classification of organisms.
- **Endemic Species**: Species restricted to a specific region.
- **Arachnid**: Class of joint-legged invertebrates (spiders, scorpions).

Ministry / Institutions / Organizations Involved

Biodiversity documentation in India is supported by Zoological Survey of India and global conservation frameworks like the International Union for Conservation of Nature.

Government Acts / Policies / Judgements

- **Biological Diversity Act, 2002**
    - Provides framework for conservation and sustainable use of biodiversity.
- **Wildlife Protection Act, 1972**
    - Protects species and habitats in India.
- **Convention on Biological Diversity (CBD)**
    - Global treaty on biodiversity conservation.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **new species discovery & taxonomy (2016, 2021, 2023)**

- UPSC asked on **biodiversity conservation frameworks (2015, 2020)**

Possible Prelims Trap Areas

- Confusing **arachnids with insects (different classes)**
- Assuming **all newly discovered species are endangered (not necessarily)**

17. Step-and-Shoot Spot-Scanning Proton Arc Therapy (SPArc Therapy)

Core Idea

SPArc Therapy is an advanced form of **proton beam therapy** used in cancer treatment. It delivers radiation in a **rotational (arc) manner using spot-scanning**, allowing highly precise tumor targeting while minimizing damage to surrounding healthy tissues.

- Key advantage: exploits the **Bragg Peak** property of protons for targeted dose delivery.

Why in News

Recent developments in radiation oncology have highlighted SPArc Therapy as a **next-generation cancer treatment technique**, improving efficiency and precision over conventional proton therapy.

Key Facts and Figures

- Based on **proton beams (charged particles)**
- Uses **arc delivery + spot scanning**
- Improves **dose conformity & reduces treatment time**

Definition of Key Terms

- **Proton Therapy**: Radiation therapy using protons instead of X-rays.
- **Bragg Peak**: Maximum energy deposition by charged particles at a specific depth.
- **Spot Scanning**: Technique to deliver radiation in small, precise spots.

Ministry / Institutions / Organizations Involved

Cancer treatment technologies in India are supported by institutions like Tata Memorial Centre under Department of Atomic Energy; global standards guided by the International Atomic Energy Agency.

Government Acts / Policies / Judgements

- **National Programme for Prevention and Control of Cancer (NPCDCS)**
  - Focuses on early detection and treatment infrastructure.
- **Atomic Energy Regulatory Board (AERB) Guidelines**
  - Regulates radiation use in medical applications.
- **National Health Policy, 2017**
  - Promotes advanced medical technologies in healthcare.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **radiation types & medical applications (2012, 2016)**
- UPSC asked on **particle physics applications (2020)**

Possible Prelims Trap Areas

- Confusing **proton therapy with conventional radiotherapy (X-rays)**
- Misunderstanding **Bragg Peak (energy peaks at depth, not surface)**

18. Rinderpest Virus

Core Idea

Rinderpest is a **viral disease affecting cattle and wild ungulates**, historically causing massive livestock losses. It is notable as the **second disease (after smallpox) to be globally eradicated**.

Why in News

Periodic references in veterinary science and disease eradication discussions highlight rinderpest as a **successful global eradication model**.

Key Facts and Figures

- Declared eradicated: **2011**
- Virus type: **Morbillivirus (Paramyxoviridae family)**
- Affects: **cattle, buffalo, wild ungulates**

Definition of Key Terms

- **Eradication**: Permanent global reduction of disease to zero cases.
- **Morbillivirus**: Genus of viruses including measles and rinderpest.
- **Ungulates**: Hoofed mammals (e.g., cattle, deer).

Ministry / Institutions / Organizations Involved

Global eradication led by the Food and Agriculture Organization and World Organisation for Animal Health (formerly OIE). In India, Department of Animal Husbandry oversees livestock health.

Government Acts / Policies / Judgements

- **FAO Global Rinderpest Eradication Programme (GREP)**
    - Coordinated vaccination and surveillance leading to eradication.
- **Livestock Health & Disease Control Programme (India)**
    - Focuses on vaccination and disease prevention.
- **National Animal Disease Control Programme (NADCP)**
    - Targets diseases like FMD and brucellosis.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **eradicated diseases (2014, 2019)**
- UPSC asked on **animal diseases & zoonotics (2017, 2022)**

Possible Prelims Trap Areas

- Confusing **rinderpest with foot-and-mouth disease (not eradicated)**
- Assuming **eradicated diseases require ongoing vaccination (generally not)**

19. Uranium Enrichment

Core Idea

Uranium enrichment is the process of **increasing the proportion of fissile isotope U-235** in uranium to make it suitable for **nuclear reactors or weapons**. Natural uranium contains only ~0.7% U-235.

Why in News

Global nuclear developments and geopolitical tensions frequently bring attention to **uranium enrichment levels**, especially in the context of nuclear energy and proliferation concerns.

Key Facts and Figures

- Natural U-235: **~0.7%**
- Reactor-grade: **~3–5% enrichment**
- Weapons-grade: **~90% enrichment**

Definition of Key Terms

- **Isotopes**: Atoms of same element with different neutron numbers.
- **Enrichment**: Increasing concentration of U-235 isotope.
- **Centrifuge**: मशीन used to separate isotopes based on mass difference.

Ministry / Institutions / Organizations Involved

Nuclear regulation globally involves the International Atomic Energy Agency. In India, Department of Atomic Energy oversees nuclear fuel cycle.

Government Acts / Policies / Judgements

- **Atomic Energy Act, 1962**
  - Governs nuclear material and energy use in India.
- **Nuclear Non-Proliferation Treaty (NPT), 1968**
  - Prevents spread of nuclear weapons (India is not a signatory).
- **India-US Civil Nuclear Agreement (2008)**
  - Enables civilian nuclear cooperation and fuel access.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **nuclear fuel cycle & isotopes (2013, 2018, 2022)**
- UPSC asked on **IAEA & nuclear safeguards (2017, 2020)**

Possible Prelims Trap Areas

- Confusing **enrichment with nuclear fission process**
- Assuming **all enriched uranium is weapons-grade (depends on level)**

20. IISc Nanozyme for Preventing Abnormal Blood Clotting

Core Idea

Researchers developed a **nanozyme (artificial enzyme)** using vanadium pentoxide nanoparticles to **reduce oxidative stress (ROS)** and prevent excessive platelet aggregation, thereby controlling **thrombosis**.

- Represents convergence of **nanotechnology + biomedical science**.

Why in News

Scientists at Indian Institute of Science reported a nanozyme-based approach to prevent abnormal clotting linked to diseases like **COVID-19 and pulmonary thromboembolism (PTE)**.

Key Facts and Figures

- Material: **Vanadium pentoxide (V_2O_5)**
- Targets: **Reactive Oxygen Species (ROS)**
- Potential use: **Stroke, thrombosis-related disorders**

Definition of Key Terms

- **Nanozyme**: Nanomaterial mimicking enzyme activity.
- **Reactive Oxygen Species (ROS)**: Oxygen-containing molecules causing oxidative stress.
- **Thrombosis**: Formation of unwanted blood clots in vessels.
- **Haemostasis**: Natural clotting process to stop bleeding.

Ministry / Institutions / Organizations Involved

Research led by IISc; broader support ecosystem includes Department of Science & Technology (DST) and Department of Biotechnology (DBT) promoting biomedical innovation.

Government Acts / Policies / Judgements

- **National Health Policy, 2017**
    - Promotes research and innovation in healthcare technologies.
- **Nano Mission (DST)**
    - Supports nanoscience and nanotechnology research in India.
- **Make in India Initiative**
    - Encourages indigenous medical technology development.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **nanotechnology applications (2016, 2019, 2023)**
- UPSC asked on **biomedical innovations (2020, 2022)**

Possible Prelims Trap Areas

- Confusing **nanozyme with natural enzyme**
- Assuming **ROS are always harmful (they also have physiological roles)**

21. Molecular Test Kits for Brain-Eating Amoeba (Kerala)

Core Idea

Development of **PCR-based molecular diagnostic kits** enables early detection of deadly **free-living amoeba (FLA)** infections causing **amoebic meningoencephalitis**, improving treatment outcomes.

Why in News

Kerala's State Public Health Laboratory developed **indigenous PCR kits** to detect multiple pathogenic amoeba species, enhancing **decentralized diagnostic capacity**.

Key Facts and Figures

- Pathogens detected: **5 species (e.g., Naegleria fowleri)**
- Disease: **Amoebic meningoencephalitis (high fatality)**
- Technology: **PCR (Polymerase Chain Reaction)**

Definition of Key Terms

- **PCR**: Technique to amplify DNA for detection of pathogens.
- **Free-Living Amoeba (FLA)**: Protozoa found in soil/water; some are pathogenic.
- **Naegleria fowleri**: "Brain-eating amoeba" infecting via nasal passage.

Ministry / Institutions / Organizations Involved

Developed by State Public Health Laboratory, Kerala; aligns with national disease surveillance under Ministry of Health & Family Welfare and global standards by the World Health Organization.

Government Acts / Policies / Judgements

- **National Health Policy, 2017**
    - Strengthens diagnostics and disease surveillance.
- **Clinical Establishments Act, 2010**
    - Regulates healthcare infrastructure and labs.
- **Article 47 (DPSP)**
    - Duty of the State to improve public health.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **PCR & diagnostic techniques (2020, 2023)**
- UPSC asked on **protozoan diseases (2017, 2021)**

Possible Prelims Trap Areas

- Confusing **amoeba with bacteria/virus (it is protozoa)**
- Assuming **all free-living amoeba are pathogenic (very few are)**

22. Astronaut Contribution to ISS & India's Participation

Core Idea

The **International Space Station (ISS)** is a multinational space laboratory in Low Earth Orbit, with countries contributing astronauts for scientific research. The **USA leads in astronaut participation**, reflecting dominance in human spaceflight.

Why in News

India is set to send its first astronaut to the ISS through Axiom-4 mission, marking a **milestone in international human spaceflight collaboration**.

Key Facts and Figures

- USA: **169 astronauts (highest)**
- Russia: **63 astronauts**
- ISS partners: **NASA, Roscosmos, ESA, JAXA, CSA**

Definition of Key Terms

- **ISS**: Space station used for microgravity research.
- **Low Earth Orbit (LEO)**: Orbit at ~160–2000 km altitude.
- **Microgravity**: Condition of near weightlessness in space.

Ministry / Institutions / Organizations Involved

ISS is operated by agencies including NASA, Roscosmos, ESA, JAXA, and CSA. India's participation is linked to ISRO and private collaboration with Axiom Space.

Government Acts / Policies / Judgements

- **Gaganyaan Mission**
  - India's indigenous human spaceflight programme.
- **Outer Space Treaty, 1967**
  - Ensures peaceful use of outer space.
- **India Space Policy, 2023**
  - Encourages global collaboration and private participation.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **ISS & international space cooperation (2015, 2018, 2022)**
- UPSC asked on **Gaganyaan & human spaceflight (2020, 2023)**

Possible Prelims Trap Areas

- Assuming **ISS is owned by a single nation (it is multinational)**
- Confusing **first Indian in space (Rakesh Sharma) vs first Indian to ISS**

23. SPArc Therapy – Advanced Precision Cancer Treatment

Core Idea

SPArc (Spot-Scanning Proton Arc Therapy) is an advanced **proton beam therapy** technique delivering radiation in **arc-based, layered precision**, minimizing damage to surrounding tissues.

- Uses **Bragg Peak principle** for depth-specific targeting.

Why in News

First successful **human application** of SPArc in treating **adenoid cystic carcinoma** has demonstrated superior precision over conventional proton therapy.

Key Facts and Figures

- Reduction in radiation exposure:
  - Brainstem: **~10%**
  - Optical chiasm: **~56%**
  - Oral cavity: **~72%**
  - Spinal canal: **~90%**

Definition of Key Terms

- **SPArc Therapy**: Proton therapy delivering radiation via multiple angles in arc form.
- **Geographic Miss**: Missing part of tumor during radiation due to movement/shrinkage.
- **Synthetic CT**: AI-generated imaging for adaptive dose planning.

Ministry / Institutions / Organizations Involved

Developed by US researchers; in India, advanced cancer therapies are supported by institutions like Tata Memorial Centre under Department of Atomic Energy and regulated by AERB.

Government Acts / Policies / Judgements

- **National Health Policy, 2017**
  - Promotes advanced medical technologies.
- **Clinical Establishments Act, 2010**
  - Ensures quality and regulation of healthcare facilities.
- **AERB Guidelines**
  - Regulate radiation-based medical technologies.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **radiation therapy & medical physics (2012, 2016)**
- UPSC asked on **AI in healthcare (2020, 2023)**

Possible Prelims Trap Areas

- Confusing **SPArc with conventional radiotherapy (X-ray based)**
- Ignoring **Bragg Peak concept (core to proton therapy)**

24. CRISPR-Based Smart Molecular Tool for Plant Resilience

Core Idea

A **CRISPR-dCas9-based molecular switch** activates plant defense genes **only under stress conditions**, improving **climate resilience and energy efficiency** in crops.

Why in News

Scientists at Bose Institute developed a novel **conditional gene activation system** for crops like tomato, potato, and tobacco.

Key Facts and Figures

- Uses: **dCas9 (non-cutting CRISPR variant)**
- Targets genes: **CBP60g, SARD1 (pathogen); NAC2, HSFA6b (heat)**
- Tested on: **Solanaceous crops**

Definition of Key Terms

- **CRISPR**: Genome-editing tool for targeted DNA modification.
- **dCas9**: Modified Cas9 protein that binds DNA without cutting it.
- **Gene Expression**: Activation of genes to produce proteins.

Ministry / Institutions / Organizations Involved

Developed under Department of Science & Technology (DST); aligns with agricultural research ecosystem including ICAR.

Government Acts / Policies / Judgements

- **National Mission for Sustainable Agriculture (NMSA)**
    - Promotes climate-resilient agriculture under NAPCC.
- **Biotechnology Regulatory Framework (GEAC)**
    - Oversees GM and gene-editing applications in India.
- **National Policy on Farmers (2007)**
    - Emphasizes technology-driven productivity.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **CRISPR & gene editing (2019, 2023)**
- UPSC asked on **GM crops & biotechnology (2014, 2018, 2022)**

Possible Prelims Trap Areas

- Confusing **CRISPR gene editing with gene expression regulation**
- Assuming **dCas9 cuts DNA (it does not)**

25. ISRO Integrated Air Drop Test (IADT-1) – Gaganyaan Mission

Core Idea

IADT-1 is a **critical safety test** for India's human spaceflight mission, validating **parachute-based crew module recovery system** during re-entry and landing.

Why in News

Indian Space Research Organisation successfully conducted the **first Integrated Air Drop Test (IADT-1)**, marking progress in **Gaganyaan mission preparedness**.

Key Facts and Figures

- Capsule weight: **~4.8 tonnes**
- Drop altitude: **~3 km**
- Target splashdown speed: **~8 m/s**

Definition of Key Terms

- **Human-Rating**: Certification of systems safe for human spaceflight.
- **Crew Escape System**: Mechanism to safely eject astronauts during failure.
- **ECLSS**: System maintaining oxygen, temperature, and pressure in spacecraft.

Ministry / Institutions / Organizations Involved

Led by ISRO with support from Indian Air Force, DRDO, Indian Navy, and Coast Guard, reflecting multi-agency coordination.

Government Acts / Policies / Judgements

- **Gaganyaan Mission**
    - India's first human spaceflight programme.
- **Indian Space Policy, 2023**
    - Encourages private and institutional collaboration.
- **Outer Space Treaty, 1967**
    - Governs peaceful use of outer space.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **Gaganyaan & space missions (2020, 2023)**
- UPSC asked on **space technology & launch systems (2016, 2022)**

Possible Prelims Trap Areas

- Confusing **IADT with launch test (it is recovery test)**
- Assuming **Gaganyaan is already operational (still under testing phase)**

26. Amoebic Encephalitis

Core Idea

Amoebic encephalitis is a **rare but often fatal brain infection** caused by **free-living amoebae (FLA)** found in soil and water. It affects the **central nervous system**, leading to inflammation and rapid deterioration.

Why in News

Rising cases of encephalitis linked to **free-living amoebae infections** and improved diagnostic capabilities (PCR-based detection) have brought attention to this disease.

Key Facts and Figures

- High fatality rate: **>90% (especially Naegleria fowleri)**
- Entry route: **Nasal passage → brain via olfactory nerve**
- Types: **Primary Amoebic Meningoencephalitis (PAM), Granulomatous Amoebic Encephalitis (GAE)**

Definition of Key Terms

- **Naegleria fowleri**: "Brain-eating amoeba" causing PAM.
- **Acanthamoeba**: Causes GAE; slower progression.
- **Protozoa**: Single-celled eukaryotic organisms.

Ministry / Institutions / Organizations Involved

Public health surveillance under Ministry of Health & Family Welfare; global monitoring by the World Health Organization.

Government Acts / Policies / Judgements

- **National Health Policy, 2017**
  - Focuses on strengthening disease surveillance and diagnostics.
- **Integrated Disease Surveillance Programme (IDSP)**
  - Tracks emerging infectious diseases.
- **Article 47 (DPSP)**
  - Duty of the State to improve public health.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **encephalitis & vector-borne diseases (2017, 2021)**
- UPSC asked on **protozoan infections (2015, 2020)**

Possible Prelims Trap Areas

- Confusing **amoeba (protozoa) with bacteria/virus**
- Assuming **all encephalitis is viral (multiple causes exist)**

27. Sickle Cell Disease and Disability Justice

Core Idea

Sickle Cell Disease (SCD) is a **genetic blood disorder** causing abnormal hemoglobin (HbS), leading to **distorted (sickle-shaped) RBCs**, reduced oxygen transport, and severe health complications. Disability justice emphasizes **equitable access to healthcare and social rights** for affected individuals.

Why in News

Policy discussions on **recognition of SCD under disability frameworks** and expansion of screening programs have highlighted issues of **health equity and tribal health** in India.

Key Facts and Figures

- Caused by mutation in **β-globin gene**
- High prevalence in **tribal populations in India**
- Leads to **anemia, pain crises, organ damage**

Definition of Key Terms

- **Sickle Cell Disease (SCD)**: Inherited disorder affecting hemoglobin structure.
- **Hemoglobin (HbS)**: Abnormal hemoglobin variant causing sickling.
- **Disability Justice**: Framework ensuring rights and inclusion of disabled persons.

Ministry / Institutions / Organizations Involved

Led by Ministry of Health & Family Welfare; implementation through National Health Mission. Supported by global agencies like the World Health Organization.

Government Acts / Policies / Judgements

- **National Sickle Cell Anaemia Elimination Mission (2023)**
    - Targets elimination by 2047; focuses on screening and awareness.
- **Rights of Persons with Disabilities Act, 2016**
    - Provides legal recognition and benefits for persons with disabilities.
- **National Health Policy, 2017**
    - Emphasizes equitable healthcare access.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **genetic disorders & hemoglobin (2016, 2020)**
- UPSC asked on **tribal health issues (2018, 2022)**

Possible Prelims Trap Areas

- Confusing **SCD with iron-deficiency anemia**
- Assuming **it is infectious (it is genetic)**

28. Easing Licence Rules for New Drugs and Clinical Trials

Core Idea

Proposed amendments aim to **simplify regulatory processes** for drug development by reducing licensing requirements and timelines, thereby boosting **pharmaceutical innovation and clinical research**.

Why in News

Union Health Ministry proposed changes to **New Drugs and Clinical Trials Rules, 2019** to enhance **ease of doing business** and attract investments in pharma R&D.

Key Facts and Figures

- Processing time reduced: **90 → 45 days**
- Application reduction: **~50% expected**
- Applies to **BA/BE studies and test licences**

Definition of Key Terms

- **Bioavailability (BA)**: Fraction of drug reaching systemic circulation.

- **Bioequivalence (BE)**: Similarity in drug absorption between formulations.
- **Clinical Trial**: Study to evaluate safety and efficacy of drugs.

Ministry / Institutions / Organizations Involved

Regulated by Ministry of Health & Family Welfare; Central Drugs Standard Control Organization (CDSCO) acts as the national regulatory authority.

Government Acts / Policies / Judgements

- **Drugs and Cosmetics Act, 1940**
  - Governs drug regulation in India.
- **New Drugs and Clinical Trials Rules, 2019**
  - Framework for approval of drugs and clinical trials.
- **Article 47 (DPSP)**
  - Mandates improvement of public health.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **clinical trials & drug approval (2017, 2020)**
- UPSC asked on **pharma regulation & CDSCO (2016, 2022)**

Possible Prelims Trap Areas

- Confusing **BA vs BE (different concepts)**
- Assuming **licence removal applies to all drugs (exceptions for high-risk drugs)**

29. Indian Radio Software Architecture (IRSA) Standard 1.0

Core Idea

IRSA 1.0 is India's first **standardized software architecture for Software Defined Radios (SDRs)**, ensuring **interoperability, waveform portability, and secure communication** across Army, Navy, and Air Force.

- Key objective: **Network-centric warfare + indigenous defence tech ecosystem**.

Why in News

Defence Research and Development Organisation released **IRSA Standard 1.0 (Oct 2025)** in collaboration with Integrated Defence Staff and Tri-Services to enhance **military communication interoperability**.

Key Facts and Figures

- Launched: **October 6, 2025**
- Focus: **Software Defined Radios (SDRs)**
- Developed since: **2022 (conceptualized in 2021)**

Definition of Key Terms

- **Software Defined Radio (SDR)**: Radio system where functions are controlled by software instead of hardware.
- **Waveform Portability**: Ability to use the same communication waveform across different devices.
- **Interoperability**: Ability of different systems/services to communicate seamlessly.
- **API (Application Programming Interface)**: Interface enabling interaction between software components.

Ministry / Institutions / Organizations Involved

Developed by DRDO in coordination with Integrated Defence Staff and Tri-Services. Supported by defence PSUs, private sector, IITs, and startups, forming a **national defence innovation ecosystem**.

Government Acts / Policies / Judgements

- **Defence Production and Export Promotion Policy (DPEPP), 2020**
    - Promotes indigenization and defence exports.
- **Defence Acquisition Procedure (DAP), 2020**
    - Prioritizes Indigenous Design, Development, and Manufacturing (IDDM).
- **National Cyber Security Policy, 2013**
    - Ensures secure digital communication infrastructure.
- **Atmanirbhar Bharat Initiative**
    - Focuses on reducing dependency on foreign defence systems.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **communication technologies & SDR (2018, 2022)**
- UPSC asked on **defence indigenization & policies (2016, 2021, 2023)**

Possible Prelims Trap Areas

- Confusing **SDR with traditional hardware radios (SDR is software-driven)**
- Assuming **IRSA is hardware standard (it is a software architecture standard)**

30. ISRO's Plan to Transfer PSLV Project to Industry

Core Idea

ISRO plans to transfer **~50% of PSLV production and development** to domestic industry, marking a shift toward **privatization and commercialization of space launch capabilities** while ISRO focuses on advanced R&D.

Why in News

Indian Space Research Organisation announced plans to **hand over PSLV production** to industry via institutional mechanisms like NSIL and IN-SPACe.

Key Facts and Figures

- Industry contribution already: **~80–85% of components**
- PSLV role: **Workhorse launch vehicle**
- Target: **50% transfer to private sector**

Definition of Key Terms

- **PSLV**: Launch vehicle for polar and sun-synchronous orbits.
- **SSO (Sun-Synchronous Orbit)**: Orbit allowing satellite to pass over same area at same time daily.
- **GTO (Geosynchronous Transfer Orbit)**: Orbit used to place satellites into geostationary orbit.

Ministry / Institutions / Organizations Involved

Implementation via NewSpace India Limited and IN-SPACe, under Department of Space.

Government Acts / Policies / Judgements

- **Indian Space Policy, 2023**
    - Enables private participation and technology transfer.
- **Space Sector Reforms (2020)**
    - Opened space activities to private players.
- **Atmanirbhar Bharat Initiative**
    - Promotes indigenous capability in strategic sectors.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **PSLV vs GSLV (2013, 2017, 2022)**
- UPSC asked on **space sector privatization (2020, 2023)**

Possible Prelims Trap Areas

- Confusing **PSLV with GSLV (different payload/orbit roles)**
- Assuming **ISRO is exiting launches completely (only partial transfer)**

31. ISRO's Upcoming Missions – Chandrayaan-4 & Space Roadmap

Core Idea

India is expanding its space ambitions with **lunar sample return missions, human spaceflight, and space station development**, marking transition toward a **major space power**.

Why in News

Government approved **Chandrayaan-4 mission** and outlined ISRO's future roadmap including LUPEX collaboration and Gaganyaan.

Key Facts and Figures

- Chandrayaan-4 timeline: **~2028**
- Gaganyaan: **~2027 (expected)**
- Indian Space Station: **by 2035**

Definition of Key Terms

- **Lunar Sample Return Mission**: Collects and returns Moon samples to Earth.
- **GSLV**: Launch vehicle for heavier payloads into geostationary orbit.
- **Space Station**: Orbiting laboratory for long-duration missions.

Ministry / Institutions / Organizations Involved

Led by ISRO; LUPEX collaboration with Japan Aerospace Exploration Agency.

Government Acts / Policies / Judgements

- **Indian Space Policy, 2023**
  - Encourages commercialization and private participation.
- **Space Activities Bill (proposed)**
  - Regulates private space activities and liability.
- **Outer Space Treaty, 1967**
  - Governs peaceful exploration of space.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **Chandrayaan missions (2019, 2023)**
- UPSC asked on **space collaboration & missions (2016, 2022)**

Possible Prelims Trap Areas

- Confusing **Chandrayaan-3 (lander mission) vs Chandrayaan-4 (sample return)**
- Assuming **India already has a space station (planned, not operational)**

32. Sanchar Saathi App & Privacy Concerns

Core Idea

Sanchar Saathi is a government mobile app aimed at **tracking lost/stolen phones and detecting fraudulent SIM connections**, but raises concerns about **privacy and consent** when mandated.

Why in News

Department of Telecommunications withdrew its directive to **mandate pre-installation of the app**

on smartphones following public backlash over privacy concerns.

Key Facts and Figures

- Fraudulent connections disconnected: **~1.5 crore**
- Lost phones traced: **~26 lakh**
- Key tools: **CEIR, TAFCOP platforms**

Definition of Key Terms

- **CEIR**: Central Equipment Identity Register for tracking devices.
- **TAFCOP**: Telecom Analytics for Fraud Management and Consumer Protection.
- **TIUE**: Telecommunication Identifier User Entities regulating number usage.

Ministry / Institutions / Organizations Involved

Developed and regulated by Department of Telecommunications (DoT), under Ministry of Communications.

Government Acts / Policies / Judgements

- **Telecommunications Act, 2023**
  - Expands regulatory powers over telecom ecosystem.
- **Right to Privacy (Puttaswamy Judgment, 2017)**
  - Recognizes privacy as a Fundamental Right under Article 21.
- **Digital Personal Data Protection Act, 2023**
  - Governs consent-based data processing.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **Right to Privacy & data protection (2017, 2020)**
- UPSC asked on **telecom regulation (2018, 2022)**

Possible Prelims Trap Areas

- Confusing **tracking app with surveillance tool (purpose vs misuse debate)**
- Assuming **mandatory installation is legally settled (still debated)**

33. Volcanic Ash and Aviation Safety – Hayli Gubbi Eruption

Core Idea

Volcanic ash poses a serious threat to aircraft as it can **melt inside jet engines and damage turbine components**, potentially causing **engine failure mid-flight**.

Why in News

Eruption of **Hayli Gubbi volcano (Ethiopia)** led to ash clouds drifting into Indian airspace, prompting aviation advisories and flight disruptions.

Key Facts and Figures

- Ash plume height: **~14 km (45,000 ft)**
- Engine temperature: **~1600°C**
- Ash melting point: **~1100°C**

Definition of Key Terms

- **Volcanic Ash**: Fine particles of rock, minerals, and glass from eruptions.
- **ASHTAM**: Aviation alert for volcanic ash hazards.
- **VAAC**: Centres monitoring volcanic ash globally.

Ministry / Institutions / Organizations Involved

India's aviation safety regulated by Directorate General of Civil Aviation; global coordination by ICAO through VAACs.

Government Acts / Policies / Judgements

- **Aircraft Act, 1934 & Rules**
    - Governs civil aviation safety in India.
- **ICAO Standards & Recommended Practices (SARPs)**
    - Global aviation safety norms.
- **DGCA Operational Advisories**
    - Provide guidelines for flight safety during hazards.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **volcanoes & hazards (2015, 2021)**
- UPSC asked on **aviation safety & ICAO (2016, 2022)**

Possible Prelims Trap Areas

- Assuming **ash behaves like smoke (it is solid particulate)**
- Ignoring **jet stream role in ash dispersion**

34. Digital Constitutionalism – Rights in the Algorithmic Era

Core Idea

Digital Constitutionalism refers to the **application of constitutional principles (liberty, privacy, equality, accountability)** in the digital domain to regulate **AI, data governance, and surveillance systems**.

- Ensures citizens remain **rights-bearing individuals, not mere data subjects**.

Why in News

The rollback of mandatory **Sanchar Saathi app installation** highlighted concerns around **privacy, consent, and state surveillance**, triggering debates on constitutional safeguards in digital governance.

Key Facts and Figures

- Rooted in **Article 21 (Right to Privacy)**
- Applies **3-fold test: legality, necessity, proportionality**
- Linked with **DPDP Act, 2023**

Definition of Key Terms

- **Digital Constitutionalism**: Extension of constitutional rights into digital governance.
- **Chilling Effect**: Self-censorship due to surveillance fear.
- **Algorithmic Governance**: Decision-making using automated systems/AI.

Ministry / Institutions / Organizations Involved

Digital governance led by MeitY; judicial interpretation by Supreme Court, especially in Justice K.S. Puttaswamy vs Union of India, which forms the constitutional basis.

Government Acts / Policies / Judgements

- **Digital Personal Data Protection Act, 2023**
    - Governs consent-based data processing; allows state exemptions.
- **Puttaswamy Judgment (2017)**
    - Recognized privacy as a Fundamental Right under Article 21.
- **Information Technology Act, 2000**
    - Provides legal framework for digital governance.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **Right to Privacy & digital governance (2017, 2020)**
- UPSC asked on **AI ethics & governance (2021, 2023)**

Possible Prelims Trap Areas

- Confusing **data protection with privacy rights (overlapping but distinct)**
- Assuming **DPDP fully ensures constitutional safeguards (debated)**

35. Neurotechnology and Brain-Computer Interfaces (BCIs)

Core Idea

Neurotechnology involves tools that **interface directly with the brain** to monitor or influence neural activity. The key application is **Brain-Computer Interface (BCI)** enabling communication between brain and external devices.

Why in News

Rapid global advances in **BCIs and neural data technologies** have raised questions on **privacy, ethics, and regulatory frameworks (neurorights)**.

Key Facts and Figures

- Types: **Invasive & Non-invasive BCIs**
- Applications: **Neuroprosthetics, rehabilitation, cognitive enhancement**
- Data type: **Highly sensitive neural signals**

Definition of Key Terms

- **BCI (Brain-Computer Interface)**: Direct communication pathway between brain and machine.
- **Neuroprosthetics**: Devices replacing lost neural functions.
- **Neurorights**: Rights protecting mental privacy and autonomy.

Ministry / Institutions / Organizations Involved

Research globally led by institutions and private sector; in India, supported by DST, DBT, and medical research bodies. Ethical frameworks being explored globally (EU, Chile).

Government Acts / Policies / Judgements

- **Article 21 (Right to Life & Privacy)**
  - Extends to dignity, mental autonomy, and health.
- **Digital Personal Data Protection Act, 2023**
  - Covers sensitive personal data including neural data.
- **Puttaswamy Judgment (2017)**
  - Basis for data privacy and informational autonomy.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **AI & emerging technologies (2020, 2023)**
- UPSC asked on **biomedical technology (2016, 2022)**

Possible Prelims Trap Areas

- Confusing **BCI with AI (BCI is interface, AI is processing)**
- Assuming **all BCIs are invasive (many are non-invasive)**

36. DHRUVA – Digital Address Infrastructure of India

Core Idea

DHRUVA is a proposed **Digital Public Infrastructure (DPI)** for **standardized, consent-based digital addresses**, integrating geo-coded systems to improve service delivery and governance.

Why in News

Department of Posts proposed **DHRUVA framework** to address inefficiencies in India's **non-standard addressing system**, especially in rural and informal areas.

Key Facts and Figures

- Integrated with **DIGIPIN (10-digit alphanumeric code)**
- Coverage: **~12 sq. metre grid-based mapping**
- Model similar to **UPI-like governance (NPCI model)**

Definition of Key Terms

- **Digital Public Infrastructure (DPI)**: Public digital systems enabling governance at scale.
- **Geo-coded Address**: Address linked to latitude-longitude coordinates.
- **Tokenisation**: Replacing sensitive data with secure identifiers.

Ministry / Institutions / Organizations Involved

Led by Department of Posts; proposed governance body similar to National Payments Corporation of India for interoperability and standards.

Government Acts / Policies / Judgements

- **Post Office Act, 2023**
    - Requires amendment to enable digital address handling.
- **Digital Personal Data Protection Act, 2023**
    - Ensures consent, data minimization, and security.
- **Article 21 (Right to Privacy)**
    - Protects personal address data as sensitive information.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **Digital Public Infrastructure (Aadhaar, UPI) (2018, 2022, 2023)**
- UPSC asked on **geospatial technologies (2017, 2021)**

Possible Prelims Trap Areas

- Confusing **DIGIPIN with PIN code (different systems)**
- Assuming **DHRUVA replaces physical addresses (it complements them)**

37. DHRUVA – Digital Address Public Infrastructure (Advanced Perspective)

Core Idea

DHRUVA is a proposed **Digital Public Infrastructure (DPI)** for **standardized, consent-based digital addressing**, enabling efficient service delivery through **geo-coded identifiers (DIGIPIN)**.

- Aims to solve **non-standard, inconsistent address systems** in India.

Why in News

Department of Posts proposed DHRUVA as a **nationwide digital address framework**, integrating with DIGIPIN for improved governance and logistics.

Key Facts and Figures

- DIGIPIN: **10-digit alphanumeric code**
- Coverage: **~12 sq. metre grid resolution**

- Model: **NPCI-like governance structure proposed**

Definition of Key Terms

- **DPI (Digital Public Infrastructure)**: Public digital systems for governance (e.g., Aadhaar, UPI).
- **Geo-coded Address**: Address mapped to latitude-longitude coordinates.
- **Tokenisation**: Replacing sensitive address data with secure identifiers.

Ministry / Institutions / Organizations Involved

Led by Department of Posts; proposed governance body similar to National Payments Corporation of India for interoperability, compliance, and ecosystem regulation.

Government Acts / Policies / Judgements

- **Post Office Act, 2023**
  - Requires amendment for digital address framework.
- **Digital Personal Data Protection Act, 2023**
  - Ensures consent-based data sharing and security.
- **Article 21 (Right to Privacy)**
  - Protects personal address as sensitive data.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **DPI (Aadhaar, UPI) (2018, 2022, 2023)**
- UPSC asked on **geospatial technologies (2017, 2021)**

Possible Prelims Trap Areas

- Confusing **DIGIPIN with traditional PIN code**
- Assuming **DHRUVA is mandatory (consent-based system)**

38. Twin Burden: Influenza (H3N2) Surge and Air Pollution

Core Idea

India is facing a **"twin burden"** where **seasonal influenza (H3N2 subtype)** and **air pollution ($PM_{2.5}$)** interact to worsen respiratory health outcomes, increasing disease severity and healthcare burden.

Why in News

ICMR surveillance reported a rise in **H3N2 influenza cases**, coinciding with high winter pollution levels across major Indian states.

Key Facts and Figures

- Dominant strain: **H3N2 (Influenza A subtype)**
- Positivity rate: **~12–13% peak**
- Key pollutant: **$PM_{2.5}$ (<2.5 µm particles)**

Definition of Key Terms

- **H3N2**: Influenza A subtype defined by hemagglutinin (H) and neuraminidase (N).
- **$PM_{2.5}$**: Fine particulate matter penetrating deep into lungs.
- **SARI**: Severe Acute Respiratory Infection requiring hospitalization.

Ministry / Institutions / Organizations Involved

Disease surveillance by Indian Council of Medical Research; environmental regulation by Central Pollution Control Board; coordinated response by Ministry of Health & Family Welfare.

Government Acts / Policies / Judgements

- **National Health Policy, 2017**
  - Strengthens disease surveillance and healthcare systems.

- **National Air Quality Index (AQI) Framework**
    - Monitors and categorizes air pollution levels.
- **Article 21 (Right to Life)**
    - Includes right to health and clean environment.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **influenza viruses & public health (2017, 2020)**
- UPSC asked on **air pollution & PM2.5 (2015, 2021, 2023)**

Possible Prelims Trap Areas

- Confusing **H3N2 with COVID-type viruses (influenza virus)**
- Assuming **pollution only causes chronic disease (also increases infection risk)**

39. Aditya-L1 & Breakthrough in Solar Storm Dynamics

Core Idea

India's first solar observatory **Aditya-L1** provided direct evidence of **magnetic reconnection within a Coronal Mass Ejection (CME)**, explaining sudden intensification of solar storms and improving **space weather prediction**.

Why in News

Data from Aditya-L1 helped explain the unusual intensity of the **May 2024 solar storm (Gannon Storm)** through CME collision and internal magnetic disruption.

Key Facts and Figures

- Location: **L1 point (~1.5 million km from Earth)**
- Reconnection region: **~1.3 million km wide**
- Collaborated with: **NASA satellites (Wind, ACE, DSCOVR)**

Definition of Key Terms

- **CME (Coronal Mass Ejection)**: Ejection of plasma and magnetic field from Sun.
- **Magnetic Reconnection**: Rearrangement of magnetic field lines releasing energy.
- **Lagrange Point (L1)**: Position where gravitational forces balance for stable observation.

Ministry / Institutions / Organizations Involved

Led by Indian Space Research Organisation with international collaboration including NASA.

Government Acts / Policies / Judgements

- **Indian Space Policy, 2023**
    - Promotes advanced space science missions.
- **International Space Collaboration Frameworks**
    - Enable joint data sharing for space weather studies.
- **Article 51A(j)**
    - Promotes excellence in scientific pursuits.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **solar phenomena & CMEs (2012, 2019, 2023)**
- UPSC asked on **Lagrange points (2020)**

Possible Prelims Trap Areas

- Confusing **solar flare vs CME (different phenomena)**
- Assuming **L1 is orbiting Earth (it is Sun–Earth equilibrium point)**

40. Space Spectrum & Orbital Slots – Megaconstellation Governance

Core Idea

Rapid expansion of satellite megaconstellations is creating **competition for limited spectrum and orbital slots**, raising concerns of **monopoly, digital divide, and space sustainability**.

Why in News

Growth of mega-constellations (Starlink, GuoWang) and debates over **ITU's allocation system** highlight governance challenges.

Key Facts and Figures

- Starlink planned: **~42,000 satellites**
- Market growth: **$4.27B → $27.31B by 2032**
- LEO latency: **~20–40 ms vs GEO ~600 ms**

Definition of Key Terms

- **Megaconstellation**: Large network of satellites in LEO.
- **Spectrum**: Radio frequency used for communication.
- **Kessler Syndrome**: Chain reaction of space debris collisions.

Ministry / Institutions / Organizations Involved

Global allocation by International Telecommunication Union; India's regulatory role via TRAI and IN-SPACe.

Government Acts / Policies / Judgements

- **Outer Space Treaty, 1967**
    - Space as global commons; no national ownership.
- **ITU Regulations (Resolution 74)**
    - Mandate debris mitigation (25-year rule).
- **Indian Space Policy, 2023**
    - Encourages private participation in space sector.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **satellite communication & ITU (2014, 2021)**
- UPSC asked on **space debris & sustainability (2018, 2023)**

Possible Prelims Trap Areas

- Confusing **LEO vs GEO latency differences**
- Assuming **spectrum is unlimited (it is scarce resource)**

41. Neuralink & Scaling of Brain-Computer Interfaces (BCI)

Core Idea

Neuralink aims to scale **Brain-Computer Interface (BCI) implants** for mass use, enabling direct communication between brain and machines for **medical and cognitive applications**.

Why in News

Neuralink announced plans for **high-volume production of brain implants by 2026**, including automated surgical robotics.

Key Facts and Figures

- Focus: **Paralysis, spinal injury patients**
- Device: **Flexible electrode threads (neural lace)**
- Uses: **Thought-controlled devices**

Definition of Key Terms

- **BCI**: Interface linking brain signals to external devices.
- **Electrophysiology**: Study of electrical activity in biological cells.
- **Biocompatibility**: Compatibility of implants with body tissues.

Ministry / Institutions / Organizations Involved

Regulated globally by agencies like Food and Drug Administration; in India, oversight would fall under CDSCO and medical device regulators.

Government Acts / Policies / Judgements

- **Medical Devices Rules, 2017**
  - Regulates high-risk implants in India.
- **Digital Personal Data Protection Act, 2023**
  - Protects sensitive neural data.
- **Article 21 (Right to Life)**
  - Includes right to health and dignity.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **AI & neurotechnology (2020, 2023)**
- UPSC asked on **medical devices & biotech (2016, 2022)**

Possible Prelims Trap Areas

- Confusing **BCI with AI systems**
- Assuming **technology is fully commercialized (still evolving)**

42. Remote Sensing Technology

Core Idea

Remote sensing involves **collecting information about Earth's surface using electromagnetic radiation** without direct contact, crucial for **resource mapping, disaster management, and environmental monitoring**.

Why in News

Advancements in missions like NISAR are enhancing capabilities to detect features under clouds and vegetation.

Key Facts and Figures

- NDVI: Measures **vegetation health**
- SAR: Works **through clouds and darkness**
- GRACE: Measures **groundwater via gravity anomalies**

Definition of Key Terms

- **Remote Sensing**: Data acquisition without physical contact.
- **SAR (Synthetic Aperture Radar)**: Active sensor using radio waves.
- **Spectral Signature**: Unique reflection pattern of materials.

Ministry / Institutions / Organizations Involved

India's remote sensing managed by National Remote Sensing Centre under ISRO.

Government Acts / Policies / Judgements

- **Indian Space Policy, 2023**
  - Promotes geospatial data usage.
- **Geospatial Guidelines, 2021**
  - Liberalized mapping and data access.
- **Article 51A(g)**
  - Duty to protect environment.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **remote sensing & GIS (2013, 2018, 2023)**

- UPSC asked on **NDVI & environmental monitoring (2017, 2021)**

Possible Prelims Trap Areas

- Confusing **SAR (active sensor) with optical sensors**
- Assuming **remote sensing only works in daylight**

43. Biomaterials & Green Manufacturing

Core Idea

Biomaterials are **materials derived from biological sources** used as sustainable alternatives to fossil-based products, supporting **circular bioeconomy and green manufacturing**.

Why in News

India is promoting biomaterials through policies like **BioE3 and Bio-RIDE**, aligning with sustainability and rural economic goals.

Key Facts and Figures

- Market size: **~$500 million (India, 2024)**
- Bio-RIDE outlay: **₹9,197 crore**
- Feedstock: **agricultural residues (bagasse, maize, stubble)**

Definition of Key Terms

- **Biomaterials**: Materials derived from biological sources.
- **Circular Bioeconomy**: Sustainable reuse of biological resources.
- **PLA (Polylactic Acid)**: Biodegradable polymer from biomass.

Ministry / Institutions / Organizations Involved

Driven by Department of Biotechnology (DBT) and Ministry of Science & Technology; supported by industry and research ecosystems.

Government Acts / Policies / Judgements

- **BioE3 Policy (2024)**
  - Focuses on biotechnology for economy, environment, employment.
- **Plastic Waste Management Rules (amended)**
  - Promote biodegradable alternatives.
- **Extended Producer Responsibility (EPR)**
  - Mandates lifecycle accountability of products.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **bioplastics & sustainability (2016, 2021)**
- UPSC asked on **circular economy (2020, 2023)**

Possible Prelims Trap Areas

- Confusing **biodegradable with compostable plastics**
- Assuming **all biomaterials are eco-friendly (depends on lifecycle)**

44. PSLV-C62 / EOS-N1 Mission (ISRO)

Core Idea

PSLV-C62/EOS-N1 mission represents a **strategic Earth observation and commercial launch milestone**, combining **defence surveillance (hyperspectral imaging)** with **private sector participation and new space technologies**.

Why in News

Indian Space Research Organisation scheduled PSLV-C62 mission (Jan 2026), marking a **comeback after PSLV-C61 failure** and showcasing new innovations like **on-orbit refueling**.

Key Facts and Figures

- Launch vehicle: **PSLV-DL variant (2 strap-ons)**
- Payload: **EOS-N1 (hyperspectral satellite)**
- Co-passengers: **18 satellites (international + startups)**

Definition of Key Terms

- **Hyperspectral Imaging**: Captures data across many wavelengths for material identification.
- **SSO (Sun-Synchronous Orbit)**: Satellite passes same location at same solar time.
- **Workhorse Rocket**: Highly reliable launch vehicle (PSLV).

Ministry / Institutions / Organizations Involved

Mission led by ISRO; payload developed by Defence Research and Development Organisation; commercial role via NSIL.

Government Acts / Policies / Judgements

- **Indian Space Policy, 2023**
  - Promotes private participation and commercialization.
- **Atmanirbhar Bharat Initiative**
  - Supports indigenous defence and space capabilities.
- **IN-SPACe Framework**
  - Facilitates private sector involvement in space activities.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **PSLV features & missions (2013, 2017, 2022)**
- UPSC asked on **remote sensing satellites (2016, 2021)**

Possible Prelims Trap Areas

- Confusing **hyperspectral vs multispectral imaging**
- Assuming **PSLV used only for polar orbits (can also support GTO missions)**

45. Antimicrobial Resistance (AMR) – India's Silent Pandemic

Core Idea

AMR is the ability of microorganisms to **resist antimicrobial drugs**, making infections harder to treat and threatening modern medicine. It is a **major public health crisis** requiring a **One Health approach**.

Why in News

Highlighted in Mann Ki Baat (Dec 2025), emphasizing rising resistance in infections like pneumonia and UTIs.

Key Facts and Figures

- Key pathogens: **E. coli, K. pneumoniae**
- Resistance seen in: **carbapenems (last-resort drugs)**
- Surveillance: **~60 sentinel labs (NARS-Net)**

Definition of Key Terms

- **AMR**: Resistance of microbes to drugs.
- **Reserve Antibiotics**: Last-line drugs (e.g., carbapenems).
- **One Health**: Integrated approach linking human, animal, environment health.

Ministry / Institutions / Organizations Involved

Surveillance by Indian Council of Medical Research and NCDC; global coordination by World Health Organization.

Government Acts / Policies / Judgements

- **National Action Plan on AMR (2025–2029)**
    - Focuses on surveillance, regulation, and awareness.
- **Drugs and Cosmetics Rules (Schedule H1)**
    - Restricts OTC antibiotic sale (Red Line campaign).
- **Article 21 & Article 47**
    - Ensure right to health and public health duty.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **AMR & antibiotics (2016, 2020, 2023)**
- UPSC asked on **public health frameworks (2017, 2021)**

Possible Prelims Trap Areas

- Confusing **antibiotic resistance (bacteria) with antiviral resistance**
- Assuming **AMR only affects hospitals (also community-level issue)**

46. Metabolic Switch in Fungal Pathogenicity (CSIR-CCMB)

Core Idea

Scientists discovered that **fungal pathogenicity is controlled by metabolic processes (glycolysis + amino acid synthesis)**, not just genes, offering a new target for antifungal therapy.

Why in News

Research by CSIR-Centre for Cellular and Molecular Biology revealed a **metabolic trigger controlling fungal invasiveness**.

Key Facts and Figures

- Model organism: **Candida albicans**
- Morphological shift: **Yeast (5 µm) → Filament (20–100 µm)**
- Key pathway: **Glycolysis-linked amino acid synthesis**

Definition of Key Terms

- **Glycolysis**: Breakdown of glucose to release energy.
- **Morphogenesis**: Change in organism structure/form.
- **Macrophage**: Immune cell engulfing pathogens.

Ministry / Institutions / Organizations Involved

Research by Council of Scientific and Industrial Research; supported by India's S&T ecosystem.

Government Acts / Policies / Judgements

- **Drugs and Cosmetics Act, 1940**
    - Regulates antifungal drugs.
- **STIP (Science Policy)**
    - Encourages biomedical innovation.
- **Article 51A(h)**
    - Promotes scientific temper.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **fungal diseases & microbiology (2015, 2021)**
- UPSC asked on **metabolism & cell biology (2016, 2022)**

Possible Prelims Trap Areas

- Assuming **pathogenicity is purely genetic (metabolism plays key role)**
- Confusing **fungi with bacteria (different biological classification)**

47. 2 nm Semiconductor Chip & India Semiconductor Mission

Core Idea

Development of **2 nm semiconductor chip design** marks India's advancement in **high-end chip design**, enabling faster processing and energy efficiency in next-gen computing.

Why in News

Launch of 2 nm chip design by Qualcomm in India signals progress under **India Semiconductor Mission (ISM)**.

Key Facts and Figures

- Node size: **2 nm**
- Performance gain: **~45% faster**
- Efficiency gain: **~30% lower power consumption**

Definition of Key Terms

- **Nanometre Node**: Scale of transistor size on chip.
- **Tape-out**: Final stage of chip design before manufacturing.
- **EDA Tools**: Software for chip design and simulation.

Ministry / Institutions / Organizations Involved

Driven by MeitY under ISM; industry participation by global firms like Qualcomm and domestic startups.

Government Acts / Policies / Judgements

- **India Semiconductor Mission (ISM)**
  - Promotes chip manufacturing and design ecosystem.
- **Production Linked Incentive (PLI) Scheme**
  - Incentivizes electronics manufacturing.
- **Design Linked Incentive (DLI) Scheme**
  - Supports chip design startups.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **semiconductors & electronics (2020, 2023)**
- UPSC asked on **PLI schemes (2021, 2022)**

Possible Prelims Trap Areas

- Assuming **smaller nm means physically exact dimension (it is tech node, not literal size)**
- Confusing **design vs fabrication (India strong in design, limited in fabs)**

48. Indigenous Kyasanur Forest Disease (KFD) Vaccine

Core Idea

Kyasanur Forest Disease (KFD) is a **tick-borne viral hemorrhagic fever** endemic to parts of India. Development of an **indigenous vaccine** is crucial for **public health preparedness and disease control in forested regions**.

Why in News

Renewed focus on improving **indigenous KFD vaccines** due to recurring outbreaks in Western Ghats and the need for **better efficacy and coverage**.

Key Facts and Figures

- Caused by: **Flavivirus (KFD virus)**
- Transmission: **Tick bite (Haemaphysalis spinigera)**
- Endemic regions: **Karnataka, Kerala, Goa, Maharashtra**

Definition of Key Terms

- **Zoonotic Disease**: Disease transmitted from animals to humans.
- **Vector**: Organism transmitting pathogen (tick in KFD).
- **Hemorrhagic Fever**: Disease causing bleeding disorders.

Ministry / Institutions / Organizations Involved

Surveillance and vaccination under Ministry of Health & Family Welfare; research support from Indian Council of Medical Research and National Institute of Virology (NIV).

Government Acts / Policies / Judgements

- **National Health Policy, 2017**
  - Strengthens disease surveillance and immunization.
- **Integrated Disease Surveillance Programme (IDSP)**
  - Tracks outbreaks like KFD.
- **Article 47 (DPSP)**
  - Mandates improvement of public health.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **vector-borne diseases (2015, 2021)**
- UPSC asked on **zoonotic diseases (2017, 2022)**

Possible Prelims Trap Areas

- Confusing **KFD with mosquito-borne diseases (tick-borne)**
- Assuming **all flaviviruses are mosquito transmitted (not always)**

49. Algorithmic Sovereignty – Strategic Imperative

Core Idea

Algorithmic Sovereignty refers to a nation's ability to **control its AI systems, datasets, and computational infrastructure**, ensuring **strategic autonomy in digital governance and decision-making**.

Why in News

Concerns over **Western bias in AI models** and reliance on foreign AI ecosystems have raised debates on India's need for an **indigenous AI stack**.

Key Facts and Figures

- AI models trained largely on **Western datasets**
- Key domains affected: **law, security, geopolitics**
- Risk: **digital colonialism via foreign AI platforms**

Definition of Key Terms

- **Algorithmic Sovereignty**: Control over algorithms and digital infrastructure.
- **EEZ (Exclusive Economic Zone)**: Up to **200 nautical miles** from coast.
- **Digital Colonialism**: Dependence on foreign digital technologies controlling local systems.

Ministry / Institutions / Organizations Involved

Policy direction by MeitY; global legal framework via United Nations and conventions like UNCLOS.

Government Acts / Policies / Judgements

- **Information Technology Act, 2000**
    - Governs cyber activities in India.
- **Digital Personal Data Protection Act, 2023**
    - Ensures data sovereignty and privacy.
- **UNCLOS (1982)**
    - Governs maritime rights including EEZ.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **AI governance & ethics (2020, 2023)**
- UPSC asked on **UNCLOS & EEZ (2014, 2021)**

Possible Prelims Trap Areas

- Confusing **data sovereignty with algorithmic sovereignty**
- Assuming **AI bias is only technical (also geopolitical)**

50. Revision of Bacterial Transcription Model

Core Idea

New research shows that **sigma factors may remain attached during transcription**, challenging the traditional **Sigma Cycle model** and redefining bacterial gene regulation.

Why in News

Scientists from Bose Institute discovered persistent sigma factor binding in **Bacillus subtilis**, overturning decades-old theory.

Key Facts and Figures

- Organism studied: **Bacillus subtilis**
- Protein: **Sigma factor (σA)**
- Traditional model: **Sigma detaches after initiation**

Definition of Key Terms

- **Transcription**: DNA → RNA conversion process.
- **Sigma Factor**: Protein enabling RNA polymerase to bind DNA.
- **RNA Polymerase**: Enzyme synthesizing RNA from DNA template.

Ministry / Institutions / Organizations Involved

Research conducted by Bose Institute under DST; collaboration with Rutgers University.

Government Acts / Policies / Judgements

- **Science, Technology and Innovation Policy (STIP)**
    - Promotes advanced research in life sciences.
- **Biotechnology Regulatory Framework**
    - Supports innovation in molecular biology.
- **Article 51A(h)**
    - Encourages scientific temper.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **gene expression & transcription (2016, 2019, 2023)**
- UPSC asked on **microbiology concepts (2015, 2021)**

Possible Prelims Trap Areas

- Assuming **sigma factor always detaches (not universal)**
- Confusing **transcription with translation (different processes)**

51. National Standards for Green Ammonia & Green Methanol

Core Idea

India has notified **emission thresholds for Green Hydrogen derivatives (Ammonia & Methanol)** to ensure **low-carbon production standards**, supporting decarbonization of hard-to-abate sectors.

Why in News

Ministry of New and Renewable Energy (MNRE) notified **official standards under the National Green Hydrogen Mission**, defining what qualifies as "green" fuels.

Key Facts and Figures

- Green Ammonia: **≤ 0.38 kg CO_2e/kg**
- Green Methanol: **≤ 0.44 kg CO_2e/kg**
- Includes lifecycle emissions (production → storage)

Definition of Key Terms

- **Green Hydrogen Derivatives**: Fuels (NH_3, CH_3OH) produced using renewable hydrogen.
- **Biogenic Carbon**: Carbon derived from biomass sources.
- **DAC (Direct Air Capture)**: Technology capturing CO_2 directly from atmosphere.

Ministry / Institutions / Organizations Involved

Standards notified by Ministry of New and Renewable Energy (MNRE); implementation aligned with Bureau of Energy Efficiency (BEE) and energy transition ecosystem.

Government Acts / Policies / Judgements

- **National Green Hydrogen Mission (2023)**
    - Promotes production, export, and use of green hydrogen and derivatives.
- **Energy Conservation Act, 2001**
    - Enables standards for energy efficiency and emissions.
- **Article 48A & 51A(g)**
    - Environmental protection mandate.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **Green Hydrogen & renewable fuels (2022, 2023)**
- UPSC asked on **climate mitigation technologies (2016, 2021)**

Possible Prelims Trap Areas

- Confusing **green ammonia with conventional ammonia (fossil-based)**
- Assuming **all methanol is green (depends on carbon source)**

52. Claude Mythos (AI Model Context)

Core Idea

Claude Mythos refers to an **advanced AI model framework focusing on contextual reasoning, narrative intelligence, and alignment**, representing evolution in **large language models (LLMs)**.

Why in News

Emergence of advanced AI systems like Claude Mythos reflects **rapid progress in generative AI and model alignment capabilities**, raising governance and ethical considerations.

Key Facts and Figures

- Category: **Large Language Model (LLM)**
- Focus: **Contextual reasoning & alignment**
- Application: **AI assistants, decision-support systems**

Definition of Key Terms

- **LLM (Large Language Model)**: AI trained on vast text data for language tasks.
- **Alignment**: Ensuring AI outputs match human values and safety norms.
- **Generative AI**: AI capable of creating new content (text, images, etc.).

Ministry / Institutions / Organizations Involved

Developed by private AI companies; governance and regulation under MeitY in India; global AI standards evolving through multilateral forums.

Government Acts / Policies / Judgements

- **Digital India Act (proposed)**
  - Expected to regulate emerging technologies including AI.
- **IT Act, 2000**
  - Current framework for digital governance.
- **NITI Aayog AI Strategy**
  - Promotes responsible AI development in India.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **AI & emerging technologies (2020, 2023)**
- UPSC asked on **data governance (2021, 2022)**

Possible Prelims Trap Areas

- Confusing **LLM with general AI (narrow AI system)**
- Assuming **AI models are unbiased (training data bias exists)**

53. CAFE-III Norms (Corporate Average Fuel Efficiency)

Core Idea

CAFE norms regulate **fuel efficiency standards for vehicles**, aiming to **reduce fuel consumption and vehicular emissions**. CAFE-III represents the **next phase of stricter standards in India**.

Why in News

India is preparing to implement **CAFE-III norms** to align with climate commitments and improve transport sector efficiency.

Key Facts and Figures

- Based on: **grams of CO_2/km emissions**
- Applies to: **passenger vehicles**
- Builds on: **CAFE-I (2017) & CAFE-II (2022)**

Definition of Key Terms

- **CAFE Norms**: Average fuel efficiency standards across a manufacturer's fleet.
- **Fuel Efficiency**: Distance travelled per unit fuel.
- **Emission Intensity**: CO_2 emissions per km travelled.

Ministry / Institutions / Organizations Involved

Implemented by Ministry of Road Transport and Highways (MoRTH) in coordination with Bureau of Energy Efficiency (BEE).

Government Acts / Policies / Judgements

- **Energy Conservation Act, 2001**
  - Provides legal backing for fuel efficiency norms.

- **Auto Fuel Policy**
    - Sets roadmap for vehicular emission standards.
- **National Electric Mobility Mission Plan (NEMMP)**
    - Promotes electric vehicles to reduce emissions.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **vehicular emission norms (BS-VI, etc.) (2016, 2020, 2023)**
- UPSC asked on **climate commitments & transport sector (2021)**

Possible Prelims Trap Areas

- Confusing **CAFE norms with BS emission standards (different objectives)**
- Assuming **CAFE applies to individual cars (applies to fleet average)**

54. Memristor (Fourth Fundamental Circuit Element)

Core Idea

A Memristor (Memory + Resistor) is a **two-terminal electronic device whose resistance depends on past current flow**, enabling **non-volatile memory and neuromorphic computing**.

Why in News

Renewed research focus on memristors for **AI hardware, brain-like computing, and next-generation memory technologies**.

Key Facts and Figures

- Proposed by: **Leon Chua (1971)**
- Realized experimentally: **HP Labs (2008)**
- Property: **Retains resistance state even without power**

Definition of Key Terms

- **Memristor**: Device whose resistance varies based on charge history.
- **Non-volatile Memory**: Memory retaining data without power.
- **Neuromorphic Computing**: Brain-inspired computing systems.

Ministry / Institutions / Organizations Involved

Research driven by global semiconductor industry and academic institutions; in India supported under MeitY and semiconductor missions.

Government Acts / Policies / Judgements

- **India Semiconductor Mission (ISM)**
    - Supports advanced chip and memory technologies.
- **National Policy on Electronics, 2019**
    - Promotes electronics manufacturing ecosystem.
- **PLI Scheme (Electronics)**
    - Incentivizes domestic production.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **semiconductors & memory devices (2020, 2023)**
- UPSC asked on **emerging electronics technologies (2016, 2022)**

Possible Prelims Trap Areas

- Confusing **memristor with transistor (different function)**
- Assuming **it replaces RAM entirely (still emerging tech)**

55. Bacille Calmette-Guérin (BCG) Vaccine

Core Idea

BCG vaccine is a **live attenuated vaccine derived from Mycobacterium bovis**, primarily used to **prevent tuberculosis (TB), especially severe forms in children**.

Why in News

Continued relevance in **TB control programs** and research exploring **broader immune benefits (trained immunity)**.

Key Facts and Figures

- Introduced: **1921**
- Target: **Tuberculosis (TB)**
- Part of: **Universal Immunization Programme (UIP)**

Definition of Key Terms

- **Live Attenuated Vaccine**: Contains weakened pathogen to induce immunity.
- **Tuberculosis (TB)**: Bacterial disease caused by *Mycobacterium tuberculosis*.
- **Trained Immunity**: Enhanced innate immune response after vaccination.

Ministry / Institutions / Organizations Involved

Implemented by Ministry of Health & Family Welfare; global coordination by World Health Organization.

Government Acts / Policies / Judgements

- **National Tuberculosis Elimination Programme (NTEP)**
    - Aims to eliminate TB in India by 2025.
- **Universal Immunization Programme (UIP)**
    - Includes BCG for newborns.
- **Article 47 (DPSP)**
    - Duty of State to improve public health.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **vaccines & immunization (2015, 2020, 2023)**
- UPSC asked on **TB control programs (2017, 2021)**

Possible Prelims Trap Areas

- Confusing **BCG with COVID vaccines (different type and target)**
- Assuming **BCG prevents all TB forms (mainly severe childhood TB)**

56. Naphthalene Diimide (NDI)

Core Idea

Naphthalene Diimide (NDI) is an **organic semiconductor material** used in **electronics, sensors, and optoelectronic devices**, known for its **electron-transport properties**.

Why in News

Increasing research into **organic electronics and flexible devices** has highlighted NDI-based materials.

Key Facts and Figures

- Class: **Organic semiconductor**
- Property: **High electron mobility**
- Applications: **OLEDs, sensors, transistors**

Definition of Key Terms

- **Organic Semiconductor**: Carbon-based material conducting electricity.
- **Electron Mobility**: Speed at which electrons move through a material.

- **Optoelectronics**: Devices interacting with light and electricity.

Ministry / Institutions / Organizations Involved

Research supported by Department of Science & Technology (DST), CSIR labs, and academic institutions.

Government Acts / Policies / Judgements

- **National Policy on Electronics, 2019**
    - Promotes advanced materials and devices.
- **Science & Technology Innovation Policy (STIP)**
    - Encourages cutting-edge material science research.
- **Make in India Initiative**
    - Supports domestic electronics manufacturing.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **organic electronics & materials (2016, 2022)**
- UPSC asked on **nanotechnology applications (2018, 2023)**

Possible Prelims Trap Areas

- Confusing **NDI with inorganic semiconductors (like silicon)**
- Assuming **organic semiconductors are less useful (key in flexible electronics)**

57. Direct-to-Device (D2D) Communication Technology

Core Idea

Direct-to-Device (D2D) technology enables **satellites to communicate directly with standard smartphones** without requiring ground-based cellular towers, bridging connectivity gaps in remote areas.

Why in News

Rapid developments by global satellite companies (e.g., Starlink, Apple-supported satellite SOS) have accelerated **D2D-based satellite communication services**.

Key Facts and Figures

- Works via: **LEO satellites**
- Use cases: **Emergency SOS, remote connectivity**
- No requirement of: **traditional telecom towers**

Definition of Key Terms

- **D2D Communication**: Direct satellite-to-smartphone connectivity.
- **LEO (Low Earth Orbit)**: Orbit at ~160–2000 km altitude.
- **Latency**: Delay in signal transmission.

Ministry / Institutions / Organizations Involved

Policy and regulation in India handled by DoT and TRAI; global coordination by International Telecommunication Union.

Government Acts / Policies / Judgements

- **Indian Space Policy, 2023**
    - Enables private participation in satellite services.
- **Telecommunication Act, 2023**
    - Governs spectrum allocation and telecom services.
- **TRAI Recommendations (Satellite Spectrum)**
    - Advocates administrative allocation for non-GEO services.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **satellite communication (2014, 2021)**
- UPSC asked on **5G & telecom technologies (2022, 2023)**

Possible Prelims Trap Areas

- Confusing **D2D with device-to-device (peer mobile communication)**
- Assuming **requires special phones (many use standard smartphones)**

58. National Quantum Mission (NQM)

Core Idea

National Quantum Mission aims to **develop quantum technologies** such as **quantum computing, communication, sensing, and materials**, ensuring India's leadership in next-generation technologies.

Why in News

Implementation progress and funding allocation under the mission highlight India's push toward **quantum technology ecosystem development**.

Key Facts and Figures

- Duration: **2023–2031**
- Outlay: **~₹6,000 crore**
- Focus areas: **Quantum computing, communication, sensing**

Definition of Key Terms

- **Quantum Computing**: Uses quantum bits (qubits) for computation.
- **Quantum Entanglement**: Correlation between particles irrespective of distance.
- **Quantum Cryptography**: Ultra-secure communication using quantum principles.

Ministry / Institutions / Organizations Involved

Implemented by Department of Science & Technology (DST); collaboration with academic institutions and research labs.

Government Acts / Policies / Judgements

- **National Quantum Mission (2023)**
  - Promotes R&D, infrastructure, and talent development.
- **Science, Technology & Innovation Policy (STIP)**
  - Encourages frontier technology research.
- **Digital India Programme**
  - Supports emerging technologies ecosystem.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **quantum communication & computing (2020, 2023)**
- UPSC asked on **emerging technologies (2018, 2022)**

Possible Prelims Trap Areas

- Confusing **quantum computing with classical computing (fundamentally different)**
- Assuming **quantum tech is only for computing (includes sensing, communication)**

59. Indian Crested Porcupine

Core Idea

The Indian Crested Porcupine is a **large rodent species known for defensive quills**, playing an important role in **ecosystem balance and soil aeration**.

Why in News

Recent ecological observations and conservation discussions have brought attention to its **habitat distribution and human-wildlife interactions**.

Key Facts and Figures

- Scientific name: **Hystrix indica**
- Habitat: **Forests, grasslands, agricultural areas**
- Distribution: **India, Middle East, South Asia**

Definition of Key Terms

- **Rodent**: Mammal with continuously growing incisors.
- **Quills**: Modified sharp hairs used for defense.
- **Nocturnal**: Active during night.

Ministry / Institutions / Organizations Involved

Conservation monitored by Ministry of Environment, Forest and Climate Change; protected under Indian wildlife laws.

Government Acts / Policies / Judgements

- **Wildlife Protection Act, 1972**
  - Provides legal protection to wildlife species.
- **National Biodiversity Act, 2002**
  - Ensures conservation of biological diversity.
- **Article 48A**
  - Mandates environmental protection.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **Indian fauna & species classification (2016, 2021, 2023)**
- UPSC asked on **Wildlife Protection Act schedules (2017, 2020)**

Possible Prelims Trap Areas

- Confusing **porcupine with hedgehog (different species)**
- Assuming **quills can be thrown (they cannot, only detach on contact)**

60. Earthquake Lights (EQL)

Core Idea

Earthquake Lights (EQL) are **rare luminous phenomena observed in the sky or near ground before or during earthquakes**, believed to be linked to **tectonic stress and electrical charge generation in rocks**.

Why in News

Recent seismic studies have revived interest in **EQL as a possible precursor signal**, aiding earthquake prediction research.

Key Facts and Figures

- Occurrence: **Before or during earthquakes**
- Associated rocks: **Igneous & metamorphic (high stress)**
- Nature: **Flashes, glowing spheres, streaks**

Definition of Key Terms

- **Piezoelectric Effect**: Electric charge generated under mechanical stress.
- **Tectonic Stress**: Pressure buildup in Earth's crust.
- **Seismic Activity**: Movement within Earth causing earthquakes.

Ministry / Institutions / Organizations Involved

Seismic monitoring by National Centre for Seismology; global research by geophysical institutions.

Government Acts / Policies / Judgements

- **Disaster Management Act, 2005**
    - Framework for earthquake preparedness.
- **National Disaster Management Authority (NDMA) Guidelines**
    - Risk mitigation strategies for earthquakes.
- **Article 21**
    - Right to life includes disaster safety.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **earthquake causes & precursors (2013, 2019, 2022)**
- UPSC asked on **geophysical phenomena (2017, 2021)**

Possible Prelims Trap Areas

- Assuming **EQL is a confirmed prediction tool (not fully proven)**
- Confusing **EQL with lightning or aurora phenomena**

61. No Cloning Theorem (Quantum Mechanics)

Core Idea

The No Cloning Theorem states that **it is impossible to create an exact copy of an arbitrary unknown quantum state**, forming a fundamental principle of **quantum mechanics and quantum computing**.

Why in News

Increasing focus on **quantum communication and cryptography** has highlighted the theorem's role in ensuring **secure data transmission**.

Key Facts and Figures

- Applies to: **Quantum states (qubits)**
- Ensures: **Security in quantum cryptography**
- Fundamental law of **quantum information theory**

Definition of Key Terms

- **Quantum State**: Complete description of a quantum system.
- **Qubit**: Basic unit of quantum information.
- **Superposition**: Ability of a quantum system to exist in multiple states simultaneously.

Ministry / Institutions / Organizations Involved

Research supported by DST under quantum initiatives; global collaboration across physics institutions.

Government Acts / Policies / Judgements

- **National Quantum Mission (2023)**
    - Promotes quantum research and applications.
- **Science & Technology Policy**
    - Encourages frontier research.
- **Article 51A(h)**
    - Promotes scientific temper.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **quantum communication (2020, 2023)**
- UPSC asked on **basic quantum principles (2016, 2022)**

Possible Prelims Trap Areas

- Confusing **quantum cloning with classical copying (allowed)**
- Assuming **quantum states can be duplicated like digital data**

62. PRISM-SG Portal

Core Idea

PRISM-SG (Platform for Regulatory Intelligence & Smart Governance) is a **digital portal designed to enhance regulatory compliance, monitoring, and governance efficiency using data analytics and AI tools**.

Why in News

Launch/expansion of PRISM-SG reflects government efforts toward **digital governance and real-time regulatory oversight**.

Key Facts and Figures

- Nature: **Digital governance platform**
- Uses: **AI, analytics, real-time monitoring**
- Purpose: **Regulatory transparency & efficiency**

Definition of Key Terms

- **Regulatory Intelligence**: Use of data analytics for governance decisions.
- **Smart Governance**: Technology-driven public administration.
- **Compliance Monitoring**: Tracking adherence to rules/regulations.

Ministry / Institutions / Organizations Involved

Developed by government agencies under digital governance frameworks; likely overseen by MeitY and sector-specific regulators.

Government Acts / Policies / Judgements

- **Digital India Programme**
    - Promotes e-governance and digital platforms.
- **IT Act, 2000**
    - Legal framework for electronic governance.
- **National e-Governance Plan (NeGP)**
    - Strengthens digital service delivery.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **e-governance platforms (2018, 2022, 2023)**
- UPSC asked on **digital administration (2017, 2021)**

Possible Prelims Trap Areas

- Confusing **PRISM-SG with general portals (specific regulatory focus)**
- Assuming **purely administrative (uses AI/data analytics)**

63. AI Tokens

Core Idea

AI tokens are **units of data (words, sub-words, or characters) processed by AI models**, forming the basis for **input/output and computation in large language models**.

Why in News

With increasing use of generative AI, tokens have become critical for **costing, efficiency, and performance measurement of AI systems**.

Key Facts and Figures

- Token ≈ **word/sub-word unit**
- Determines: **processing cost & model limits**
- Used in: **LLMs, chatbots, NLP systems**

Definition of Key Terms

- **Tokenization**: Breaking text into smaller units for processing.

- **NLP (Natural Language Processing)**: AI field dealing with language understanding.
- **Context Window**: Maximum tokens AI can process at once.

Ministry / Institutions / Organizations Involved

AI governance and policy in India led by MeitY; development by private AI companies globally.

Government Acts / Policies / Judgements

- **Digital India Act (proposed)**
    - Will regulate AI and digital ecosystems.
- **IT Act, 2000**
    - Governs digital systems and data.
- **NITI Aayog AI Strategy**
    - Promotes responsible AI adoption.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **AI & NLP (2020, 2023)**
- UPSC asked on **digital technologies (2021, 2022)**

Possible Prelims Trap Areas

- Confusing **AI tokens with cryptocurrency tokens**
- Assuming **token = word always (can be sub-word/character)**

64. SRY Gene Screening

Core Idea

SRY gene screening involves detecting the **Sex-determining Region Y (SRY) gene**, which plays a crucial role in **male sex determination** by initiating testis development in embryos.

Why in News

Advances in genetic diagnostics have increased focus on **SRY gene screening for disorders of sex development (DSDs)** and forensic identification.

Key Facts and Figures

- Located on: **Y chromosome**
- Function: **Triggers male differentiation**
- Used in: **genetic testing & forensic science**

Definition of Key Terms

- **SRY Gene**: Gene responsible for initiating male sex determination.
- **DSDs (Disorders of Sex Development)**: Conditions involving atypical sexual development.
- **Karyotyping**: Analysis of chromosome structure and number.

Ministry / Institutions / Organizations Involved

Research and diagnostics supported by Department of Biotechnology (DBT) and medical genetics institutions; forensic use by law enforcement agencies.

Government Acts / Policies / Judgements

- **Pre-Conception and Pre-Natal Diagnostic Techniques (PCPNDT) Act, 1994**
    - Prohibits misuse of genetic testing for sex selection.
- **National Health Policy, 2017**
    - Encourages genetic screening and diagnostics.
- **Article 21**
    - Includes right to health and dignity.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **genetics & chromosomes (2015, 2021, 2023)**

- UPSC asked on **PCPNDT Act (2017, 2020)**

Possible Prelims Trap Areas

- Confusing **SRY gene presence with biological sex certainty (exceptions exist)**
- Assuming **screening allowed for sex selection (legally restricted)**

65. Biotechnology Research and Innovation Council (BRIC)

Core Idea

BRIC is an **umbrella institutional framework for biotechnology research**, aimed at **integrating autonomous DBT institutes and enhancing translational research and innovation**.

Why in News

Government initiatives to strengthen **biotech ecosystem and coordination among research institutions** have led to emphasis on BRIC.

Key Facts and Figures

- Established under: **Department of Biotechnology (DBT)**
- Purpose: **Research integration & innovation**
- Focus: **Healthcare, agriculture, industrial biotech**

Definition of Key Terms

- **Translational Research**: Converting lab research into practical applications.
- **Biotechnology**: Use of biological systems for technological solutions.
- **Bioeconomy**: Economic activity based on biological resources.

Ministry / Institutions / Organizations Involved

Implemented by Department of Biotechnology (DBT); includes collaboration with research institutes, academia, and industry.

Government Acts / Policies / Judgements

- **Biotechnology Policy Frameworks (DBT)**
  - Promote research and commercialization.
- **BioE3 Policy (2024)**
  - Focuses on biotech-driven economy and employment.
- **Startup India Initiative**
  - Supports biotech startups.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **biotech institutions & policies (2016, 2022)**
- UPSC asked on **bioeconomy & innovation (2020, 2023)**

Possible Prelims Trap Areas

- Confusing **BRIC with BRICS (international grouping)**
- Assuming **purely regulatory body (also promotes research)**

66. OPU–IVF–ET Technology

Core Idea

OPU–IVF–ET (Ovum Pick-Up – In Vitro Fertilization – Embryo Transfer) is an **advanced reproductive biotechnology technique** used for **rapid multiplication of high-quality livestock**.

Why in News

Growing adoption in animal husbandry for **genetic improvement and boosting dairy/meat productivity**.

Key Facts and Figures

- OPU: **Collection of oocytes from donor animal**
- IVF: **Fertilization outside body**
- ET: **Transfer of embryo into surrogate**

Definition of Key Terms

- **In Vitro Fertilization (IVF)**: Fertilization outside organism in lab.
- **Embryo Transfer (ET)**: Implantation of embryo into surrogate mother.
- **Genetic Improvement**: Enhancing desirable traits in livestock.

Ministry / Institutions / Organizations Involved

Implemented by Ministry of Fisheries, Animal Husbandry & Dairying; research support from ICAR institutions.

Government Acts / Policies / Judgements

- **Rashtriya Gokul Mission**
  - Promotes indigenous cattle breeding using advanced technologies.
- **National Livestock Mission**
  - Supports livestock productivity and genetic improvement.
- **Article 48 (DPSP)**
  - Focuses on animal husbandry and breed improvement.

Previous Year Linkage (PYQ Linkage)

- UPSC asked on **IVF & reproductive technologies (2015, 2022)**
- UPSC asked on **animal husbandry schemes (2016, 2021)**

Possible Prelims Trap Areas

- Confusing **IVF in humans vs livestock applications**
- Assuming **OPU-IVF-ET is cloning (it is not cloning)**

QUICK AND FAST LEARN TOPICS OF SCIENCE AND TECH

BATCH 1: Artificial Intelligence & Emerging Digital Tech

(PYQ-based dimension mapping | UPSC Prelims 2026)

1. Artificial Intelligence (AI) & India AI Mission

- **Concept** – Machines performing tasks requiring human intelligence
- **Working** – Data → Algorithm → Model → Output

- **Application** – Healthcare, agriculture, governance, defence
- **Comparison** – AI (broad) > ML (subset) > Deep Learning (subset)
- **Advantages** – Automation, efficiency, scalability
- **Limitations** – Bias, data dependence, job loss
- **Current Affairs** – IndiaAI Mission, AI governance initiatives
- **Institution** – MeitY, NITI Aayog
- **Trap** – "AI always requires human supervision" (Incorrect)

2. Generative AI & Large Language Models (LLMs)

- **Concept** – AI systems generating text, images, and code
- **Working** – Neural networks trained on massive datasets
- **Application** – Chatbots, coding assistants, content generation
- **Comparison** – Generative AI vs traditional rule-based AI
- **Advantages** – Creativity, automation of cognitive work
- **Limitations** – Hallucination, misinformation, bias
- **Current Affairs** – Tools like ChatGPT
- **Trap** – "LLMs understand meaning like humans" (Incorrect)

3. Machine Learning vs Deep Learning

- **Concept** – ML learns from data; DL uses neural networks
- **Working** – Supervised, unsupervised, reinforcement learning
- **Comparison** – ML uses structured data; DL handles unstructured data
- **Application** – Fraud detection, speech and image recognition
- **Advantages** – Pattern recognition, prediction capability
- **Limitations** – High data requirement, low interpretability
- **Trap** – "Deep learning works without data" (Incorrect)

4. Explainable AI (XAI) & AI Ethics

- **Concept** – AI whose decisions can be understood by humans
- **Need** – Transparency, accountability, fairness
- **Application** – Judiciary, healthcare, finance
- **Comparison** – Black-box AI vs explainable AI
- **Advantages** – Trust, regulatory acceptance
- **Limitations** – Possible reduction in performance
- **Current Affairs** – Global push for ethical AI frameworks
- **Institution** – OECD AI Principles, UNESCO guidelines
- **Trap** – "All AI systems are explainable" (Incorrect)

5. Metaverse & Virtual Reality

- **Concept** – Persistent immersive virtual world for interaction
- **Components** – VR, AR, blockchain
- **Application** – Gaming, education, meetings, digital economy
- **Comparison** – VR (fully immersive), AR (real-world overlay), MR (mixed)
- **Advantages** – Immersion, remote collaboration
- **Limitations** – Privacy risks, addiction, hardware cost
- **Current Affairs** – Increasing global investment in metaverse
- **Trap** – "Metaverse is only for gaming" (Incorrect)

6. Blockchain & Web 3.0

- **Concept** – Decentralized distributed digital ledger
- **Working** – Blocks + cryptographic hash + consensus mechanism
- **Application** – Cryptocurrency, supply chain, smart contracts
- **Comparison** – Web 1.0 (static), Web 2.0 (centralized), Web 3.0 (decentralized)
- **Advantages** – Transparency, immutability, decentralization
- **Limitations** – Energy consumption, scalability issues
- **Current Affairs** – Governance, digital identity use-cases
- **Trap** – "Blockchain cannot be altered" (Incorrect)

7. Quantum Computing

- **Concept** – Computing using quantum bits (qubits)
- **Principles** – Superposition, entanglement
- **Comparison** – Classical uses bits; quantum uses qubits
- **Application** – Cryptography, drug discovery, optimization
- **Advantages** – High processing power for specific problems
- **Limitations** – Instability, error rates, high cost
- **Current Affairs** – India's National Quantum Mission
- **Trap** – "Quantum computers replace classical computers" (Incorrect)

8. Neuromorphic Computing

- **Concept** – Brain-inspired computing systems
- **Working** – Artificial neurons and synapses
- **Comparison** – Traditional (separate memory-processing) vs brain-like systems
- **Application** – Robotics, edge AI, low-power computing
- **Advantages** – Energy efficiency, real-time learning
- **Limitations** – Still in experimental stage
- **Trap** – "Neuromorphic computing equals AI" (Incorrect)

Biotechnology & Health Tech

(MOST IMPORTANT | PYQ-heavy area | UPSC Prelims 2026)

9. Genome India Project

- **Concept** – Large-scale initiative to map genetic diversity of Indian population
- **Working** – DNA sequencing → genome analysis → data storage
- **Application** – Personalized medicine, disease prediction
- **Comparison** – Genome sequencing vs DNA fingerprinting
- **Advantages** – Better healthcare targeting, precision medicine
- **Limitations** – Data privacy, ethical concerns
- **Current Affairs** – India's indigenous genome database development
- **Institution** – DBT (Department of Biotechnology)
- **Trap** – "Genome mapping identifies only diseases" (Incorrect)

10. CRISPR-Cas9 Gene Editing

- **Concept** – Tool for precise editing of DNA sequences
- **Working** – Guide RNA directs Cas9 enzyme to cut specific DNA
- **Application** – Genetic disorder treatment, crop improvement
- **Comparison** – CRISPR vs traditional gene therapy
- **Advantages** – High precision, low cost
- **Limitations** – Ethical issues, off-target effects
- **Current Affairs** – Nobel Prize recognition, ongoing clinical trials
- **Trap** – "CRISPR works only in bacteria" (Incorrect)

11. mRNA Vaccines

- **Concept** – Vaccines using messenger RNA to produce antigen proteins
- **Working** – mRNA enters cells → protein synthesis → immune response
- **Application** – COVID-19 vaccines, future cancer vaccines
- **Comparison** – mRNA vs traditional vaccines (live/inactivated)
- **Advantages** – Faster development, high adaptability
- **Limitations** – Storage issues, instability
- **Current Affairs** – Expansion beyond COVID vaccines
- **Trap** – "mRNA vaccines alter human DNA" (Incorrect)

12. DNA & RNA Technologies

- **Concept** – Study and manipulation of genetic material
- **Working** – Replication, transcription, translation processes

- **Application** – Forensics, diagnostics, genetic engineering
- **Comparison** – DNA (stable, double-stranded) vs RNA (unstable, single-stranded)
- **Advantages** – Accurate genetic analysis
- **Limitations** – Technical complexity
- **Trap** – "RNA is always permanent genetic material" (Incorrect)

13. Synthetic Biology

- **Concept** – Designing and constructing new biological systems
- **Working** – Genetic circuits, engineered DNA sequences
- **Application** – Biofuels, artificial organisms, medicine
- **Comparison** – Synthetic biology vs genetic engineering
- **Advantages** – Custom biological solutions
- **Limitations** – Biosecurity risks
- **Current Affairs** – Growing biotech industry applications
- **Trap** – "It only modifies existing organisms" (Incorrect)

14. Biofoundries & Biomanufacturing

- **Concept** – Automated facilities for designing biological systems
- **Working** – High-throughput DNA design → testing → production
- **Application** – Drug production, enzymes, vaccines
- **Advantages** – Scalability, efficiency
- **Limitations** – High setup cost
- **Current Affairs** – Push under bioeconomy initiatives
- **Trap** – "Biofoundries are traditional labs" (Incorrect)

15. Stem Cell Therapy

- **Concept** – Use of undifferentiated cells for treatment
- **Working** – Stem cells differentiate into specialized cells
- **Application** – Regenerative medicine, organ repair
- **Comparison** – Embryonic vs adult stem cells
- **Advantages** – Potential to cure degenerative diseases
- **Limitations** – Ethical issues, tumor risk
- **Current Affairs** – Clinical trials expansion
- **Trap** – "Stem cells are already fully safe and widely used" (Incorrect)

16. Extracellular RNA (exRNA)

- **Concept** – RNA molecules present outside cells
- **Working** – Circulate via vesicles in body fluids
- **Application** – Disease biomarkers, diagnostics
- **Advantages** – Non-invasive detection

- **Limitations** – Early-stage research
- **Current Affairs** – Emerging research area
- **Trap** – "RNA exists only inside cells" (Incorrect)

17. One Health Approach

- **Concept** – Integrated approach linking human, animal, and environmental health
- **Working** – Multisectoral coordination
- **Application** – Zoonotic disease control, pandemic prevention
- **Advantages** – Holistic disease management
- **Limitations** – Coordination challenges
- **Current Affairs** – Post-COVID global emphasis
- **Institution** – WHO, FAO, UNEP
- **Trap** – "Only related to human health" (Incorrect)

18. Antimicrobial Resistance (AMR)

- **Concept** – Microbes developing resistance to drugs
- **Working** – Mutation, gene transfer mechanisms
- **Application** – Relevant in medicine, agriculture
- **Comparison** – Antibiotic resistance vs antiviral resistance
- **Advantages** – (None; harmful phenomenon)
- **Limitations/Concerns** – Treatment failure, global health threat
- **Current Affairs** – WHO priority pathogen list
- **Trap** – "Only bacteria show resistance" (Incorrect)

Space Technology (ISRO Focus)

(High scoring | PYQ-relevant | UPSC Prelims 2026)

19. Gaganyaan Mission

- **Concept** – India's human spaceflight mission by ISRO
- **Working** – Crew module + service module + human-rated launch vehicle
- **Application** – Space exploration, human space capability
- **Comparison** – Human spaceflight vs unmanned missions
- **Advantages** – Technological advancement, strategic capability
- **Limitations** – High cost, safety risks
- **Current Affairs** – Test flights, crew escape system trials
- **Institution** – ISRO
- **Trap** – "India has already completed human spaceflight mission" (Incorrect)

20. Aditya-L1 Mission

- **Concept** – Solar observation mission at Lagrange Point L1

- **Working** – Halo orbit around L1 to observe Sun continuously
- **Application** – Solar corona study, space weather
- **Comparison** – LEO satellites vs Lagrange point missions
- **Advantages** – Continuous solar observation
- **Limitations** – Complex orbital positioning
- **Current Affairs** – First dedicated solar mission of India
- **Institution** – ISRO
- **Trap** – "Aditya-L1 studies Earth's atmosphere" (Incorrect)

21. NISAR Satellite (NASA–ISRO)

- **Concept** – Joint Earth observation satellite by NASA and ISRO
- **Working** – Synthetic Aperture Radar (SAR) imaging
- **Application** – Disaster monitoring, land deformation
- **Comparison** – Optical vs radar satellites
- **Advantages** – All-weather, day-night imaging
- **Limitations** – Complex data processing
- **Current Affairs** – Upcoming launch collaboration
- **Institution** – NASA + ISRO
- **Trap** – "Radar satellites require sunlight" (Incorrect)

22. NavIC (Indian GPS)

- **Concept** – India's regional navigation satellite system
- **Working** – Satellite constellation providing positioning signals
- **Application** – Navigation, disaster management, military use
- **Comparison** – NavIC (regional) vs GPS (global)
- **Advantages** – Better accuracy in Indian region
- **Limitations** – Limited global coverage
- **Current Affairs** – Integration in smartphones
- **Institution** – ISRO
- **Trap** – "NavIC provides global coverage" (Incorrect)

23. Small Satellite Launch Vehicle (SSLV)

- **Concept** – Low-cost launch vehicle for small satellites
- **Working** – Multi-stage solid propulsion rocket
- **Application** – Commercial satellite launches
- **Comparison** – PSLV vs SSLV
- **Advantages** – Quick launch, cost-effective
- **Limitations** – Limited payload capacity
- **Current Affairs** – Commercialization push
- **Institution** – ISRO
- **Trap** – "SSLV replaces PSLV" (Incorrect)

24. Space Docking & Reusable Launch Vehicles

- **Concept** – Docking connects spacecraft; reusable rockets reduce cost
- **Working** – Autonomous rendezvous + re-entry and landing systems
- **Application** – Space stations, long-duration missions
- **Comparison** – Reusable vs expendable launch vehicles
- **Advantages** – Cost reduction, sustainability
- **Limitations** – Technical complexity
- **Current Affairs** – ISRO RLV experiments
- **Trap** – "Reusable rockets are fully risk-free" (Incorrect)

25. Space Situational Awareness (SSA)

- **Concept** – Monitoring objects in space to avoid collisions
- **Working** – Tracking satellites and debris using sensors
- **Application** – Satellite safety, defence
- **Comparison** – Space traffic management vs SSA
- **Advantages** – Collision prevention
- **Limitations** – Tracking small debris is difficult
- **Current Affairs** – Increasing concern due to space debris
- **Institution** – ISRO SSA initiatives, global cooperation
- **Trap** – "Space is empty and collision-free" (Incorrect)

Defence Technology

(Highly dynamic | Statement-based UPSC | Prelims 2026)

26. Hypersonic Missiles

- **Concept** – Missiles traveling at speeds greater than Mach 5
- **Working** – Scramjet engines enabling sustained hypersonic flight
- **Application** – Strategic strike capability, rapid response
- **Comparison** – Supersonic (Mach 1–5) vs hypersonic (>Mach 5)
- **Advantages** – High speed, difficult interception
- **Limitations** – Heat management, high cost
- **Current Affairs** – Global race (US, China, Russia, India)
- **Trap** – "Hypersonic missiles cannot be detected" (Incorrect)

27. Directed Energy Weapons (Laser, HPM)

- **Concept** – Weapons using focused energy instead of kinetic force
- **Working** – Laser beams or high-power microwaves disable targets
- **Application** – Anti-drone, missile defence

- **Comparison** – Kinetic weapons vs energy weapons
- **Advantages** – Precision, low per-use cost
- **Limitations** – Weather dependence, power requirement
- **Current Affairs** – Increasing deployment for drone defence
- **Trap** – "Laser weapons work equally in all weather conditions" (Incorrect)

28. Drone Warfare & Counter-Drone Systems

- **Concept** – Use of UAVs for surveillance and combat
- **Working** – Remote/autonomous operation using GPS, sensors
- **Application** – Reconnaissance, targeted strikes
- **Comparison** – Manned vs unmanned systems
- **Advantages** – Reduced human risk, cost-effective
- **Limitations** – Vulnerable to jamming, hacking
- **Current Affairs** – Extensive use in modern conflicts
- **Trap** – "Drones cannot be intercepted" (Incorrect)

29. Ballistic Missile Defence (BMD)

- **Concept** – System to intercept incoming ballistic missiles
- **Working** – Detection → tracking → interception (exo/endo-atmospheric)
- **Application** – National missile shield
- **Comparison** – Ballistic vs cruise missiles
- **Advantages** – Strategic defence capability
- **Limitations** – High cost, not foolproof
- **Current Affairs** – India's multi-layer BMD development
- **Trap** – "BMD guarantees 100% interception" (Incorrect)

30. S-400 Air Defence System

- **Concept** – Advanced surface-to-air missile defence system from Russia
- **Working** – Multi-layer radar + missile interception system
- **Application** – Airspace defence against aircraft, missiles
- **Comparison** – S-400 vs other air defence systems
- **Advantages** – Long range, multi-target tracking
- **Limitations** – Expensive, geopolitical issues
- **Current Affairs** – Induction into Indian Air Force
- **Trap** – "S-400 can intercept only aircraft" (Incorrect)

31. Autonomous Weapons Systems

- **Concept** – Weapons capable of operating without human intervention

- **Working** – AI-based target identification and engagement
- **Application** – Modern warfare, surveillance
- **Comparison** – Autonomous vs remotely operated systems
- **Advantages** – Speed, reduced human involvement
- **Limitations** – Ethical concerns, accountability issues
- **Current Affairs** – Global debate on lethal autonomous weapons
- **Trap** – "All autonomous weapons are fully independent" (Incorrect)

Energy & Environment Technology

(High relevance | Increasing UPSC weightage | Prelims 2026)

32. Green Hydrogen Mission

- **Concept** – Hydrogen produced using renewable energy via electrolysis
- **Working** – Water split into hydrogen and oxygen using electricity from renewables
- **Application** – Clean fuel, fertilizer industry, steel production
- **Comparison** – Green vs Blue vs Grey hydrogen
- **Advantages** – Zero carbon emissions at production stage
- **Limitations** – High cost, storage and transport challenges
- **Current Affairs** – National Green Hydrogen Mission (India)
- **Institution** – Ministry of New and Renewable Energy (MNRE)
- **Trap** – "Hydrogen is a primary energy source" (Incorrect)

33. Sodium-ion Batteries

- **Concept** – Batteries using sodium ions instead of lithium ions
- **Working** – Ion movement between cathode and anode during charge/discharge
- **Application** – Energy storage, electric mobility
- **Comparison** – Sodium-ion vs Lithium-ion batteries
- **Advantages** – Abundant raw material, lower cost
- **Limitations** – Lower energy density
- **Current Affairs** – Emerging alternative for grid storage
- **Trap** – "Sodium-ion batteries have higher energy density than lithium-ion" (Incorrect)

34. Nuclear Fusion (ITER, Tokamak)

- **Concept** – Energy generation by fusing light nuclei (e.g., hydrogen isotopes)
- **Working** – High temperature plasma enables fusion reactions
- **Application** – Future clean energy source
- **Comparison** – Fusion vs fission
- **Advantages** – High energy output, low radioactive waste

- **Limitations** – Technological complexity, not yet commercially viable
- **Current Affairs** – ITER project
- **Trap** – "Fusion is currently used in nuclear power plants" (Incorrect)

35. Small Modular Reactors (SMRs)

- **Concept** – Compact nuclear reactors with modular design
- **Working** – Factory-built units assembled on-site
- **Application** – Decentralized power generation
- **Comparison** – SMRs vs traditional nuclear reactors
- **Advantages** – Safer design, flexible deployment
- **Limitations** – High initial investment
- **Current Affairs** – Interest in clean energy transition
- **Trap** – "SMRs produce no radioactive waste" (Incorrect)

36. Carbon Capture, Utilization and Storage (CCUS)

- **Concept** – Capturing CO_2 emissions and storing or reusing them
- **Working** – Capture → transport → storage/use
- **Application** – Industrial emission reduction
- **Comparison** – Carbon capture vs carbon offsetting
- **Advantages** – Reduces atmospheric CO_2
- **Limitations** – Expensive, energy-intensive
- **Current Affairs** – Climate mitigation strategies
- **Trap** – "CCUS eliminates emissions completely" (Incorrect)

37. Biofuels (2G, 3G Ethanol, SAF)

- **Concept** – Fuels derived from biological materials
- **Working** – Conversion of biomass into fuel
- **Application** – Transport fuel, aviation fuel (SAF)
- **Comparison** – 1G (food crops) vs 2G (agri waste) vs 3G (algae)
- **Advantages** – Renewable, reduces fossil fuel dependence
- **Limitations** – Land use, production cost
- **Current Affairs** – Ethanol blending program, SAF development
- **Trap** – "All biofuels are carbon neutral" (Incorrect)

ICT, Cybersecurity & Communication

(Final batch | High relevance | Prelims 2026)

38. 5G & 6G Technology

- **Concept** – Next-generation wireless communication technologies with high speed and low latency

- **Working** – Uses higher frequency spectrum, small cells, MIMO, beamforming
- **Application** – IoT, smart cities, autonomous vehicles, telemedicine
- **Comparison** – 4G (high speed) vs 5G (ultra-low latency, high capacity) vs 6G (future ultra-high speed, AI integration)
- **Advantages** – Faster data, low latency, massive connectivity
- **Limitations** – Infrastructure cost, limited coverage (high frequency bands)
- **Current Affairs** – 5G rollout in India, 6G research initiatives
- **Institution** – DoT, TSDSI
- **Trap** – "5G signals travel longer distances than 4G" (Incorrect)

39. Satellite Internet

- **Concept** – Internet provided via satellites instead of terrestrial infrastructure
- **Working** – Communication between user terminal and satellites (often LEO constellations)
- **Application** – Remote connectivity, disaster zones, rural internet
- **Comparison** – Fiber internet vs satellite internet
- **Advantages** – Wide coverage, accessibility in remote areas
- **Limitations** – Latency (especially GEO), weather interference, cost
- **Current Affairs** – Services like Starlink
- **Trap** – "Satellite internet works only with geostationary satellites" (Incorrect)

40. Cybersecurity & Quantum Cryptography

- **Concept** – Protection of digital systems; quantum cryptography uses quantum mechanics for secure communication
- **Working** – Encryption, firewalls, intrusion detection; quantum key distribution (QKD)
- **Application** – Banking, defence, data protection
- **Comparison** – Classical cryptography vs quantum cryptography
- **Advantages** – High security, detection of interception (quantum)
- **Limitations** – High cost, limited scalability
- **Current Affairs** – Rising cyber threats, quantum communication research
- **Trap** – "Quantum cryptography cannot detect eavesdropping" (Incorrect)

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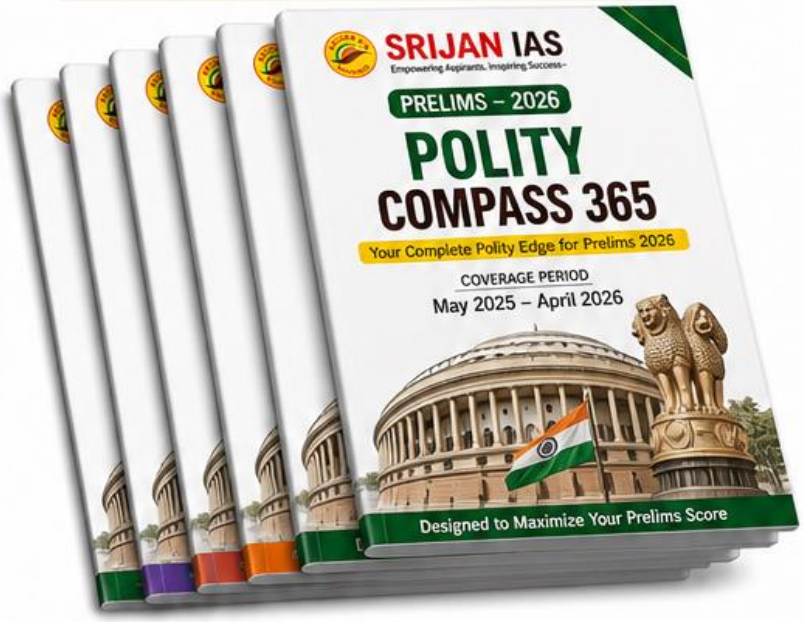

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