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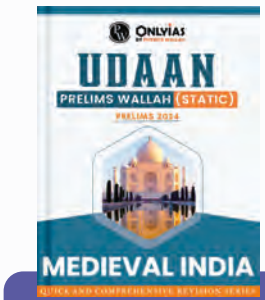

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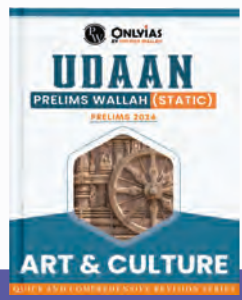

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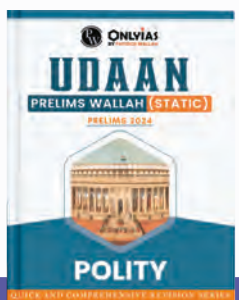

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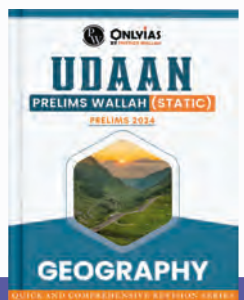

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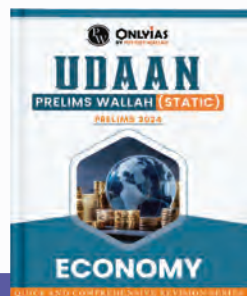

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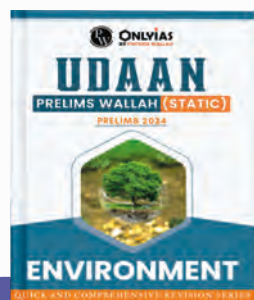

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PREFACE

A highly skilled professional team of PW ONLY IAS works arduously to ensure that the students receive the best content for the UPSC exam.

A plethora of UPSC study materials are available in the market, but PW ONLY IAS professionals continuously work to provide supreme-quality study material for our UPSC students.

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- Holistic coverage of topics, strictly as per exam syllabus.
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- Diagrams and Timelines for quick understanding and revision.
- Quick Revision Module for the UPSC Prelims examination.
- Every topic is structured in headings and bullets for easy understanding of the students.

CONTENTS

1 Biology and Its Applications

Biology is **the study of living organisms** and **is divided into many specialised fields that cover their morphology**, **physiology**, **anatomy**, **behaviour**, **origin**, and **distribution**.

CELL BIOLOGY

The cell is **the fundamental**, **structural** and **functional** unit of all living organisms.

- **Anton Van Leeuwenhoek** first **saw and described a live cell**.
- **Robert Brown** later **discovered the nucleus**.

Cells are characteristically microscopic in size (**with exceptions-The largest isolated single cell is the egg of an ostrich**). A typical eukaryotic cell is 10 to 100 µm in diameter, while most prokaryotic cells range only 1 to 10 µm in diameter.

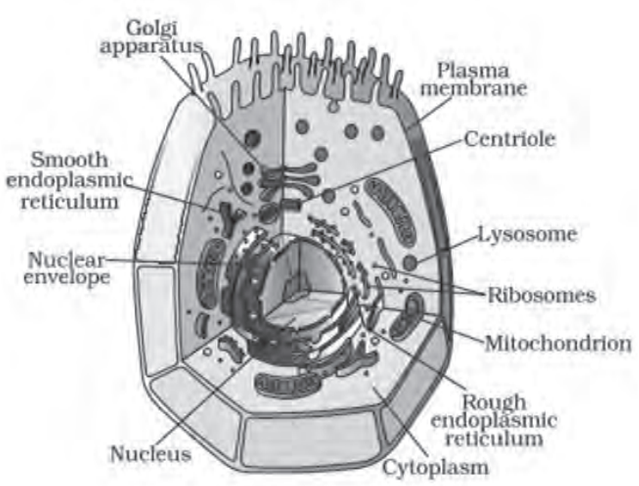

Fig: Archetypal Animal Cell

Components of a Cell

The **general plan of cellular organisation varies between different organisms**, but despite these modifications, **all cells resemble one another in certain fundamental ways**. Features **common to all cells** are:

- **Nucleoid/ Nucleus:** Every cell contains **DNA (deoxyribonucleic acid), the hereditary molecule. In prokaryotes, the simplest organisms,** most of the genetic material **lies in a single circular molecule of DNA** near the centre of the cell **in a region called the Nucleoid. The DNA of Eukaryotes,** on the other hand, **is contained in the nucleus, surrounded by a double membrane structure called the Nuclear Envelope**
- **Plasma Membrane:** It is made up of **phospholipids** and **proteins**, is **selectively permeable**, **regulates transport into** and **out of cells**, and **separates cellular contents from surroundings enclosing it**.
- **Cytoplasm:** It is a **semifluid matrix that fills the interior of the cell** containing **various organelles and micro/macro molecules which help in the functioning of the cell.**
- **Ribosomes:** The ribosome is a complex molecule made of **ribosomal RNA** (**Ribonucleic Acid**) and proteins that form a factory for protein synthesis in cells. The **eukaryotic ribosomes are the 80S** while the **prokaryotic ribosomes are 70S**. Here **S** (**Svedberg's Unit**) **stands for the sedimentation coefficient**; it is **indirectly a measure of density and size.**

Cell Organelles

These are **specialised structures that serve specific functions to keep a cell alive** [**e.g., mitochondria produce ATP** (**Adenosine Triphosphate**), **the energy currency of cells**].

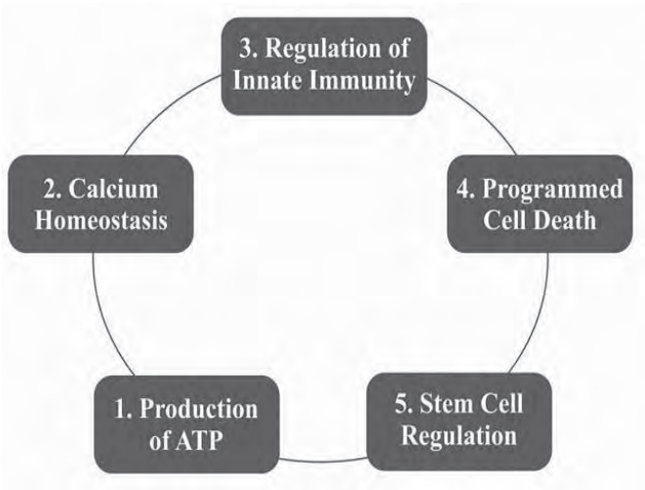

Fig: Functions of mitochondria in a cell.

Mitochondria

- These are **double membrane-bound structures**.
- Mitochondria are the **sites of aerobic respiration producing cellular energy in the form of ATP**; hence they are **called power houses of the cell**.
- They also **possess a single circular DNA molecule**, **a few RNA molecules**, **ribosomes** (**70S**) and **the components required for the synthesis of proteins**.

Endo-Membrane System

Many **cell organelles are considered together** as **an endomembrane system because their functions are coordinated** and it includes **endoplasmic reticulum** (**ER**), **Golgi complex**, **lysosomes** and **vacuoles**.

- **Endoplasmic Reticulum (ER):** It is a network of membranes inside a cell through which proteins and other molecules move.

Rough Endoplasmic Reticulum (ER)	Smooth Endoplasmic Reticulum (ER)
It has **ribosomes attached to its surface** and **is an active site for protein synthesis.**	Due to **the absence of ribosomes**, they **appear smooth** and are **major sites for the synthesis of lipids**. In **animal cells, lipid-like steroidal hormones are synthesised in SER**.

- **Golgi Apparatus:** A **Golgi body**, also known as a **Golgi apparatus**, is a **cell organelle that helps process** and **package proteins** and **lipid molecules**.
- **Lysosomes:** These are membrane-bound cell organelles that **contain various hydrolytic enzymes**. These enzymes help in the **destruction** and **breakdown of various worn-out cell parts**, **helping a cell in de-toxification**. They also destroy **pathogens**, such as **bacteria** and **viruses** and **play a role in immunity**. They are also called **suicidal bags of the cell** because they help in the **self-destruction of the cells**.
- **Vacuoles:** It is **a membrane-bound space found in the cytoplasm containing water, sap, excretory products** and **other materials not useful for the cell**. **Large vacuoles** are bound **by a single membrane called tonoplast**. In plant cells, the vacuoles can occupy up to **90 % of the volume of the cell.**

Plastids

- Plastids are **found in all plant cells** and in **euglenoids**.
- They **bear some specific pigments**, thus **imparting specific colours to the plants**.
- Based on the **type of pigments**, plastids can be **classified into chloroplasts**, **chromoplasts** and **leucoplasts**.
- Like mitochondria, the **chloroplasts are also double-membraned structures containing small, double-stranded circular DNA molecules** and **ribosomes**.

Classification of Cells

On the basis of complexity, cells can be classified as:

- **Eukaryotic cells-** contain **well-defined membrane-bound nuclei**.
- **Prokaryotic cells- do not have well-defined membrane-bound nuclei**.

On the **basis of components**, **Eukaryotes are further divided into Animal cells** and **Plant cells**. Plant cells have a **cell wall** outside **the cell membrane**.

Characteristic	Prokaryotic cell	Eukaryotic cell
Size of cell	Typically 0.2-2.0 μm in diameter	Typically 10-100 μm in diameter
Example	Bacteria and Archaea	Animals and Plants
Nucleus	Absent	Present
Membrane-enclosed organelles	Absent	Present: Examples include lysosomes, Golgi complex, endoplasmic reticulum, mitochondria and chloroplasts.
Flagella	Consist of two protein building blocks	Complex: consist of multiple microtubules
Cell wall	Usually present: chemically complex	Only in plant cells and fungi (chemically simpler)
Plasma membrane with steroid	Usually no	Yes

Cytoplasm	No cytoskeleton or cytoplasmic streaming	Cytoskeleton: cytoplasmic streaming
Ribosomes	Smaller	Larger
Cell division	Binary Fission	Mitosis
Number of chromosomes	One, but not true, chromosome	More than one
Sexual reproduction	No meiosis: transfer of DNA fragments only (conjugation)	Involves meiosis

Table: Difference between Prokaryotic and Eukaryotic Cells

Plant Cell	Animal Cell
Usually, they are larger than animal cells	Usually, smaller than plant cells
Cell wall present in addition to plasma membrane and consists of middle lamella, primary and secondary walls	Cell wall absent
Plasmodesmata present	Plasmodesmata absent
Chloroplast present	Chloroplast absent
Vacuole large and permanent	Vacuole small and temporary
Tonoplast present around vacuole	Tonoplast absent
Centrioles absent except motile cells of lower plants	Centrioles present
Nucleus present along the periphery of the cell	Nucleus at the centre of the cell
Lysosomes are rare	Lysosomes present
Storage material starch grains	Storage material a glycogen granule

Table: Difference between Plant and Animal Cells

Deviation from Basic Cell Types

- **Virus(means poisonous fluid):** These are obligate parasites inert outside their specific host cell.
- **Virions:** The main difference between a virus and a virion is that **a virus is the nucleoprotein particle**, whereas **a virion is the active, infectious form of the virus.**
- **Viroids:** These are **infectious agents that consist only of naked RNA without any protective layer**, such as a protein coat.
  - These **infect plants** (**but no other forms of life**) and **are replicated at the expense of the host cell**.
  - Viroid genomes **are small single-stranded circles of RNA that are only 250–400 bases long**.
- **Lichens:** Lichens are **symbiotic associations** (**mutually useful associations**) between algae and fungi.
  - The **algal component is known as phycobiont**, and **the fungal component is mycobiont**, which are **autotrophic** and **heterotrophic**, **respectively**.
  - Algae prepare **food for fungi**, and **fungi provide shelter** and **absorb mineral nutrients** and **water for their partners**.
  - Lichens are very **good pollution indicators- they do not grow in polluted areas**.

Positive-sense single-stranded RNA virus	Negative-sense single-stranded RNA virus
• In the host cell, the positive-sense RNA of these viruses is directly translated into viral proteins. • Their RNA is 5' to 3', the same as the host mRNA. • Since the host ribosome moves from 5' to 3' for translation, the positive-sense single-stranded RNA is directly used for protein synthesis.	• These viruses contain negative-sense RNA as genetic material • Their RNA is not readable by the host ribosome. • First, the negative-sense RNA (3' to 5') is converted into positive-sense RNA (5' to 3') by virus RNA-dependent RNA polymerase. • The positive-sense RNA then functions as mRNA and is translated into protein by the ribosome.

Table: Difference between Positive-sense single-stranded and Negative-sense single-stranded RNA viruses

CLASSIFICATION OF ORGANISMS

Aristotle was **the earliest to attempt a scientific classification**, using simple **morphological characteristics to classify plants** into **trees**, **shrubs** and **herbs**. He also divided animals into two groups, those which had **red blood** and **those that did not**.

- **Taxonomy** is **the branch of science concerned with classification, especially of organisms**.

Taxonomic Category

There are **seven main taxonomic ranks**: **kingdom**, **phylum** or **division**, **class**, **order**, **family**, **genus**, and **species**.

- **Kingdom:** The kingdom is the highest level of classification, with subcategories at other levels.
- **Phylum:** Phylum is the classification of living organisms to find some kind of physical similarities among organisms within the Kingdom. E.g., Phylum Arthropoda Under Kingdom Animalia.
- **Class:** A class is a rank used in the biological taxonomy of all organisms and is split into orders.
- **Order:** It is a group of organisms above the taxa family, sharing a similar set of characters. E.g., order primates contains humans and other apes.
- **Family:** It is a taxonomic group containing one or more genera sharing a common set of characteristics.
- **Genus:** Condensed group of related species having similar characters in common.
- **Species:** Its basic unit of classification. For example: **Homo Sapiens**.

Five Kingdom Classification

R.H. Whittaker proposed a Five Kingdom Classification in 1969. The kingdoms classified by him were named **Monera**, **Protista**, **Fungi**, **Plantae** and **Animalia**.

Kingdom Monera

- Bacteria are the **sole members of the Kingdom Monera.**
- Some of the **bacteria are autotrophic**, i.e., they synthesise their own food from inorganic substrates.
- They may be **photosynthetic autotrophic** or **chemosynthetic autotrophic**.
- The vast majority of bacteria are **heterotrophs**, i.e. **they depend on other organisms or on dead organic matter for food**. E.g., **Methanogens** present in the gut of several ruminant animals, such as cows and buffaloes, and responsible for the production of **methane** (**biogas**) from the dung of these animals.
- The **Mycoplasma** are **organisms that completely lack a cell wall**. They are the **smallest living cells known and can survive without oxygen**. Many **mycoplasma induce diseases in animals and plants**.

Kingdom Protista

- All **single-celled eukaryotes are placed under Protista**.
- Members of **Protista are primarily aquatic**.
- The **protist cell body contains a well-defined nucleus and other membrane-bound organelles.**

Algae

- These **are members of a group of predominantly aquatic photosynthetic organisms of the kingdom Protista.**
- Algae **have many types of life cycles**, and **they range in size from microscopic Micromonas species to giant kelps that reach 60 metres (200 feet) in length**.
- Their **photosynthetic pigments are more varied than those of plants**, and **their cells have features not found among plants and animals.**
- At least **half of the total carbon dioxide fixation on earth is carried out by algae through photosynthesis.**
- In addition **to their ecological roles as oxygen producers** and **as the food base for almost all aquatic life,** algae are economically important **as a source of crude oil** and **as sources of food** and **a number of pharmaceutical** and **industrial products** for humans.

- The taxonomy of **algae is contentious** and **subject to rapid change as new molecular information is discovered.**
- The **study of algae is called phycology**, and **a person who studies algae is a phycologist**.

Kingdom Fungi

- Fungi are **multicellular**, **with a cell wall** (**made up of Chitin**), organelles **including a nucleus**, but no chloroplasts.
- They have **no mechanisms for locomotion**.
- **Mushroom** Belongs to this Phylum. They are **saprophytic**, **decomposers**, **parasitic** or **coprophilous** (**growing on dung**). **[UPSC 2023]**

- **Mucormycosis** (also called **zygomycosis**) is a serious but rare fungal infection caused by a group of moulds called **mucormycetes**. People **get mucormycosis by coming in contact with the fungal spores in the environment.** It is also termed as black fungus due to the **necrosis of affected tissue of the patient's skin which turns it into black.**
- Mycorrhizal fungi play a crucial role in **plant nutrient uptake**, **water relations**, **ecosystem establishment**, **plant diversity**, **and productivity of plants. They also protect plants against root pathogens and toxic stresses.** The fundamental importance of **mycorrhizal biotechnology in the restoration and to improve revegetation of disturbed mined lands is well recognised. [UPSC 2013]**

Kingdom Plantae

- It includes **all eukaryotic chlorophyll-containing organisms commonly called plants.**
- A few members **are partially heterotrophic such as the insectivorous plants** or **parasites**.
- **Bladderwort** and **Venus fly trap** are examples of **insectivorous plants** and **Cuscuta is a parasite**.
- The plant cells have an **eukaryotic structure with prominent chloroplasts** and **cell walls mainly made of cellulose.**

Kingdom Animalia

- This kingdom is characterised by **heterotrophic eukaryotic organisms that are multicellular**, and **their cells lack cell walls.**
- They **directly** or **indirectly depend on plants for food**.
- Their mode of **nutrition is holozoic- by ingestion of food**.
- Higher forms **show elaborate sensory** and **neuromotor mechanisms**.
- Most of them **are capable of locomotion**.

Characteristic	Monera	Protista	Fungi	Plantae	Animalia
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell wall	Noncellulosic (Polysaccharide + amino acid)	Present in some	Present (without cellulose)	Present (cellulose)	Absent
Nuclear membrane	Absent	Present	Present	Present	Present
Body organisation	Cellular	Cellular	Multiceullar/ loose tissue	Tissue/ organ	Tissue /organ/ organ system
Mode of nutrition	Autotrophic (chemosynthetic and photosynthetic) and Heterotrophic (saprophytic/ parasitic)	Autotrophic (Photosynthetic) and Heterotrophic	Heterotrophic (Saprophytic/ Parasitic)	Autotrophic (Photosynthetic)	Heterotrophic (Holozoic/ Saprophytic etc.)

Table: Characteristics of the Five Kingdoms

Classification of Plants

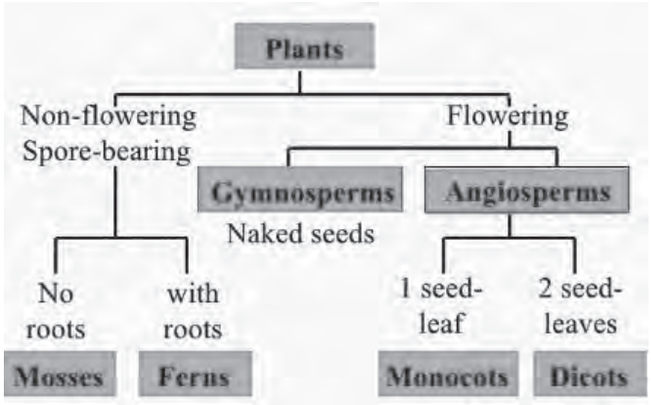

Fig: Classification of Plant Kingdom

Bryophytes

- Bryophytes include the **various mosses** and **liverworts that are found commonly growing in moist, shaded areas in the hills**.
- Bryophytes are **also called amphibians of the plant kingdom because these plants can live in soil but are dependent on water for sexual reproduction**.
- They lack **true roots, stems or leaves** (**may possess root-like, leaf-like or stem-like structures**).
- Bryophytes, in general, are of little economic importance, but **some mosses provide food for herbaceous mammals, birds and other animals**.
- Species of **Sphagnum**, **a moss**, **provide peat that has long been used as fuel** and **as packing material for transhipment of living material because of their capacity to hold water**.

Pteridophytes

- Pteridophytes are used for **medicinal purposes** and **as soil- binders**.
- They are **also frequently grown as ornamentals**.
- Evolutionarily, **they are the first terrestrial plants to possess vascular tissues- xylem** and **phloem**.

Gymnosperms

- The gymnosperms (**gymnos**: **naked**, **sperma**: **seeds**) are **plants in which the ovules are not enclosed by any ovary wall and remain exposed, both before and after fertilisation**.
- The seeds **that develop post-fertilisation are not covered**, i.e., **are naked**.
- Gymnosperms **include medium-sized trees** or **tall trees** and **shrubs.**
- Roots **in some genera have a fungal association** in the form of **mycorrhiza** (**Pinus**), while in some others (**Cycas**), **small specialised roots** called **coralloid roots** are associated with N_2 **fixing cyanobacteria.**

Angiosperms

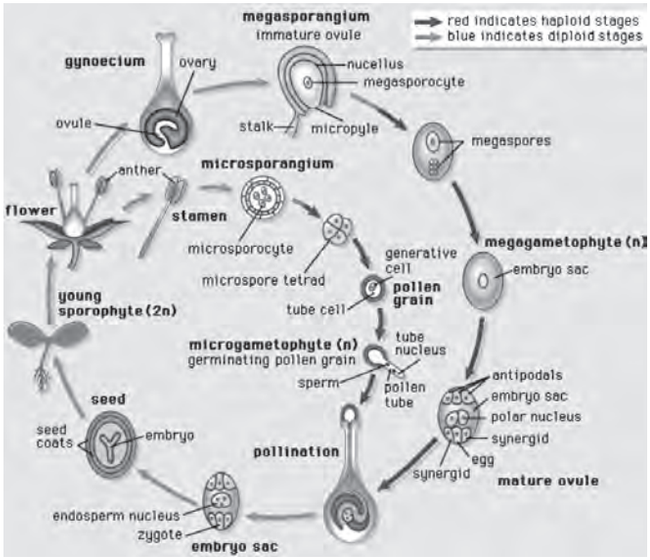

Fig: Life cycle of an Angiosperm.

- They are **also called Flowering plants**.
- The **pollen grains** and **ovules are developed in specialised structures called flowers**.
- The **male sex organ in a flower is the stamen.**
- Each **stamen consists of a slender filament with anther at the tip.**
- The **female sex organ in a flower is the pistil**. Pistil **consists of a swollen ovary at its base**, a long **slender style** and a **stigma**.
- In **angiosperms**, the **seeds are enclosed in fruits**. The angiosperms **are an exceptionally large group of plants occurring in a wide range of habitats**.

Classification of Animals

Phylum- Porifera

- Members **of this phylum are commonly known as sponges**. They **are generally marine** and **mostly asymmetrical animals**.
- They **range in size from a few millimetres** to a **few meters**.
- **Sponges are filter feeders:** They filter out food particles suspended in the surrounding water as they draw it through their body.
- Sponges **have a water transport or canal system**.
- Sponges **lack tissues**.
- The body **is supported by a skeleton made up of spicules or spongin fibres**.
- Sexes are not **separate** (**hermaphrodite**), i.e., **eggs** and **sperm are produced by the same individual**.

Phylum- Coelenterata (Cnidaria)

- They are **aquatic**, **mostly marine**, **sessile** or **free-swimming**.

- The name **cnidaria** is **derived from the cnidoblasts** or **cnidocytes**.
- Cnidoblasts are used for **anchorage**, **defence** and for **the capture of prey**.
- Cnidarians exhibit **tissue level of organisation** and **are diploblastic.**
- Example: **All coral reefs**, **Physalia** (**Portuguese man-of-war**), **Adamsia** (**Sea anemone**).

Phylum- Platyhelminthes

- These are **commonly known as Flatworms**.
- These are **mostly endoparasites found in animals**, **including human beings**.
- Flatworms are **bilaterally symmetrical**, **triploblastic** and **acoelomate animals** with **organ level of organisation.**
- Specialised cells **called flame cells help in osmoregulation** and **excretion**.
- Some members, like **Planaria**, **possess high regeneration capacity**.
- Example: **Taenia** (**Tapeworm**), **Fasciola** (**Liver fluke**).

Phylum- Aschelminthes

- **Phylum- Aschelminthes** commonly called **Roundworms**.
- They may be **free living**, **aquatic** and **terrestrial** or **parasitic in plants** and **animals**.
- Roundworms **have an organ-system level of body organisation**.
- **Males** and **females are distinct**. **Often females are longer than males**.
- Example: **Ascaris** (**Roundworm**), **Wuchereria** (**Filarial worm**), **Ancylostoma** (**Hookworm**).

Phylum- Annelida

- They may be **aquatic** (**marine and freshwater**) or **terrestrial**, **free-living**, and **sometimes parasitic**.
- Their body surface **is distinctly marked out into segments** or **metameres** and, hence, **the phylum name Annelida.**
- Their **excretory** and **osmoregulatory organ** is **called Nephridia**.
- **Pheretima** (**Earthworm**) and **Hirudinaria** (**Bloodsucking leech**).

Phylum- Arthropoda

This is the **largest phylum of Kingdom Animalia**, which **includes insects**. Over two-thirds of all named species on Earth are arthropods.

- The body of **arthropods is covered by a chitinous exoskeleton**.
- Respiratory organs are **gills**, **book gills**, **book lungs** or **tracheal system**.
- The **circulatory system is of open type**.
- Sensory organs like **antennae**, **eyes** (**compound and simple**), **statocysts** or **balancing organs are present**.
- Excretion takes place through **malpighian tubules**.
- Examples: **Economically important insects- Apis** (**Honey bee**), **Bombyx** (**Silkworm**), **Laccifer** (**Lac insect**), **Vectors- Anopheles**, **Culex** and **Aedes** (**Mosquitoes**), **Gregarious pest- Locusta** (**Locust**), **Living fossil- Limulus** (**King crab**).

Phylum- Mollusca

- This is the **second largest animal phylum.**
- Molluscs are **terrestrial** or **aquatic** (**marine or freshwater**), having **an organ-system level** of organisation.
- Body is covered by a **calcareous shell** and is **unsegmented with a distinct head**, **muscular foot** and **visceral hump**.
- Example: **Pila** (**Apple snail**), **Pinctada** (**Pearl oyster**), **Sepia** (**Cuttlefish**).

Phylum- Echinodermata

- These animals have an endoskeleton of **calcareous ossicles** and, hence, **the name Echinodermata**.
- All **are marine** with an **organ-system level of organisation**.
- The most **distinctive feature of echinoderms is the presence of a water vascular system** which helps in **locomotion**, **capture** and **transport of food** and **respiration**.
- An **excretory system is absent**.
- Example: **Asterias** (**Starfish**), **Echinus** (**Sea urchin**), **Cucumaria** (**Sea cucumber**).

Phylum- Chordata

- Animals belonging to the **phylum Chordata** are **fundamentally characterised by the presence of a notochord**, **a dorsal hollow nerve cord** and **paired pharyngeal gill slits**.
- Phylum Chordata is divided into three subphyla: **Urochordata** or **Tunicata**, **Cephalo-chordata** and **Vertebrata**.

Chordates	Non-chordates
Notochord present	Notochord absent.
The central nervous system is dorsal. hollow and single.	The central nervous system is ventral. solid and double.
Pharynx perforated by gill sits.	Gill slits are absent.
The heart is ventral.	The heart is dorsal (if present).
A post-anal (tail) is present	Post-anal tail is absent.

Table: Comparison of chordates and non-chordates

Sub-Phylum Vertebrata

Possess **notochord during the embryonic period,** which **is replaced by a cartilaginous** or **bony**

vertebral column in adulthood. The **vertebrates are also characterised by a muscular system consisting primarily of bilaterally paired masses** and **a central nervous system partly enclosed within the backbone**.

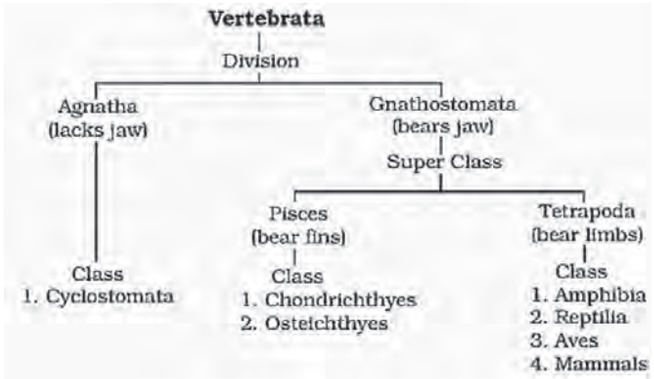

Fig: Classification of Vertebrates.

Class- Cyclostomata

- Members of the class Cyclostomata **are known to be ectoparasites on some fishes**.
- Cyclostomes **have a sucking** and **circular mouth without jaws**.
- Their **body is devoid of scales** and **paired fins**.
- **Cranium** and **vertebral columns are cartilaginous**.
- Example: **Petromyzon** (**Lamprey**) and **Myxine** (**Hagfish**).

Class- Chondrichthyes

- They are **marine animals with streamlined bodies** and **have cartilaginous endoskeleton**.
- Notochord **is persistent throughout life**.
- The **skin is tough, containing minute placoid scales**.
- **Heart is two-chambered** (**one auricle and one ventricle**).
- Example: **Scoliodon** (**Dogfish**), **Pristis** (**Sawfish**).

Class- Osteichthyes

- It includes **both marine** and **freshwater fishes with bony endoskeleton**.
- **Heart is two-chambered** (**one auricle and one ventricle**).
- They are **cold-blooded animals.**
- Example:
  - **Marine- Exocoetus** (**Flying fish**), **Hippocampus** (**Sea horse**).
  - **Freshwater- Labeo** (**Rohu**), **Catla** (**Katla**).

Class- Amphibia

- Amphibians **can live in aquatic** as well as **terrestrial habitats**.
- Most of **them have two pairs of limbs**.
- The body is divisible into the **head** and **trunk**.
- The **eyes have eyelids.**
- **Respiration is by gills, lungs and through the skin**.
- The heart is **three-chambered** (**two auricles** and **one ventricle**).
- These are **cold-blooded animals.**
- Example: **Bufo** (**Toad**), **Rana** (**Frog**), **Hyla** (**Tree frog**)

Class- Reptilia

- The class name refers to their **creeping or crawling mode of locomotion** (Latin- **repere or reptum**- to **creep or crawl**).
- They **are mostly terrestrial animals,** and t**heir body is covered by dry** and **cornified skin**, **epidermal scales** or **scutes**.
- They **do not have external ear openings**.
- The **tympanum represents the ear**.
- Heart is usually **three-chambered** but **four-chambered in crocodiles**.
  - Example: **Chelone** (**Turtle**), **Testudo** (**Tortoise**), **Chameleon** (**Tree lizard**).
  - Poisonous snakes- **Naja** (**Cobra**), **Bungarus** (**Krait**).

Class- Aves

- The characteristic features of Aves (birds) **are the presence of feathers** and **most of them can fly** except **flightless birds** (**e.g., Ostrich**).
- They possess beaks.
- The **forelimbs are modified into wings**.
- The hind limbs generally have scales and are modified for walking, swimming or clasping the tree branches.
- Skin is **dry without glands except the oil gland at the base of the tail**.
- Endoskeleton is **fully ossified (bony)**, and the **long bones are hollow with air cavities** (**pneumatic**).
- Heart is **completely four-chambered**.
- They are **warm-blooded** (**homeothermic**) animals, i.e., **they are able to maintain a constant body temperature.**
- Example: **Corvus** (**Crow**), **Columba** (**Pigeon**), **Psittacula** (**Parakeet**), **Struthio** (**Ostrich**)

Class- Mammalia

- They are found in a variety of habitats – polar ice caps, deserts, mountains, forests, grasslands and dark caves.
- Some of them have adapted to fly or live in water.
- The most unique mammalian characteristic is the **presence of milk-producing glands** (**mammary glands**) by which the young ones are nourished.
- **External ears or pinnae are present**. Different types of teeth are present in the jaw.
- **Heart is four-chambered**.
- Example: **Oviparous-Ornithorhynchus** (**Platypus**); **Viviparous- Macropus** (**Kangaroo**), **Pteropus** (**Flying fox Balaenoptera** (**Blue whale**), **Panthera tigris** (**Tiger**), **Panthera leo** (**Lion**).

Biorock Technology: Biorock is the name given to the substance formed **by the electro-accumulation of minerals dissolved in seawater on steel structures that are lowered onto the sea bed** and **are connected to a power source**, **e.g., solar panels that float on the surface**. It has been used for **coral restoration. [UPSC 2022]**

EMERGING TECHNOLOGIES IN BIOLOGY

- **Neuroinformatics:** It **seeks to create and maintain web-accessible databases of experimental and computational data, together with innovative software tools, essential for understanding the nervous system in its normal function and in neurological disorders.** Neuroinformatics includes **traditional bioinformatics of gene** and **protein sequences in the brain**; **atlases of brain anatomy** and **localisation of genes and proteins**; **imaging of brain cells**; **brain imaging by positron emission tomography (PET)**, **functional magnetic resonance imaging** (**fMRI**), **electroencephalography** (**EEG**), **magnetoencephalography** (**MEG**) and other methods.
- **Neuroprosthetics:** These **devices are designed to interact with the nervous system** and **restore function** to address **losses of motility**, **sensation**, **quality** and **ease of living due to injury or disease**. Neuroprosthetics is **a multidisciplinary field at the interface between neurosciences and biomedical engineering.** The first **commercially available cochlear implant** was developed in 1972; **it remains the most successful clinical neuroprosthesis**.
  - **Neuroprosthetic interfaces** can record from and/or **stimulate select areas of the nervous system**, traditionally via electrodes placed near the cells or tissues of interest.When localised to the **central nervous system** (**i.e., the brain and spinal cord**), such devices are referred to as **brain-machine interfaces** (**BMIs**) or **brain-computer interfaces** (**BCIs**).
  - **Bionic Eyes** are **visual prostheses that provide artificial vision to visually impaired people who could previously see.**
- **Microbial fuel cells:** These are **bioreactors** that convert the energy in the chemical bonds of organic compounds into electrical energy through **the catalytic activity of microorganisms under anaerobic conditions.**
  - **Microbial fuel cells (MFCs)** have shown **immense potential as a one-stop solution** for three major sustainability issues confronting the world today- **energy security, global warming** and **wastewater management.**

BIOTECHNOLOGY

The term biotechnology was used for the first time by Karl Erkey, a Hungarian Engineer, in 1919. It is the **application of the principles of engineering** and **biological science to create new products from raw materials of biological origin**, for example, **vaccines** or **food**. The two core fields that enabled the birth of modern biotechnology are:

- **Genetic engineering:** It includes techniques to alter the chemistry of genetic material (DNA and RNA) to introduce these into host organisms and thus change the phenotype of the host organism.
- **Bioprocess engineering**: Maintenance of sterile (**microbial contamination-free**) ambience in chemical engineering processes to enable growth of only the desired **microbe/eukaryotic cell in large quantities for the manufacture of biotechnological products like antibiotics, vaccines, enzymes,** etc.

Recombinant DNA Technology [UPSC 2013]

- **Recombinant DNA:** A DNA molecule made **in vitro with segments from different sources**.
- **Restriction Enzymes:** Restriction enzymes belong to **a larger class of enzymes called nucleases**.
  - These are of **two kinds**: **exonucleases** and **endonucleases**.
  - Exonucleases **remove nucleotides from the ends of the DNA**, whereas **endonucleases make cuts at specific positions within the DNA**.
  - **Restriction endonucleases** are **used in genetic engineering to form recombinant molecules of DNA**, which are composed of DNA from different sources/ genomes.
- **Separating DNA molecules**:
  - The fragments produced by restriction enzymes would not be of much use if we could not also easily separate them for analysis.
  - The most common separation technique **used is gel electrophoresis**.
  - This technique **takes advantage of the negative charge on DNA molecules by using an electrical field to provide the force necessary to separate DNA molecules based on size**.
  - The separated **DNA fragments can be visualised after staining the DNA with a compound known as ethidium bromide**, **followed by exposure to UV radiation**.
- **Cloning Vectors**: Vectors used at present, are **engineered in such a way that they help easy linking of foreign DNA** and **selection of recombinants from non-recombinants**.
- **Origin of replication:** This is a **sequence from where replication starts**, and **any piece of DNA when linked to this sequence, can be made to replicate within the host cells**.
- **Plasmid:** A plasmid is a small circular piece of **DNA found in bacterial cells** that is physically separated from chromosomal DNA and can replicate independently.
- **Selectable marker:** which **helps in identifying and eliminating non-transformants** and selectively permitting the growth of the transformants. **Transformation is a procedure through which a piece of DNA is introduced in a host bacterium.**
- **Cloning sites:** In order to link the alien DNA, the vector needs to have very few, preferably single, recognition sites for the commonly used restriction enzymes.
- **Methods of Insertion of DNA in Host Cells:**
  - **Micro-injection:** recombinant DNA is directly injected into the nucleus of an animal cell.
  - **Biolistic or gene gun**: In this process, particles of heavy metals are coated with a gene of interest. Cells are then **bombarded with high-velocity micro-particles of gold or tungsten coated with DNA** in a method known as biolistics or gene gun. **This method is suitable for plants.**
- **Cutting of DNA at Specific Locations**: Restriction enzyme digestions are performed by incubating purified DNA molecules with the restriction enzyme.
- **Amplification of Gene of Interest using PCR:** PCR stands for **Polymerase Chain Reaction**. It is a laboratory method used to make many **copies of a specific piece of DNA from a sample that contains very tiny amounts of that DNA**.
- **Obtaining the Foreign Gene Product:** The Transformed cells produce products of genes of interest which are isolated for further uses.

GENOME EDITING

Genome editing, also known as genome engineering or gene editing, is a sort of genetic engineering that involves inserting, deleting, modifying, or replacing DNA in a living organism's genome.

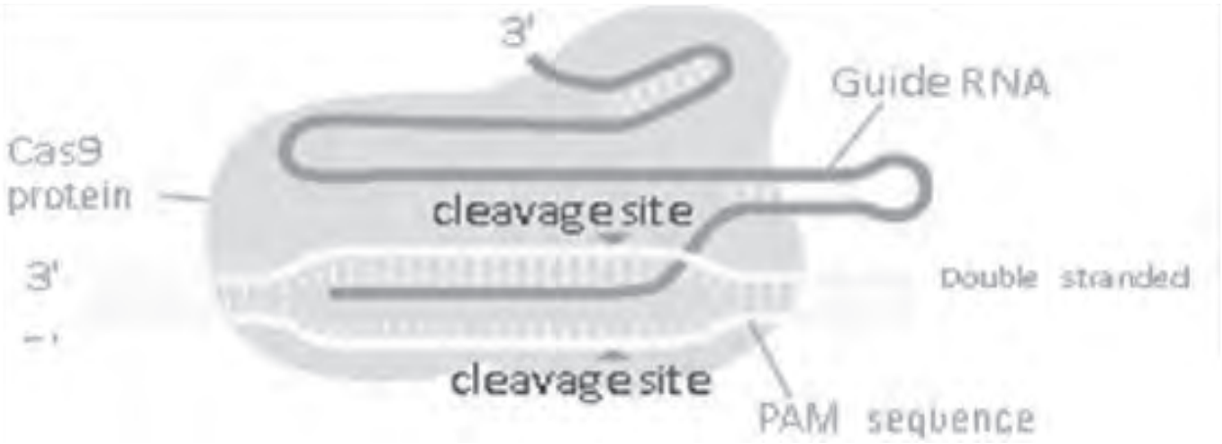

Fig: Genome editing

Genome Editing Techniques [UPSC 2020]

- **Clustered regularly interspaced short palindromic repeats (CRISPR)- CRISPR- associated protein 9 (Cas9)**: CRISPR is the DNA-targeting component of the system, and it is made up of an RNA molecule, or guide, that is engineered to attach to certain DNA bases via complementary base-pairing.
  - CRISPR-associated protein 9 (Cas9) is the nuclease component that cuts the DNA.
  - The CRISPR-Cas9 genetic scissors were discovered by Emmanuelle Charpentier and Jennifer A. Doudna, who won the Nobel Prize in Chemistry in 2020. **[UPSC 2019]**
- **Transcription activator-like effector nucleases (TALENs)**: Transcription activator-like effector (TALE) domains make up the DNA-binding domain of TALENs.
- **Zinc-finger nucleases (ZFNs):** ZFNs are fusions between a custom-designed Cys2-His2 zinc-finger protein and the cleavage domain of the FokI restriction endonuclease. FokI cleavage domain, which cuts DNA within a five- to seven-bp spacer sequence that separates two flanking zinc-finger binding sites.
- **Homing endonucleases or mega-nucleases:** Homing endonucleases, also known as mega-nucleases.
  - These enzymes make extensive sequence-specific contacts with their DNA substrate.
  - However, unlike ZFNs and TALENs, the binding and cleavage domains in homing endonucleases are not modular.
  - This overlap in form and function makes their repurposing challenging and limits their utility for more routine applications of genome editing.

Significance of Genome Editing

- These techniques affect different areas such as disease management, basic biomedical research, agriculture and environmental sciences.
- They could also be used to customise human characteristics for extra-therapeutic enhancement purposes.

Human Genome Project [UPSC 2011]

- In the 1980s, scientists began discussing the possibility of sequencing all 3.2 billion nucleotide pairs in the human genome.
- These discussions led to the launch of the Human Genome Project in 1990. The initial goals of the Human Genome Project were:
  - To map all the human genes,
  - To construct a detailed physical map of the entire human genome, and
  - To determine the nucleotide sequence of all 24 human chromosomes by the year 2005.

General Features of the Human Genome

- The entire human genome contains about 3.2 billion base pairs of DNA.
- The base-pair composition of the DNA varies across regions of the human genome.
- On average, about 41 per cent of the DNA consists of G: C base pairs. However, some regions are G: C rich, and others are G: C poor.
- The Human Genome Project, which operated from 1990 to 2003, provided researchers with basic information about the genetic content of the human organism, opening new avenues of discovery in fields such as cancer research.

Genome India Project

- Taking inspiration from the Human Genome Project, the **Department of Biotechnology (DBT)** initiated the ambitious Genome India Project (GIP) on 3rd January 2020.
- The GIP aims to collect 10,000 genetic samples from citizens across India, to build a reference genome.
- Whole-genome sequencing and subsequent data analysis of the genetic data of these 10,000 individuals would be carried out.
- This would aid our understanding of the nature of diseases affecting the Indian population and then ultimately support the development of predictive diagnostic markers.
- It would also open new vistas for advancing next-generation personalised medicine in the country, paving the way for predicting health and disease outcomes.
- The initiative would also support the development of targeted preventive care, as it has the potential to help identify those population groups which are more susceptible to various risk factors for certain diseases.
- For instance, if a region shows a tendency towards a specific disease, customised interventions can be made in the region, accordingly, leading to more effective treatment overall.
- This project is led by the Centre for Brain Research at Bengaluru-based Indian Institute of Science, which acts as the central coordinator between a collaboration of 20 leading institutions, each collecting samples and conducting its own research.
- This initiative reflects India's progress in gene therapies and precision medicine and its movement towards emerging next-generation medicine which yields the possibilities for greater customisation, safety, and earlier detection.
- This initiative would help lay the foundation of personalised healthcare for a very large group of persons on the planet.

Human Microbiome Initiative of Select Endogamous Population of India

- Health and disease outcomes are determined by interactions between the genome and the environment. An important component of the environment in the context of human health is the human microbiota.
- The Human Microbiome Initiative of select endogamous populations of India aims at comprehensive characterisation of human-associated microbes in carefully selected endogamous population groups with diverse dietary habits including key tribal populations which are not much influenced by modern lifestyle.
- The study is investigating the influence of diet, lifestyle, geography and age on gut microbiome using targeted metagenomic and whole metagenomic approaches. The study would also attempt to find the association between microbial enterotypes and three distinct Ayurvedic Prakriti types.
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Earth Bio-Genome Project

- The Earth Bio-Genome Project is a project aiming at analysing and sequencing genomes and building a new basis for biology to drive solutions for biodiversity preservation and human society sustainability.
- The Earth Bio-Genome Project (EBP) is a worldwide group of scientists who plan to sequence, classify, and characterise the genomes of all eukaryotic biodiversity on Earth over the course of ten years.
  - It's a global catalogue of life on the planet.
  - In three phases, it hopes to sequence 1.5 million species.
- The EBP project will assist in the creation of a precise genetic sequence as well as the discovery of evolutionary relationships between the species, orders, and families that will make up the Digital Library of Life. **[UPSC 2017]**

- **Transcriptome** refers to the protein-coding part of an organism's genome. It **refers to the set of RNA molecules such as messenger RNA (mRNA), transfer RNA (tRNA), ribosomal RNA (rRNA), and other noncoding RNA molecules** that are present in cells. **[UPSC 2016]**
- **Aerial metagenomics** typically refers to **the study of genetic material (such as DNA or RNA) collected from the air, usually in the form of airborne particles or aerosols. [UPSC 2023]**

Somatic Cell Nuclear Transfer

- Somatic cell nuclear transfer (SCNT), technique in which the nucleus of a somatic (body) cell is transferred to the cytoplasm of an enucleated egg (an egg that has had its own nucleus removed). Once inside the egg, the somatic nucleus is reprogrammed by egg cytoplasmic factors to become a zygote (fertilized egg) nucleus.
- The egg is allowed to develop to the blastocyst stage, at which point a culture of embryonic stem cells (ESCs) can be created from the inner cell mass of the blastocyst. **[UPSC 2017]**

Cloning of Dolly Sheep

- Dolly was cloned from a cell taken from the mammary gland of a six-year-old Finn Dorset sheep and an egg cell taken from a Scottish Blackface sheep.
- She was born to her Scottish Blackface surrogate mother on 5th July 1996.
- Dolly's white face was one of the first signs that she was a clone because if she was genetically related to her surrogate mother, she would have had a black face.

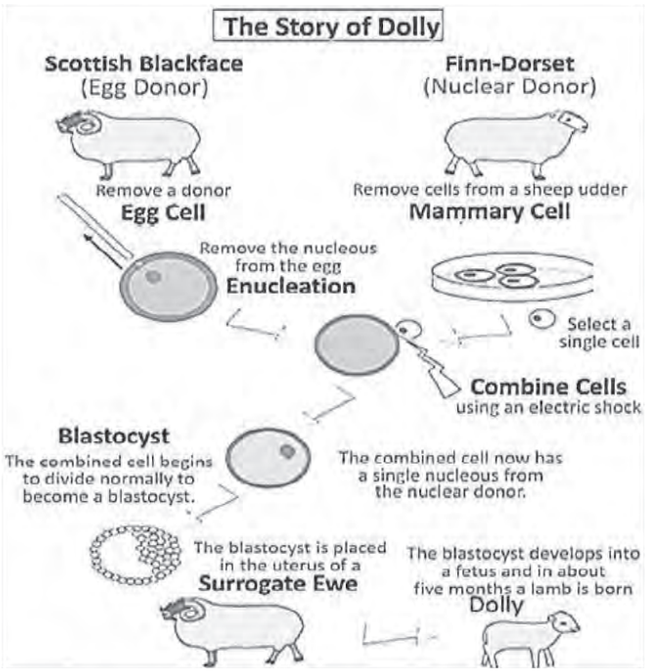


Fig: Cloning Of Dolly Sheep

3-Parent Baby [UPSC 2021]

- Techniques to create 'three-parent babies' seek to offer mothers a way to have a child without passing on metabolic diseases caused by faulty mitochondria.
- Researchers do this by exchanging the diseased mitochondria of a prospective mother with those of a healthy, unrelated donor: the third parent.
- In addition to DNA in the nucleus, some DNA is also present in the mitochondria.
- During fertilisation, the nuclear DNA is formed with 46 chromosomes (i.e., 23 from the mother & 23 chromosomes from the father).
- The Mitochondrial DNA has only one chromosome, and it codes for only specific proteins responsible for metabolism.
- Mitochondrial DNA is inherited only from the mother & thus, it is more effective to trace human ancestry.

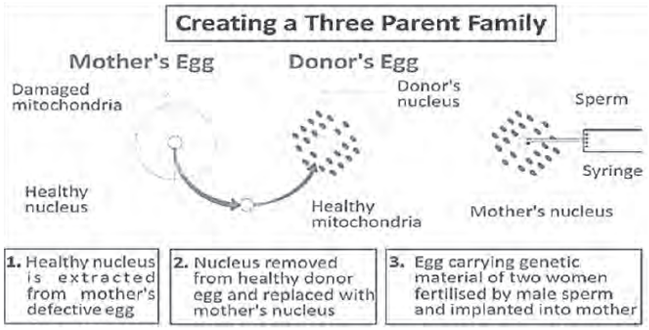


Fig: 3-Parent Baby

Stem Cell Therapy [UPSC 2012]

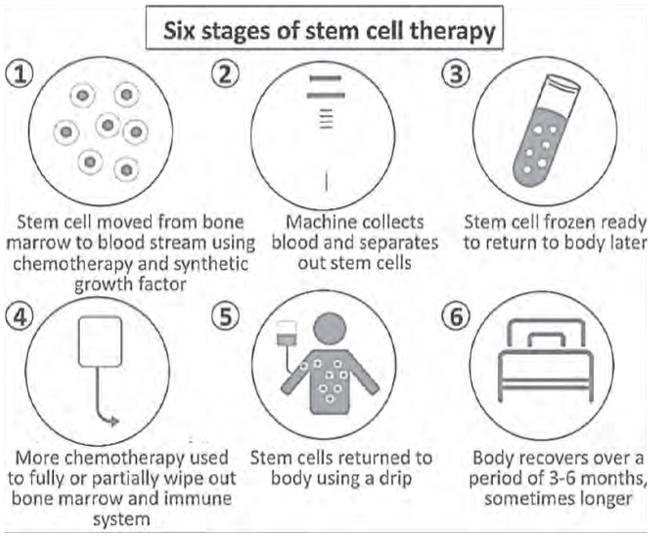


Fig: Stages of Stem Cell Therapy

For purposes of tissue engineering and cell therapies, stem cells are usually obtained from four basic sources.

The Main Sources are:

- Embryonic tissue,
- Fetal tissues, such as fetus, placenta (i.e., amnion and chorion), amniotic fluid and umbilical cord (wharton jelly, blood),
- Specific locations in the adult organism, Example: Fat, bone marrow, skeletal muscle, skin or blood.
- Differentiated somatic cells after they have been genetically reprogrammed.

Hierarchy of Cell Potency [UPSC 2020]

- **Totipotent Stem Cells** can give rise to any of 220 cell types found in embryos as well as extraembryonic cells(placenta).
- **Pluripotent Stem Cells** can give rise to all cell types of the body (but not the placenta).
- **Multipotent Stem Cells** can develop a limited number of cell types in a particular lineage.
- **Unipotent Stem Cells** give rise to cells of their own type along a single lineage.

Characteristics of Stem Cells

- **Totipotency**: generates all types of cells, including germ cells.
- **Pluripotency**: generate all types of cells except cells of the embryonic membrane.
- **Multipotency**: differentiate into more than one mature cell.
- **Self-renewal:** divide without differentiation and create everlasting supply.
- **Plasticity:** Multipotent stem cells have plasticity and can undergo differentiation. The trigger for plasticity is stress or tissue injury, which upregulates the stem cells and releases chemoattractants and growth factors.
- **Stem cell therapy,** also known as regenerative medicine, promotes the repair response of diseased, dysfunctional or injured tissue using stem cells or their derivatives.
- Researchers grow stem cells in a lab.
- These stem cells are manipulated to specialise into specific types of cells, such as heart muscle cells, blood cells or nerve cells.
- The specialised cells can then be implanted into a person.
    - For example, if the person has heart disease, the cells could be injected into the heart muscle. The healthy transplanted heart muscle cells could then contribute to repairing defective heart muscle.

Application of Biotechnology in Agriculture

Genetically Modified (GMO) Food Crops [UPSC 2012]

- **Genetically modified** (**GM**) foods are foods derived from organisms whose genetic material (DNA) has been modified in a way that does not occur naturally, e.g. through the introduction of a gene from a different organism.
- **GM crops** were first commercially introduced in 1996 all over the world. Their popularity has skyrocketed since then.
- **Corn**, **cotton**, and **soybeans** have been genetically modified to withstand insect pests and herbicides, and they are now widely cultivated in many regions of the world.
- The Government of India approved Bt cotton as the only genetically modified (GM) crop for commercial production in 2002.

Case of Bt Cotton

- **Bt toxin** is produced by a bacterium called **Bacillus thuringiensis** (**Bt**).
- **Bollgard technology** is about a genetic sequence from a microorganism called Bacillus thuringiensis (Bt). **[UPSC 2021]**
- The toxin gene has been cloned from the bacteria and been expressed in plants to provide resistance to insects without the need for insecticides.
- B. Thuringiensis forms protein crystals during a particular phase of their growth. These crystals contain a toxic insecticidal protein.
- The toxin is coded by a gene cryIAc named cry.
- There are a number of them, for example, the protein encoded by the genes cryIAc and cryIIAb control the cotton bollworms, that of cryIAb controls corn borer.

DMH-11

- The commercial release of the GM mustard Dhara Mustard Hybrid 11 (DMH 11) created by Delhi University is pending since the GEAC has urged that thorough safety assessment data on environmental biosafety, particularly effects on beneficial insect species, be generated first.
- It is a genetically modified hybrid variety of the mustard species Brassica juncea.
- The transgenic mustard DMH-11 was developed in 2002 using genetic material isolated from nonpathogenic soil bacteria.
- Three genes, Bar, Barnase and Barstar, were extracted from Bacillus amyloliquefaciens to produce the hybrid seed.
- DMH 11's Glufosinate resistance is due to an enzyme expressed by the Bar (Bialaphos resistance) gene.

Bt Brinjal [UPSC 2012]

- Bt Brinjal is a transgenic brinjal developed by introducing the cry1Ac gene from the Bacillus thuringiensis soil bacterium into Brinjal.
- This brinjal has been genetically modified to withstand insects like the Brinjal Fruit and Shoot Borer (Leucinodes orbonalis).
- Maharashtra Hybrid Seeds Company created Bt Brinjal (Mahyco).

Golden Rice

- Golden Rice is a new form of rice that contains beta-carotene (provitamin A), which the body converts to vitamin A as needed and gives the grain its golden colour.
- It's made possible by genetic engineering, and it produces two new enzymes that finish the beta-carotene expression in rice grains.

Terminator Seed Technology

- The genetic alteration of plants to make them produce sterile seeds is known as Terminator seed technology.
- Suicide seeds are another name for them.
- Genetic Use Restriction Technologies is Terminator's official name, as used by the UN and scientists (GURTs).

Regulations of GMs in India

- The **Environment Protection Act of 1986** notified the rules governing the management of genetically modified organisms (GMOs) and their products in 1989, with guidelines provided later.
- The **Genetic Engineering Appraisal Committee (GEAC)** functions in the Ministry of Environment, Forest and Climate Change (MoEF&CC). As per Rules, 1989, it is responsible for the appraisal of activities involving large-scale use of hazardous microorganisms and recombinants in research and industrial production from the environmental angle.
- The committee is also responsible for the appraisal of proposals relating to the release of genetically engineered (GE) organisms and products into the environment, including experimental field trials.
- There are **six authorities** in total to deal with various areas of the regulation:
  1. Recombinant DNA Advisory Committee,
  2. Institutional BioSafety Committee,
  3. Review Committee on Genetic Manipulation,
  4. Genetic Engineering Approval Committee (GEAC),
  5. State Biotechnology Coordination Committee, and
  6. The district-level Committee

Biofortification

- It is the process of improving the nutritional value of food crops by increasing the density of vitamins and minerals in the crop, which can be accomplished

by traditional plant breeding, agronomic methods, or biotechnology.

- These genetically changed and nutrition-added crops, dubbed biologically fortified or biofortified, vary from commercially available fortified foods in that additional nutrients are genetically entrenched rather than chemically supplied.
- Example: Iron-biofortification of rice, beans, sweet potato, cassava and legumes.

RNA Interference (RNAi)

- It's a gene-silencing technique that uses double-stranded RNA to prevent protein production in target cells.
- RNAi takes place in all eukaryotic organisms as a method of cellular defence.
- This method involves silencing of a specific mRNA due to a complementary Double-stranded RNA (dsRNA) molecule that binds to and prevents translation of the mRNA (silencing).
- This natural mechanism for sequence-specific gene silencing promises to revolutionize experimental biology and may have important practical applications in functional genomics, therapeutic intervention, agriculture and other areas. **[UPSC 2019]**

Production of Pest-resistant plants using RNAi

- Several nematodes parasitise a wide variety of plants and animals, including human beings.
- A nematode, Meloidogyne incognita, infects the roots of tobacco plants and causes a great reduction in yield.
- A novel strategy was adopted to prevent this infestation which was based on the process of RNA interference (RNAi).
- Using Agrobacterium vectors, nematode-specific genes were introduced into the host plant.
- The introduction of DNA was such that it produced both sense and antisense RNA in the host cells. These two RNA being complementary to each other, formed a double-stranded (dsRNA) that initiated RNAi and, thus, silenced the specific mRNA of the nematode.
- The consequence was that the parasite could not survive in a transgenic host expressing specific interfering RNA.

Application of Biotechnology in Medicine

Genetically Engineered Insulin

- Insulin used for diabetes was earlier extracted from pancreas of slaughtered cattle and pigs.
- Insulin from an animal source, though, caused some patients to develop allergy or other types of reactions to the foreign protein.
- In 1983, Eli Lilly, an American company prepared two DNA sequences corresponding to A and B, chains of human insulin and introduced them in plasmids of E. coli to produce insulin chains.
- Chains A and B were produced separately, extracted and combined by creating disulfide bonds to form human insulin.

Gene Therapy

- Gene therapy is a technique for treating genetic problems that includes replacing faulty genes with healthy ones.
- It is a way of introducing DNA into human cells that is done artificially.
- Gene therapy can be divided into two categories:

Gene Therapy in the Somatic cells	Gene Therapy in the Germline cells
• This type is most commonly seen in the somatic cells of the human body. • This is specific to a particular person, and the damaged cells will only be replaced with healthy cells in that person. • Therapeutic genes are introduced into the somatic cells of the human body using this procedure. • This approach of gene therapy is thought to be the best and safest.	• It happens in the human body's germline cells. • Generally, this approach is used to address disease-causing genetic abnormalities that are handed on from parents to their children. • The procedure entails inserting healthy DNA into the cells that produce reproductive cells, eggs, or sperm.

Application in Bio-energy

- Biofuels derived from biomass are renewable and sustainable energies with the potential to replace fossil fuels.
- Biotechnology can help to speed up the selection of varieties that are more suited to biofuel production with increased -
  - Biomass per hectare,
  - Increased content of oils (biodiesel crops) or
  - Fermentable sugars (ethanol crops), or
  - Improved processing characteristics that facilitate their conversion to biofuels.
- Utilization of microbial fuel cells is found to be useful for sustainable bioenergy synthesis via completing the wastewater treatment processes with electric energy synthesis.

Environmental Biotechnology

Environmental biotechnology, specifically, refers to the use of procedures to safeguard and restore theenvironment's quality.

Bioremediation	Bioremediation is the process of using microorganisms to remove or detoxify toxins from soils, water, or sediments that would otherwise be harmful to human health.
Phytoremediation	Phytoremediation is a bioremediation process that uses various types of plants to remove, transfer, stabilise, and/ or destroy contaminants in the soil and groundwater.
Phyto-degradation	In this process, plants actually metabolize and destroy contaminants within plant tissues.
Phyto-volatilization	In this process, plants take up water containing organic contaminants and release the contaminants into the air through their leaves.
Biosensors	A biosensor is an analytical device that converts a biological response into a physical, chemical or electrical signal.

- **DNA barcodes** consist of **a standardized short sequence of DNA** (**400-800 bp**) that in principle should be easily generated and characterized for all species on the planet. **A massive online digital library of barcodes will serve as a standard to which the DNA barcode sequence of an unidentified sample from the forest, garden, or market can be matched**.
- Applications of DNA barcoding **include the identification of new species**, **safety assessment of food**, **identification and assessment of cryptic species**, **detection of alien species**, **identification of endangered and threatened species** etc. **[UPSC 2022]**

Gene Silencing

- Gene silencing is the regulation of gene expression in a cell to prevent the expression of a certain gene.
- When genes are silenced, their expression is reduced. Ex: the researchers designed two small RNA molecules that silence the fungal genes which produce aflatoxin in Groundnut.
- When genes are knocked out, they are completely erased from the organism's genome and thus, have no expression.

Applications of Gene Silencing

- Specific gene silencing using RNAi in cell culture.
- Cancer treatments
- RNA interference has been used for applications in biotechnology.
- Useful in epigenomic analysis and clinical application of molecular diagnosis.
- Neuro-degenerative disorders treatment.

Colour Classification of Branches of Biotechnology

- **Gold biotechnology** or **Bioinformatics**: Computational Biology addresses biological problems using computational techniques.
- **Red Biotechnology**: Biopharma relates to medicine and veterinary products.
- **White Biotechnology**: Industrial Biotech to design more energy-efficient, low-resource consuming products.
- **Yellow Biotechnology**: Biotech in the Food Industry.
- **Grey Biotechnology**: Environmental applications to maintain Biodiversity
- **Green Biotechnology**: Emphasizes Agriculture interests.
- **Blue Biotechnology**: Based on the use of marine resources.
- **Violet Biotechnology**: Deals with law, ethical and philosophical issues of biotechnology.
- **Dark Biotechnology**: Associated with bioterrorism and biological weapons.

Government Initiative for Biotechnology

National Biotechnology Development Strategy

The Department of Biotechnology (DBT), Government of India, announced the First National

Biotechnology Development Strategy in September 2007.

In 2015, DBT announced The National Biotechnology Development Strategy-2015-2020 and later in

2020 for National Biotechnology Development Strategy 2021- 2025.

Key elements of Strategy-II are as follows

- Empower, scientifically and technologically, India's incomparable human resource;
- Create a strong infrastructure for research, development and commercialisation for a robust Bioeconomy;
- Establish India as a world-class bio-manufacturing hub for developing and developed markets.

BIRAC

- Biotechnology Industry Research Assistance Council (BIRAC) is a not-for-profit Section 8, Schedule B, Public Sector Enterprise, set up by the Department of Biotechnology (DBT).
- It is an Interface Agency to strengthen and empower the emerging Biotech enterprise to undertake strategic research and innovation, addressing nationally relevant product development needs.

Mendel's Laws

Mendel is known as the father of genetics. He worked on the pea plants and proposed the fundamental laws of inheritance. These are:

Law of Dominance: States that when two different genes controlling for the same character come together in an organism, only one is expressed, and this expressed gene is known as the dominant gene.

Law of Independent Assortment: Separate genes for separate traits are passed independently of one another from parents to offspring; genes do not influence each other with regard to the sorting of alleles into gametes.

Law of Segregation: states that a diploid organism passes a randomly selected allele for a trait to its offspring, such that the offspring receives one allele from each parent. According to the law of segregation, only one of the two gene copies present in an organism is distributed to each gamete (egg or sperm cell) that it makes, and the allocation of the gene copies is random. When an egg and a sperm join in fertilisation, they form a new organism whose genotype consists of the alleles contained in the gametes.

Chromosomal Basis of Inheritance

In 1900, three Scientists (de Vries, Correns and von Tschermak) independently rediscovered Mendel's results on the inheritance of characters.

- Chromosomes, as well as genes, occur in pairs.
- The two alleles of a gene pair are located on homologous sites on homologous chromosomes.
- Pairing and separation of a pair of chromosomes would lead to the segregation of a pair of factors they carried.

Molecular Basis of Inheritance

- DNA, or deoxyribonucleic acid, is the central information storage system of most animals and plants, and even some viruses.
- The name comes from its structure, which is a sugar and phosphate backbone which have bases sticking out from it—so-called bases.
  - It's a polymer of four bases - A, C, T, and G.
  - DNA is organised structurally into chromosomes and then wound around nucleosomes as part of those chromosomes.
  - The two chains have antiparallel polarity. It means if one chain has the polarity 5' to 3', the other has 3' to 5'.

In 1953 **James Watson** and **Francis Crick**, based on the X-ray diffraction data produced by Maurice Wilkins and Rosalind Franklin, proposed a very simple but famous **Double Helix model** for the structure of DNA. One of the hallmarks of their proposition was base pairing between the two strands of polynucleotide chains.

RNA

- Like DNA, each RNA strand has the same basic structure, composed of nitrogenous bases covalently bound to a sugar-phosphate backbone. However, unlike DNA, RNA is usually a single-stranded molecule.
- Also, the sugar in RNA is ribose instead of deoxyribose (ribose contains one more hydroxyl group on the second carbon), which accounts for the molecule's name.
- RNA consists of four nitrogenous bases: adenine, cytosine, uracil, and guanine.
- Uracil is a pyrimidine that is structurally similar to the thymine, another pyrimidine that is found in DNA. Like thymine, uracil can base-pair with adenine.

Why is DNA widely acceptable as a better Genetic material?

- The presence of free-OH at the 2nd position at every nucleotide in RNA is a reactive group and makes RNA labile and easily degradable.
- DNA chemically is less reactive and structurally more stable when compared to RNA. Therefore, among the two nucleic acids, DNA is a better genetic material.

Packaging of DNA

- Proteins called histones are responsible for the main level of DNA packing in chromatin.
- Histones are rich in the basic amino acid residues lysine and arginine. Both the amino acid residues carry positive charges in their side chains.
- Histones are organized to form a unit of eight molecules called histone octamer.

- The negatively charged DNA is wrapped around the positively charged histone octamer to form a structure called nucleosome.
- Nucleosomes constitute the repeating unit of a structure in the nucleus called chromatin.
- Chromatin further folds and forms the structure of the chromosomes.

RNA World Hypothesis

- According to this hypothesis, RNA stored both genetic information and catalysed the chemical reactions in primitive cells. Only later in evolutionary time did DNA take over as the genetic material and proteins became the major catalyst and structural component of cells.
- Trivia (Trivia is information and data that are considered to be of little value.)
- Artificial chromosomes are artificially created chromosomes having the properties of centromeres, telomeres, and origins of replication, and specified sequences required for their stable maintenance within the cell as autonomous, self-replicating chromosomes.

Flow of Genetic Information: From DNA to Proteins

Central Dogma states that the genetic information flows from DNA to RNA to Protein.

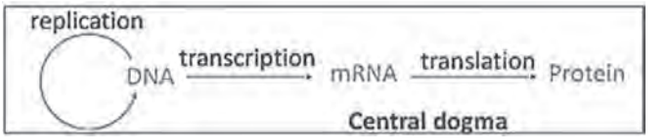


Fig: Flow of Genetic Information

- DNA Replication: DNA replication is the process by which DNA makes a copy of itself during cell division.
- Transcription: The process by which a cell makes an RNA copy of a piece of DNA. This RNA copy, called messenger RNA (mRNA), carries the genetic information needed to make proteins in a cell.
- Translation: The process by which a cell makes proteins using the genetic information carried in messenger RNA (mRNA). The mRNA is made by copying DNA, and the information it carries tells the cell how to link amino acids together to form proteins.

Genetic code

- The process of translation requires the transfer of genetic information from a polymer of nucleotides to synthesise a polymer of amino acids.
- This led to the proposition of a genetic code that could direct the sequence of amino acids during the synthesis of proteins.
- The genetic code is a set of rules defining how the four-letter code of DNA is translated into the 20-letter code of amino acids, which are the building blocks of proteins.
- The genetic code is a set of three-letter combinations of nucleotides called codons, each of which corresponds to a specific amino acid or stop signal.
  - For example: The RNA sequence UUU specifically coded for the amino acid phenylalanine.
  - 3 Codons in Humans are Stop Codon: UGA, UAA, and UAG.
- There are 64 possible permutations, or combinations, of three-letter nucleotide sequences that can be made from the four nucleotides.
- Of these 64 codons, 61 represent amino acids, and three are stop signals.

DNA Profiling or DNA Fingerprinting

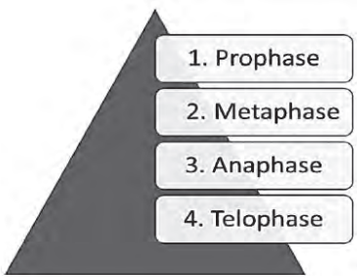
- DNA profiling is the process where a specific DNA pattern, called a profile, is obtained from a person or sample of bodily tissue.
- It is a forensic technique in criminal investigations, comparing criminal suspects' profiles to DNA evidence so as to assess the likelihood of their involvement in the crime.
- It is also used in parentage testing, to establish immigration eligibility, and in genealogical and medical research.
- **Microsatellite DNA**, as related to genomics, **refers to a short segment of DNA, usually one to six or more base pairs in length, that is repeated multiple times in succession at a particular genomic location.** These DNA sequences are typically non-coding. The number of repeated segments within a microsatellite sequence often varies among people, **which makes them useful as polymorphic markers for studying inheritance patterns in families** or **for creating a DNA fingerprint from crime scene samples. [UPSC 2023]**

Division of Cell or Cell Cycle

- The sequence of events by which a cell duplicates its genome, synthesises the other constituents of the cell and eventually divides into two daughter cells is termed the cell cycle.
- A cell spends most of its time in what is called interphase, and during this time, it grows, replicates its chromosomes, and prepares for cell division.

Phases of Cell Cycle:

- The cell cycle is divided into two basic phases:
  1. Interphase
  2. M Phase (Mitosis phase)
- The M phase involves the following four stages:



- The M Phase represents the phase when the actual cell division or mitosis occurs, and the interphase represents the phase between two successive M phases.

Interphase

- The interphase, though called the resting phase, is the time during which the cell is preparing for division by undergoing both cell growth and DNA replication in an orderly manner.
- The interphase is divided into three further phases:
  1. **G1 phase (Gap 1)**: G1 phase corresponds to the interval between mitosis and initiation of DNA replication. During the G1 phase, the cell is metabolically active and continuously grows but does not replicate its DNA.
  2. **S phase (Synthesis)**: S or synthesis phase marks the period during which DNA synthesis or replication takes place. During this time, the amount of DNA per cell doubles.
  3. **G2 phase (Gap 2):** It follows the successful completion of the S phase, during which the cell's DNA is replicated. The Cell "double checks" the duplicated chromosomes for error, making any needed repairs.

Inactive Stage

- Some cells in adult animals do not appear to exhibit division (e.g., heart cells) and many other cells divide only occasionally, as needed to replace cells that have been lost because of injury or cell death.
- These cells that do not divide further exit the G1 phase to enter an inactive stage called the quiescent stage (G0) of the cell cycle.
- Cells in this stage remain metabolically active but no longer proliferate unless called on to do so, depending on the requirement of the organism.

Genetic Disorders

- A genetic disorder is a disease that is caused by a change, or mutation, in an individual's DNA sequence.
- These mutations can be due to an error in DNA replication or due to environmental factors, such as cigarette smoke & exposure to radiation, which cause changes in the DNA sequence.
- The three main categories are:
  1. **Single Gene Disorders**: Disorders caused by defects in one particular gene, often with simple and predictable inheritance patterns. Example: **Huntington's disease, Cystic fibrosis.**
  2. **Chromosome Disorders**: Disorders resulting from changes in the number or structure of the chromosomes. Example: **Down's syndrome,** which results from an extra chromosome 21.
  3. **Multifactorial Disorders** (Complex Diseases): Disorders caused by changes in multiple genes, often in a complex interaction with environmental & lifestyle factors such as diet or cigarette smoke. Example: **Cancer.**

What Is A Mutation?

- Mutations are changes in the genetic sequence, and they are the main cause of diversity among organisms.
- A single mutation can have a large effect, but in many cases, evolutionary change is based on the accumulation of many mutations with small effects.
- Mutational effects can be beneficial, harmful, or neutral, depending on their context or location.
- Example: **Sickle cell anaemia** disease in Humans caused due to single gene mutation

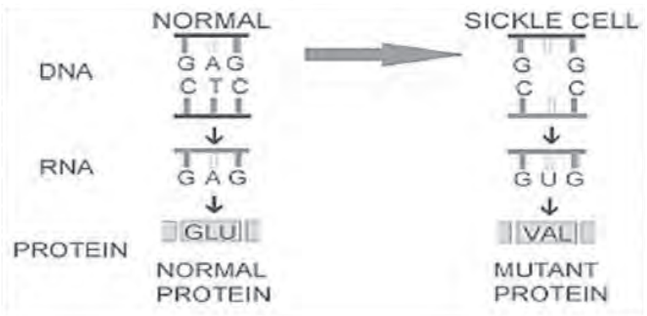


Fig: Mutation

Sickle Cell Anemia

- It is an inherited blood disorder in affected individuals at birth, causing the production of abnormal haemoglobin.
- Normally, the haemoglobin protein, which resides inside red blood cells, attaches to oxygen in the lungs and carries it to all parts of the body.
- Healthy red blood cells are flexible so that they can move through the smallest blood vessels.
- In sickle cell disease, the haemoglobin is abnormal, causing the red blood cells to be rigid and shaped like a C or sickle, the shape from which the disease takes its name.
- Sickle cells can get stuck and block blood flow, causing pain and infections.

Amino Acids

- Amino acids are small molecules that are the building blocks of proteins.

- Chemically, an amino acid is a molecule that has a carboxylic acid group, and an amino group that are each attached to a carbon atom called the á carbon.
- There are 20 types of Amino acids. These 20 amino acids can be classified as Essential and Non-Essential Amino Acids.
- Nonessential amino acids can be synthesised in the body, whereas essential amino acids must be obtained in the diet.
- There are 9 Essential Amino acids and 11 Non-essential Amino acids.
- Collagen is the most abundant protein in the animal world and Ribulose bisphosphate Carboxylase-Oxygenase (RuBisCO) is the most abundant protein in the whole of the biosphere.

Proteins

- Each protein is a molecule made up of different combinations of 20 types of smaller, simpler amino acids.
- Protein molecules are long chains of amino acids that are folded into a three-dimensional shape.
- Dietary proteins are the source of essential amino acids.
- Proteins carry out many functions in living organisms, some transport nutrients across cell membranes, some fight infectious organisms, some are hormones, and some are enzymes.

Enzymes

- Enzymes are biological catalysts (also known as biocatalysts) that speed up biochemical reactions in living organisms.
- Almost all enzymes are proteins. There are some nucleic acids that behave like enzymes. These are called ribozymes.
- An active site of an enzyme is a crevice or pocket into which the substrate fits. Thus enzymes, through their active site, catalyse reactions at a high rate.
- Inorganic catalysts work efficiently at high temperatures and high pressures, while enzymes get damaged at high temperatures (say above 40°C).
- However, enzymes isolated from organisms who normally live under extremely high temperatures (e.g., hot vents and sulphur springs), are stable and retain their catalytic power even at high temperatures (up to 80°- 90°C).

Ribozymes

- Ribozymes are catalytically active RNA molecules or RNA– protein complexes, in which solely the RNA provides catalytic activity.
- The term ribozyme refers to the enzymatic activity and ribonucleic acid nature at the same time.
- Ribozymes can be used in the study of gene function and gene therapy for diseases.

Vitamins

- A vitamin is an organic molecule that is an essential micronutrient which an organism needs in small quantities for the proper functioning of its metabolism.
- Most of the vitamins cannot be synthesised in our body but plants can synthesise almost all of them.
- Vitamins can be classified on the basis of solubility:
  - Fat-Soluble vitamins: Soluble in fats and oil but insoluble in water. They are stored in the liver and adipose tissues. E.g., vitamin A, D, E, K (KEDA).
  - Water-soluble vitamins: need regular supply in the diet, excreted in urine and cannot be stored in our body. E.g., vitamin B and C groups (except B12).
- Deficiency of vitamins can cause several diseases.

Vitamins/Minerals	Sources	Functions
B1 (Thiamine) – Water soluble (Anti-stress vitamin)	Fresh fruits, corn, cashew nuts, peas, wheat, milk, dates, black beans etc.	Part of an Enzyme, needed for energy metabolism and nerve functions.
B2 (Riboflavin) - Water soluble	Bananas, grapes, pumpkin, yoghurt, mushroom, popcorn, liver etc.	Essentials for growth, enzymatic role in tissue respiration and acts as transporter of hydrogen ions.
B3 (Niacin) - Water soluble	Meat, eggs, fish, milk, guava, peanuts, cereals, green peas etc.	Helps in oxidation and Energy releases, synthesis of glycogen and breakdown of fatty acids.
B5 (Pantothenic Acid) - Water soluble	Meat, kidney, egg yolk, chicken, fish, legumes, avocado etc.	Synthesis of vital body compounds, essential in intermediary metabolism of carbohydrates, fats and protein.
B6 (Pyridoxine) - Water soluble	Pork, chicken, bread, wholegrain, soya beans, cereals etc.	Essential for normal growth, Synthesis and breakdown of amino acids and unsaturated fatty acids.

B7 (Biotin) - Water soluble	Walnuts, peanuts, milk,egg yolks, salmon, mushroom, cauliflower, banana, raspberries.	Essential components of enzymes, carrier of carbon dioxide, metabolism of fatty acids and amino acids
B9 (Folic Acid) - Water soluble	Citrus fruits, green leafy vegetables, beets, legumes etc.	Essential in biosynthesis of nucleic acids, necessary for red blood cell maturation.
B12 (Cobalamin)	Fish, meats, poultry, eggs, Breast milk etc.	Essential in biosynthesis of nucleic acids, red blood cell maturation; involved in central nervous system metabolism

Table: Dietary Sources and Functions of Vitamins

Lipids or Fats

Lipids are **generally water-insoluble**. They could be simple fatty acids. **A fatty acid has a carboxyl group attached to an R group.** Fatty acids could be **saturated** (**without double bonds**) or unsaturated (**with one or more C=C double bonds**).

Saturated Fat	Unsaturated Fat
• Fats in which the fatty acids all have single bonds. • Saturated fat has the maximum number of hydrogens bonded to the carbons. • Most animal fats are saturated, whereas plants and animal fats are unsaturated. • Not healthy, less vulnerable to rancidity, solid at room temperature.	• In which there is at least one double bond within the fatty acid. • Hydrogen is eliminated by double bonds. • Unsaturated fats are lesser in energy than the equivalent amount of saturated fats. • The greater the unsaturation means more vulnerability to rancidity.

Cholestrol

- It is an organic compound, **a fat-like insoluble waxy substance**, found in all cells of our body and **is circulated through the blood cells with the help of Lipoproteins**.
- Cholesterol **is synthesized in the liver**.
- Two types of Cholesterol:
  - **Low-Density Lipoproteins** (**LDL**): Bad cholesterol.
  - **High-density lipoproteins** (**HDL**): Good cholesterol.
- Cholesterol plays an important role in **creating cells**, **hormones**, **vitamin D** production and **bile acids**.

Unhealthy fat

- **Saturated fat** and **Trans-fat.**
- Saturated fats **are primarily found in meats and dairy products**.
- Solid fats are unhealthy because they increase **LDL(bad cholesterol) levels** and **increase heart diseases.**
- Trans-fat is **simply liquid oils turned into solid fats during food processing**.
- **Trans-fats are worse than saturated fats**, they **increase LDL** and decrease **HDL**.
- Efforts of the **Government of India** to control Trans-fats:
  - India **has set an aim to reduce the industrially produced trans-fat to less than 2 % by the year 2022** in a phased manner, a year ahead of the WHO target.
  - Trans-fat content in fats and oils is currently limited to 5% by the Food Safety and Standards Authority of India (FSSAI).

Carbohydrates

- Carbohydrates, or carbs, are sugar molecules.
- They contain hydrogen and oxygen in the same ratio as water (2:1) and typically can be broken down to release energy in the animal body.

Types of Carbohydrates

Carbohydrates are divided into four types:

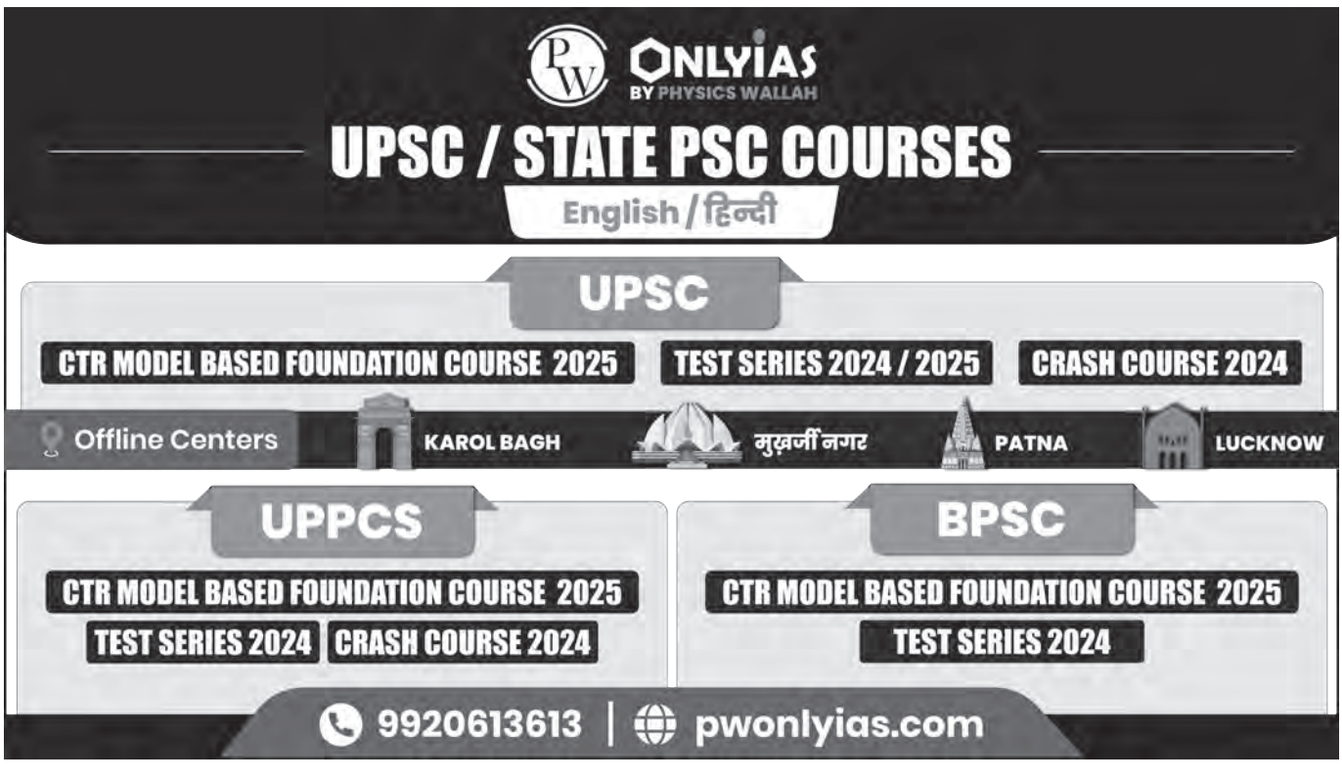
- Monosaccharides: E.g., Glucose, Fructose, Ribose, Galactose, etc.
- Disaccharides: E.g., Sucrose, lactose, and maltose, etc.
- Oligosaccharides: E.g., disaccharides, trisaccharide, etc.
- Polysaccharides: E.g., Starch, Cellulose, Glycogen, etc.

Diabetes and Sugar

- Diabetes is a disease that occurs when your blood glucose, also called blood sugar, is too high.
- Blood glucose is your main source of energy and comes from the food you eat.
- Insulin, a hormone made by the pancreas, helps regulate blood sugar.

Diabetes Mellitus	Diabetes Insipidus
• Generally referred to as Diabetes is a chronic condition where the Pancreas gland does not generate enough insulin required by the body to regulate glucose metabolism, which leads to high blood sugar levels in the body. • All carbohydrates are broken down into glucose in the blood. • Insulin is a hormone produced by the pancreas, which helps glucose to get into cells. (insulin converts glucose into glycogen)	• Diabetes insipidus is a rare condition that occurs when the kidneys are unable to conserve water during the process of filtering blood. • It is associated with inadequate arginine vasopressin (AVP)or antidiuretic hormone (ADH) secretion or renal response to AVP, resulting in hypotonic polyuria and a compensatory/underlying polydipsia.

Table: Comparison between Diabetes Mellitus & Insipidus.



2 Health and Diseases

According to the WHO, '**Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity**'. Health encompasses various dimensions which include **physical**, **mental**, **social**, **emotional** and **spiritual health**.

HUMAN PHYSIOLOGY

Physiology is **the study of normal function and vital processes of living organisms encompassing a range of subjects that include organs, anatomy, cells, biological compounds, and how they all interact to make life possible.** Human Physiology broadly includes the study of:

- **Digestive System**
- **Respiratory System**
- **Circulatory System**
- **Excretory System**
- **Endocrine System**
- **Reproductive System**
- **Nervous System**
- **Musculoskeletal System**

Digestive System

The human digestive system breaks food (**Proteins** are **broken down into amino acids**, **Fats** are broken into **fatty acids** and **glycerol,** and **Carbohydrates** into **simple sugars**) into parts small enough for our body to absorb and use for various functions, including **energy**, **growth**, and **cell repair** and **expels unabsorbed waste products.** The digestive system is made up of:

- **Gastrointestinal tract** (also called the GI tract/ digestive tract)
- **Accessory digestive organs** (including liver, pancreas, gall bladder etc.)

Processes involved in digestion include **ingestion**, **secretion** (of enzymes, digestive juices, buffers etc.), **peristalsis** (**the involuntary constriction and relaxation of the muscles of the GI tract, creating wave-like movements that push the contents of the canal forward**), **digestion** (break down of food into absorbable molecules), **absorption** (of digested constituents by the epithelial cells lining the GI tract), and **defecation** (expulsion of waste products).

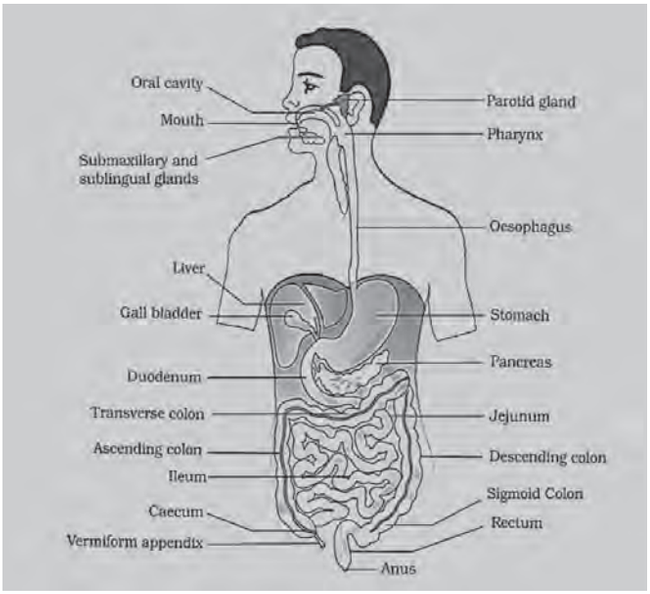


Fig: Human Digestive System

Gastrointestinal Tract

The **gastrointestinal (GI) tract**, or **alimentary canal**, is a continuous tube that extends from the mouth to the anus. Its walls, from the lower oesophagus to the anus, have the same basic, **four-layered arrangement of tissues** (from deep to superficial)- **the mucosa**, **submucosa**, **muscularis propria**, and **the serosa**. The hollow organs that make up the GI tract are the **mouth**, **oesophagus**, **stomach**, **small intestine**, **large intestine**, and **anus.**

- **Mouth:** It is also known as **the 'Oral cavity'** or **'Buccal Cavity'** and performs two major functions, **mastication of food** and **facilitation of swallowing**. **The saliva** secreted by salivary glands in the mouth **contains electrolytes** and **enzymes- salivary amylase (digestion initiating carbohydrate splitting enzyme)** and **lysozyme(that lyses many bacteria and prevents the overgrowth of oral microbial populations).**
- **Oesophagus:** It secretes mucus and transports food into the stomach (not involved in digestion or absorption).
- **Stomach:** The **stomach stores the food for 4-5 hours**; here, food mixes thoroughly with the **acidic gastric juice** by the churning movements of its muscular walls

and **is called the chyme**. The **proenzyme pepsinogen**, on exposure to **hydrochloric acid, gets converted into the active enzyme pepsin**, the **proteolytic enzyme** (**enzymes that break down protein**) of the stomach. Pepsin converts proteins into **proteoses** and **peptones** (**peptides**). The **mucus** and **bicarbonates** present in the gastric juice play an important role in the **lubrication** and **protection** of the **mucosal epithelium** from **excoriation** (**abrasion**) by highly concentrated hydrochloric acid. **HCl provides the pH 1.8 optimal for pepsins. Rennin** is a **proteolytic enzyme** found in the **gastric juice of infants,** which helps in the **digestion of milk proteins**.

- **Small Intestine:** Here, various types of movements **generated by the muscularis layer** help in a thorough mixing up of the food with **various secretions (bile**, **pancreatic juice** and **intestinal juice), facilitating digestion.**
  - **Pancreatic juice** and **bile** are released through **the hepato-pancreatic duct**. **The pancreatic juice** contains **inactive enzymes- trypsinogen, chymotrypsinogen, procarboxypeptidases, amylases, lipases and nucleases.**
  - **The bile released into the duodenum contains bile pigments** (**bilirubin** and **biliverdin**), **bile salts**, **cholesterol** and **phospholipids but no enzymes** and **helps in emulsification of fats (breaking down of the fats into very small micelles)** and **activation of lipases.**
  - The secretions of the **brush border cells of the mucosa,** along with **the secretions of the goblet cells,** constitute **the intestinal juice or succus entericus.** This juice contains a variety of enzymes like **disaccharidases (e.g., maltase), dipeptidases, lipases, nucleosidases, etc. The mucus, along with the bicarbonates from the pancreas, protects the intestinal mucosa from acid as well as provides an alkaline medium (pH 7.8) for enzymatic activities.**
  - **The breakdown of biomacromolecules occurs in the duodenum region of the small intestine, and the simple substances** thus formed are absorbed in the **jejunum** and **ileum regions** of the small intestine.
- **Large Intestine:** The **undigested** and **unabsorbed substances** are passed on to the large intestine, whose functions include:
  - **absorption** of **some water**, **minerals** and **certain drugs**.
  - **secretion of mucus**, which helps in **adhering waste particles** and **lubricating them**.

The **undigested**, **unabsorbed substances called faeces** enter into the **caecum of the large intestine through ileo-caecal valve**, which **prevents the backflow** of the faecal matter. **Faecum** is temporarily stored **in the rectum till defecation** through the anus.

Accessory Digestive Organs

The accessory digestive organs include the teeth, tongue, salivary glands, liver, gallbladder, pancreas etc., which perform various functions in the course of digestion.

- **Liver: It is the largest gland in the human body (1.2-1.5 kg),** situated in the abdominal cavity, just below the diaphragm and has two lobes. **The hepatic lobules are the structural and functional units of the liver containing hepatic cells arranged in the form of cords. The bile secreted by the hepatic cells passes through the hepatic ducts and is stored and concentrated in a thin muscular sac called the gall bladder. The gallbladder sends** this stored bile into the small intestine to **aid in the digestion of food. The duct of the gall bladder (cystic duct),** along with the **hepatic duct from the liver**, **forms the common bile duct. The liver is vital** for the **detoxification** and **destruction** of **endogenous** and **exogenous substances** that are harmful to the body.
- **Pancreas:** The pancreas is an organ located in the abdomen that has two main functions:
  - **Exocrine function- The pancreas contains exocrine glands** that produce **enzymes trypsin** and **chymotrypsin** to **digest proteins**, **amylase** for **the digestion of carbohydrates**, and **lipase to break down fats**.
  - **Endocrine function-** The **endocrine component** of the pancreas consists of **islet cells** (**islets of Langerhans**) that create and release important hormones, **insulin** (lowers blood sugar) and **glucagon** (raises blood sugar) directly into the bloodstream regulating sugar levels.

Respiratory System

The process of **exchange of O2 from the atmosphere** with **CO2 produced by the cells is called breathing**, also known as respiration. Mechanisms of **breathing vary among different groups of animals** depending mainly on their habitats and level of organisation:

- **Lower invertebrates**, like **sponges**, **coelenterates**, **flatworms**, etc., breathe through **simple diffusion over their entire body surface.**
- **Earthworms** use **moist cuticles**.
- **Insects** have a network of **tubes called trachea**.
- **Arthropods**(**aquatic**) and **Molluscs**(**aquatic**)- **vascularised structures called gills.**
- **Arthropods**(**terrestrial**) and **Molluscs**(**terrestrial**)- **vascularised bags called lungs.**
- **Vertebrates- fishes use gills**; **amphibians**, **reptiles**, **birds** and **mammals respire through lungs**. **Some**

amphibians, **like frogs**, can respire through their **moist skin** (**cutaneous respiration**) **too**.

Human Respiratory System

It structurally extends from the **nose**, and **pharynx**, all the way to the **alveoli of the lungs.** The part starting with the external nostrils up to the terminal bronchioles constitutes **the conducting part** (transports the **atmospheric air to the alveoli**, **clears it from foreign particles**, **humidifies** and **also brings the air to body temperature**), whereas the alveoli and their ducts form, the **respiratory or exchange part** (**the site of actual diffusion of O2 and CO2 between blood and atmospheric air**) of the respiratory system.

- **Nose:** Consists of a pair of **external nostrils** opening out above the upper lips, **which leads to a nasal chamber through the nasal passage**.
- **Pharynx:** The nasal chamber opens into the **pharynx**, a portion of **which is the common passage for food and air**. The pharynx opens through the larynx region into the trachea.
- **Larynx:** Also called '**sound box**' is a **cartilaginous box** which helps in sound production. During **swallowing**, the **glottis** (thin opening at the top of the larynx) can be covered by a thin elastic **cartilaginous flap called epiglottis** to prevent the entry of food into the larynx.
- **Trachea:** It is a **straight tube extending up to the mid-thoracic cavity**, which divides at the level of the fifth thoracic vertebra into a **right** and **left primary bronchi**.
- **Bronchi:** Each **bronchi undergoes repeated divisions** to form the **secondary** and **tertiary bronchi** and **bronchioles** ending up in very thin **terminal bronchioles**. The **trachea**, **primary**, **secondary** and **tertiary bronchi**, and **initial bronchioles** are supported by **incomplete cartilaginous rings**.
- **Alveoli:** Numerous **vascularised bag like structures** which **rise from terminal bronchioles**.
- **Lungs:** The branching network of **bronchi**, **bronchioles** and **alveoli** comprise the lungs. Humans have two lungs which **are covered by a double-layered pleura** (with pleural fluid between them), which reduces friction on the lung surface.
- **Diaphragm:** It is a **dome-shaped**, **muscular** and **membranous structure** that separates the **thoracic** (chest) and **abdominal cavities** in humans (mammals) and is **the principal muscle of respiration**.

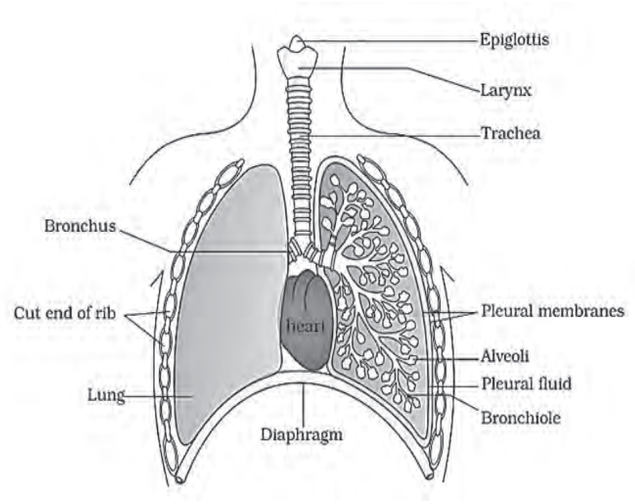


Fig: Human Respiratory System

Mechanism of Breathing

Breathing involves two stages: **inspiration** (**atmospheric air is drawn in**) and expiration (**alveolar air is released out**). Inspiration can occur if the pressure within the lungs (**intra-pulmonary pressure**) is less than the atmospheric pressure. The **diaphragm** and **a specialised set of muscles- external** and **internal intercostals** between the ribs help in the generation of such gradients. Inspiration is initiated by the **contraction of the diaphragm,** which increases the volume of the thoracic chamber. The **contraction of external intercostal muscles lifts up the ribs** and **the sternum,** also increasing the volume of the thoracic chamber. The **overall increase in the thoracic volume** causes **a similar increase in pulmonary volume**, decreasing the **intra-pulmonary pressure below the atmospheric pressure**, forcing air outside to move into the lungs, i.e., **inspiration**. **Relaxation of the diaphragm** and **the intercostal muscles** returns the **diaphragm** and **sternum** to their normal positions, **reducing the thoracic volume** and **the pulmonary volume**. This **increases intra-pulmonary pressure slightly above the atmospheric pressure** causing the expulsion of air from the lungs, i.e., **expiration**.

Oxidative stress is used to describe **the condition of oxidative damage resulting** when the critical balance between **free radical generation** and **antioxidant defences is unfavourable**. **Antioxidants prevent free radical induced tissue damage** by **preventing the formation of radicals, scavenging them, or by promoting their decomposition. [UPSC 2011]**

Circulatory System

Different **groups of organisms have evolved different methods of transport** in **order to provide their cells with nutrients, O_2 and other essential substances** and **also to remove waste and other harmful substances** produced as a result of various metabolic processes.

The circulatory patterns are of two types; **the open circulatory system** (present in **arthropods** and **molluscs** in which **blood pumped by the heart passes through large vessels into open spaces or body cavities called sinuses**) and **the closed circulatory system** (present in **annelids** and **chordates** in which **the blood pumped by the heart is circulated through a closed network of blood vessels**). All **vertebrates possess a muscular chambered heart**. A **brief outline of circulatory systems** in different **groups of vertebrates**:

- **Fishes have a 2-chambered heart with an atrium and a ventricle**. In fishes, **the heart pumps out deoxygenated blood** which is **oxygenated by the gills** and supplied to the body parts from where deoxygenated blood is returned to the heart (**single circulation**).
- **Amphibians** and **reptiles** (**except crocodiles**) have a **3-chambered heart** with **two atria** and a **single ventricle**. In amphibians and reptiles, the **left atrium receives oxygenated blood from the gills/lungs/skin** and **the right atrium gets the deoxygenated blood from other body parts**. However, **they get mixed up in the single ventricle**, which pumps out mixed blood (**incomplete double circulation**).
- **Crocodiles**, **birds** and **mammals** possess a **4-chambered heart** with **two atria** and **two ventricles**. In birds and mammals, **oxygenated** and **deoxygenated blood** received by the **left** and **right atria, respectively,** passes **on to the ventricles of the same sides**. The **ventricles pump it out without any mixing up**, i.e., two separate circulatory pathways are present in these organisms; hence, **these animals have double circulation.**

Human Circulatory System

It (also called the **blood vascular system**) consists of a **muscular chambered heart**, **a network of closed branching blood vessels** and **blood**, the fluid which is circulated.

- **Heart:** It is **situated in the thoracic cavity**, in between the two lungs, **slightly tilted to the left** and is the size of a clenched fist. Our **heart has four chambers**, two relatively **small upper chambers called atria** and **two larger lower chambers called ventricles** (**separated from each other by walls called septum**). However, each of these septums is **provided with an opening** (**guarded by valves- tricuspid or bicuspid**) through which the **two chambers on the same side are connected**. The **valves in the heart allow only unidirectional flow of blood, preventing any backward flow.**
  - **Cardiac Cycle:** The **sequential pumping of the heart**, which is cyclically repeated, is called the cardiac cycle, and it consists of the **systole** (**contraction**) and **diastole** (**expansion**) of both the **atria and ventricles**. The heart beats **72 times per minute** (**beats per minute/bpm**), and during a cardiac cycle, **each ventricle pumps out approximately 70 ml of blood**, which is called the **stroke volume**. The **stroke volume** multiplied by the **heart rate** (**bpm**) gives the **cardiac output**. The body has the ability to **alter the stroke volume** as well as the **heart rate** and, thereby, **the cardiac output** (**the cardiac output of an athlete will be much higher than that of an ordinary man**).

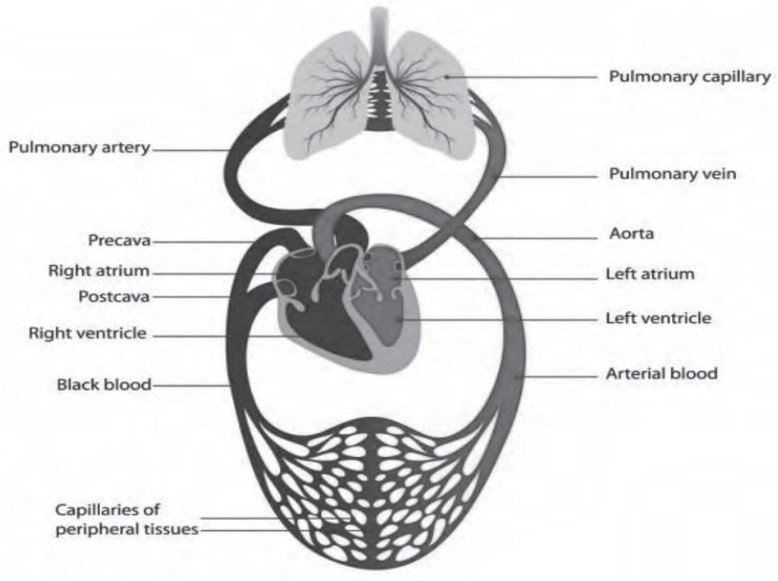


Fig: Schematic representation of the Human Circulatory System

- **Blood Vessels:** The blood flows strictly by a fixed route through the Blood Vessels-the **arteries**, **veins** and **capillaries**. Each **artery** and **vein** consists of **three layers**: an inner lining of squamous endothelium, the **tunica intima**, a middle layer of smooth muscle and elastic fibres, the **tunica media**, and an external layer of fibrous connective tissue with collagen fibres, the **tunica externa**. **The tunica media is comparatively thin in the veins. All arteries** except the **pulmonary artery** (**which carries blood from the heart to lungs**) **carry oxygen-rich blood**, and **all veins except the pulmonary vein** (which carries blood from the lungs to heart) **carry deoxygenated blood**. **Capillaries** (**the smallest and most numerous of the blood vessels**) form the connection between **arteries** and **veins**. **The primary function of capillaries is the exchange of materials between the blood and tissue cells**.
- **Blood:** Blood is a special connective tissue consisting of a **fluid matrix**, **plasma**, and **formed elements**.
  - **Plasma:** It is a **straw-coloured**, **viscous fluid** constituting nearly **55 per cent of the blood**. 90-92 per cent of **plasma is water**, and **proteins** (**fibrinogen**, **globulins**, **albumins**) contribute **6-8 per cent** of it. **Fibrinogens are needed for clotting or coagulation of blood**, **Globulins primarily are involved in defence mechanisms** of the body, and **albumins help in osmotic balance**. Plasma also contains small amounts of **minerals** (**Na+, Ca++, Mg++, HCO3-, Cl-**) and other substances like **glucose**, **amino acids**, **lipids**, etc. **Factors for coagulation or clotting of blood** are also present in the **plasma in an inactive form**. **Plasma without the clotting factors is called serum**.
  - **Formed Elements: Erythrocytes**, **leucocytes** and **platelets** are **collectively called formed elements** and constitute nearly 45 per cent of the blood.
    - **Erythrocytes:** Also known as **red blood cells** (**RBCs**) are the **most abundant of all the cells in blood**. **RBCs are formed in the red bone marrow in adults**, are **biconcave in shape** and are **devoid of nuclei** in **most mammals**. They have a **red-coloured**, **iron-containing complex protein** called **haemoglobin**. A healthy individual has **12-16 gms of haemoglobin** in every **100 ml of blood**. These molecules play a significant role in the transport of respiratory gases. **RBCs have an average life span of 120 days, after which they are destroyed in the spleen** (**graveyard of RBCs**).
    - **Leucocytes:** Also known as **white blood cells** (**WBC**) are **colourless due to the lack of haemoglobin**. These are **nucleated**, **short-lived** and **relatively lesser in number**. There are **two main categories of WBCs - granulocytes** (**neutrophils**, **eosinophils** and **basophils**) and **agranulocytes** (**lymphocytes** and **monocytes**). **Neutrophils are the most abundant cells** (**60-65 %**) **of the total WBCs,** and **basophils are the least** (**0.5-1 %**) among them. **Neutrophils** and **monocytes** (**6-8 %**) are **phagocytic cells which destroy foreign organisms entering the body**. **Basophils** secrete **histamine**, **serotonin**, **heparin**, etc., and are **involved in inflammatory reactions**. **Eosinophils** (**2-3 %**) **resist infections** and **are also associated with allergic reactions**. **Lymphocytes** (**20-25 %**) are of **two major types**-'**B**' and '**T**' forms. **Both B and T lymphocytes are responsible for the immune responses of the body**.
    - **Platelets:** Also called **thrombocytes**, are cell fragments produced from **megakaryocytes** (**special cells in the bone marrow**). Platelets **release a variety of substances**, most of which are **involved in the coagulation or clotting of blood**. A reduction in their number can lead to clotting disorders.
  - **Blood Groups:** The **surfaces of erythrocytes contain a genetically determined assortment of antigens** (called **agglutinogens**), which occur in **characteristic combinations across human populations**. Blood group **is the classification of blood-based on inherited differences** in antigens on the surfaces of the **red blood cells** (**erythrocytes**).
    - **ABO grouping:** It is based on the **presence or absence of two surface antigens** (**chemicals that can induce an immune response**) **on the RBCs**, namely **A** and **B**. Similarly, the plasma of different individuals contain two natural **antibodies** (**proteins produced in response to antigens**). The **distribution of antigens** and **antibodies** results in the **four groups of blood**, **A**, **B**, **AB** and **O.** During **blood transfusion**, any **blood cannot be used**; the **blood of a donor has to be carefully matched with the blood of a recipient before any blood transfusion to avoid severe problems of clumping** (**destruction of RBC**). **'O' blood can be donated to people with any other blood group**, and hence **'O' group individuals are called 'universal donors'. People with 'AB' group can accept blood from persons with AB as well as the other groups of blood** and are **called 'universal recipients'**. Blood groups and donor compatibility are shown in the table below.

Blood Group	Antigen on RBCs	Antibodies in Plasma	Donor's Group
A	A	anti- B	A, O
B	B	anti- A	B, O
AB	A, B	nil	AB, A, B, O
O	nil	anti- A, B	O

Table: ABO Blood Groups & Donor Compatibility

- **Rh grouping:** Another antigen, **the Rh antigen similar to one present in Rhesus monkeys** (hence Rh), is also observed **on the surface of RBCs of majority (nearly 80 per cent) of humans.** Such individuals are called **Rh+ve**, and **those in whom this antigen is absent are called Rh-ve**. An **Rh-ve person**, **if exposed to Rh+ve blood**, **will form specific antibodies against the Rh antigens,** and hence, **the Rh group is matched before transfusions**. A special case of **Rh incompatibility** is observed between the **Rh-ve blood of a pregnant mother** and **the Rh+ve blood of the foetus**. **Rh antigens of the foetus do not get exposed to the Rh-ve blood of the mother in the first pregnancy as the two bloods are well separated by the placenta**. However, during the delivery of the first child, **there is a possibility of exposure of the maternal blood to small amounts of the Rh+ve blood from the foetus**. In such cases, **the mother starts preparing antibodies against the Rh antigen in her blood**. In **case of her subsequent pregnancies**, **the Rh antibodies from the mother (Rh-ve) can leak into the blood of the foetus (Rh+ve) and destroy the foetal RBCs** causing possibly fatal severe anaemia or jaundice in the baby (**called erythroblastosis foetalis**). This **can avoided by administering anti-Rh antibodies to the mother immediately after the delivery of the first child**.

- **Lymph (Tissue Fluid):** As the blood passes through the capillaries in tissues, **some water, along with many small water-soluble substances, move out into the spaces between the cells of tissues** leaving **the larger proteins** and **most of the formed elements in the blood vessels**. This fluid released is called the **interstitial fluid or tissue fluid**. **An elaborate network of vessels called the lymphatic system** collects this fluid and drains it back to the major veins. The **colourless fluid** present in the **lymphatic system is called the lymph** and **contains specialised lymphocytes, which are responsible for the immune responses of the body.** Lymph is also an important carrier of nutrients, hormones, etc. **Fats are absorbed through lymph in the lacteals present in the intestinal villi**.

Excretory System

- Animals accumulate **ammonia**, **urea**, **uric acid**, **carbon dioxide**, **water** and ions like **Na+**, **K+**, **Cl-**, **phosphate**, **sulphate**, etc., **either by metabolic activities** or **by other means like excess ingestion**. These substances have to be **removed totally or partially**.

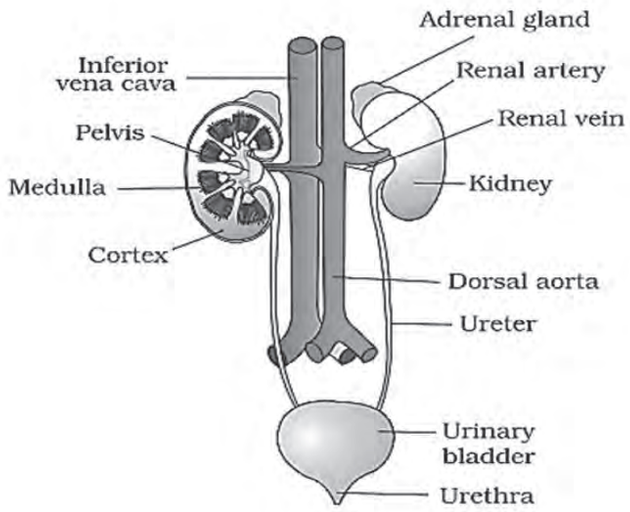


Fig: Human Excretory System.

- The process of **excreting ammonia is Ammonotelism**. Many **bony fishes**, **aquatic amphibians** and **aquatic insects** are **ammonotelic** in nature.
- **Terrestrial adaptation** necessitated the **production of lesser toxic nitrogenous wastes like urea** and **uric acid** for conservation of water.
- **Mammals**, many **terrestrial amphibians** and **marine fishes** mainly **excrete urea** and are called **ureotelic animals**.
- **Ammonia produced by metabolism is converted into urea in the liver of these animals** and **released into the blood which is filtered and excreted out by the kidneys**.

- **Reptiles**, **birds**, **land snails** and **insects excrete nitrogenous wastes** as **uric acid in the form of pellet or paste** with a minimum loss of water and **are called uricotelic animals**.

Human Excretory System

- In humans, the excretory system **consists of a pair of kidneys**, **one pair of ureters**, **a urinary bladder** and **a urethra**.
- Each kidney of an adult human measures **10-12 cm in length**, **5-7 cm in width**, and **2-3 cm in thickness,** with **an average weight of 120- 170 g**.
- Inside the kidney, there are **two zones**, **an outer cortex** and **an inner medulla**.
- Each kidney has nearly **one million complex tubular structures called nephrons**, which a**re the functional units**.
- Each nephron has two parts- **the glomerulus** and **the renal tubule**.
- Urine formed by the **nephrons is ultimately carried to the urinary bladder**, where it is stored till a voluntary signal is given by the Central Nervous System (CNS).
- This signal is **initiated by the stretching of the urinary bladder as it gets filled with urine**. In response, **the stretch receptors on the walls of the bladder send signals to the CNS**.
- The process of **release of urine is called micturition**, and **the neural mechanism causing it is called the micturition reflex**.
- An **adult human excretes, on average, 1 to 1.5 litres of urine per day**.
- The urine formed is a **light yellow coloured watery fluid** which is slightly acidic (pH-6.0).
- **Malfunctioning of kidneys** can lead to accumulation of urea in blood, **a condition called uremia**, which is highly harmful and may lead to kidney failure.
- In such patients, **urea can be removed by a process called hemodialysis**.
- **Renal calculi:** Stone or insoluble mass of crystallised salts (oxalates, etc.) formed within the kidney.

Endocrine System

Endocrine glands lack ducts (**called ductless glands**) and **secrete hormones**. **Hormones are non-nutrient chemicals which act as intercellular messengers** and **are produced in trace amounts**. The **endocrine glands** and **hormone-producing diffused tissues/cells** located in different parts of our body constitute **the endocrine system.** Various **glands of the endocrine system** and **their functions**:

- **Hypothalamus:** It contains several groups of **neurosecretory cells called nuclei, which produce hormones**. These hormones reach the **pituitary gland through a portal circulatory system and regulate the functions of the anterior pituitary**.
- **Pituitary: Oxytocin** and **arginine vasopressin** (**AVP**) are neuropeptides **synthesised in the hypothalamus** and secreted from the **posterior pituitary gland**. Other hormones produced by the Pituitary gland include **Growth Hormones** (**GH**), **Luteinizing Hormone** (**LH**), and **Follicle Stimulating Hormone** (**FSH**)
  - **GH** promotes **growth** and its excess secretion in adulthood results in **Acromegaly**. In **childhood**, this leads to increased height and is called **gigantism**.
  - **LH** stimulates the production of androgens in the **testes** (**in males**), and it helps to **regulate the length** and **order of the menstrual cycle** in **females** by playing roles in **both ovulation** and **implantation of an egg** in the **uterus.**
- **Thyroid:** Secretes **thyroxine** which **regulates and controls appetite and metabolism**.
- **Thymus:** Secretes **Thymopoietin:** which **fuels the production of T-cells**, **Thymosin** and **thymulin**: **help make specialised types of T-cells**, **Thymic humoral factor**: keeps **the immune system working properly**.
- **Pancreas:** Secretes **Insulin** (**secreted by pancreatic β-cell**) and **Glucagon** (**secreted by islet α-cells**), which regulate blood sugar levels and play an important role in **glucose homeostasis**.
- **Adrenal:** Hormones produced by adrenal glands include **Cortisol**, **Aldosterone**, **Epinephrine** (**Adrenaline**), **Norepinephrine** (**Noradrenaline**) etc. **Epinephrine** and **Norepinephrine** are capable of **increasing the heart rate** and **force of heart contractions**, **increasing blood flow to the muscles** and **brain**, **relaxing airway smooth muscles**, and **assisting in glucose metabolism**. They also control the **squeezing of the blood vessels** (**vasoconstriction**) and help **maintain blood pressure**, **increasing it in response to stress.**
- **Testes:** Secretes **testosterone** which **regulates the development of male secondary sexual characteristics**, **axial** and **facial hair growth** etc.
- **Ovaries:** Secrete **estrogen** and **progesterone,** which **control and regulate the female reproductive cycle**
- **Pineal:** Secretes **melatonin** (also known as **hormone of darkness**) which regulates the sleep cycle.

Endocrine Disruptors

- Some **environmental contaminants interact with hormones** and **may exert adverse consequences due to their actions as Endocrine Disrupting Chemicals** (**EDCs**).

- Exposure in people is **typically due to contamination of the food chain**, **inhalation of contaminated house dust**, or **occupational exposure**.
- EDCs include **pesticides** and **herbicides** [such as **diphenyl- dichloro-trichloroethane** (DDT) or its metabolites], **methoxychlor**, **biocides**, **heat stabilisers** and **chemical catalysts** (such as **tributyltin**, TBT), **plastic contaminants** (e.g. **bisphenol A**), **pharmaceuticals** (i.e. **diethylstilbestrol**, **17 alpha ethinylestradiol**, **EE2**), or **dietary components** (such as **phytoestrogens**)

Reproductive System

The **male** and **female reproductive systems** typify the **sexual differentiation** of humans on both a **structural and physiological level**. The primary responsibility of the reproductive system is to produce separate gametes- **the male sperm** and **the female secondary oocyte**.

Male Reproductive Organs

- The male reproductive system is characterised by the dominance of the associated anatomical structures located outside the body**- the scrotum, penis and testes.**

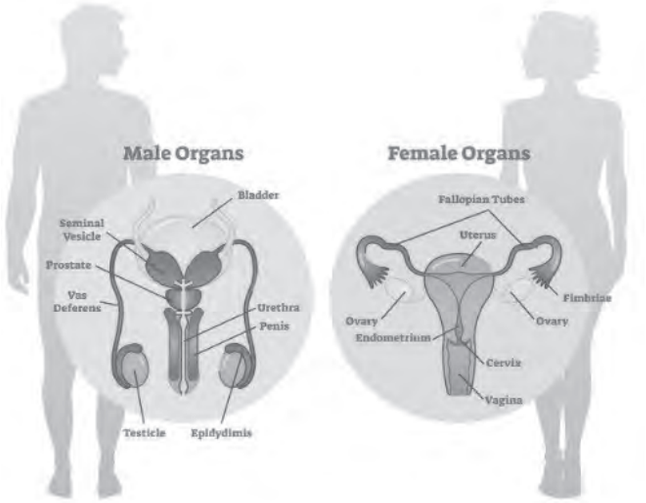


Fig: Male and Female Reproductive System.

Female Reproductive Organs

- The female reproductive system, on the other hand, **is located inside the body** and includes the **vagina**, **cervix**, **uterus**, **fallopian tubes** and **ovaries**.
- The ovaries produce secondary oocytes that will make their journey to the fallopian tubes, which are controlled by hormones.
- **Progesterone and oestrogens**, like male testosterone, **are also controlled from the level of the hypothalamus** and **anterior pituitary gland.**

Puberty

It is the **beginning of sexual maturity**, which usually happens between **ages 10 and 14 for girls** and **ages 12 and 16 for boys**. It causes physical changes and affects boys and girls differently.

Menstrual Cycle

It involves **periodic** (**usually every 28 days**) **discharge of blood**, **tissue fluid**, **mucous**, and **epithelial cells** that usually lasts for **4-5 days** and **is triggered by a sudden reduction in estrogens and progesterone**. **Menarche** is defined as the **first menstrual period in a female adolescent. Menopause** (**diagnosed after 12 months without a menstrual period in adult females**)**is the time that marks the cessation of menstrual cycles.**

Nervous System

- The nervous system **is an organised group of cells specialised for the conduction of electrochemical stimuli from sensory receptors through a network to the site at which a response occurs**.
- Nervous systems are of two general types, **diffuse** and **centralised**.

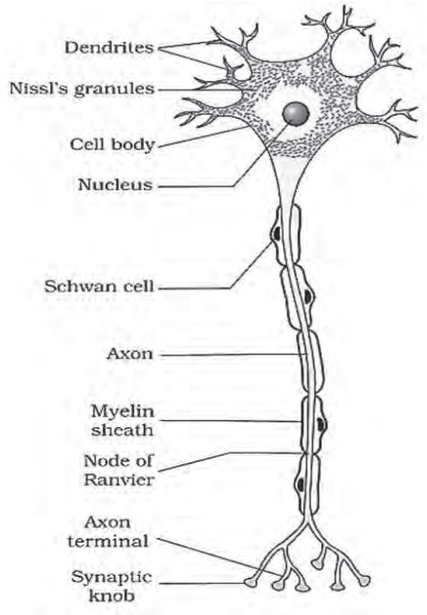


Fig: Structure of Neuron

- In the **diffuse type** of system (**found in lower invertebrates**), **the brain is absent**, and **neurons** are distributed throughout the organism in a netlike pattern.
- In **the centralised systems** (**higher invertebrates** and **vertebrates**), a portion of the nervous system has **a dominant role in coordinating information and directing responses,** with this **centralisation reaching its zenith in vertebrates**, which have a **well-developed brain and spinal cord** [**central nervous system** (**CNS**)]. Impulses **are carried to**

and from the CNS by nerve fibres that make up the **peripheral nervous system** (**PNS**).

- It is the **body's command centre**.

Neurons

- A neuron is a microscopic structure composed of three major parts, namely, **cell body**, **dendrites** and **axon**.
- The **cell body contains cytoplasm** with typical cell organelles and **certain granular bodies called Nissl's granules**.
- Dendrites are projections of a **neuron** (**nerve cell**) that **receive signals** (**information**) from other neurons.
- The **transfer of information from one neuron to another** is achieved through **chemical signals** and **electric impulses** (**electrochemical signals**).
- Neurons are **excitable cells because their membranes are in a polarised state**. Different types of **ion channels** are **present on the neural membrane**. These **ion channels are selectively permeable** to different ions.
- A nerve impulse is transmitted from **one neuron to another through junctions called synapses**. A synapse is formed by the **membranes of a pre-synaptic neuron** and **a postsynaptic neuron**, which may or may not be separated by a gap called **synaptic cleft**.

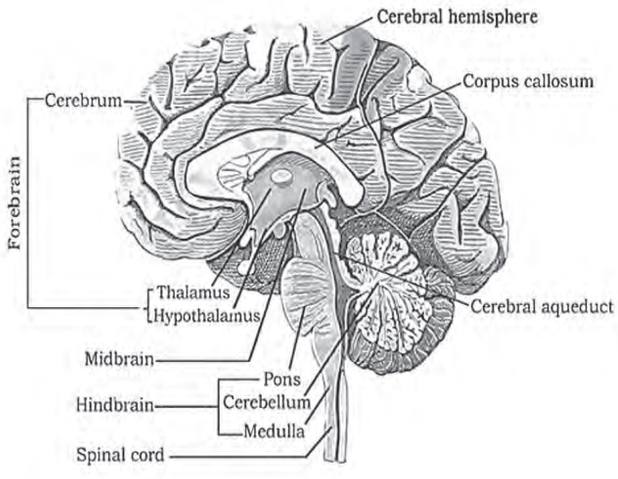


Fig: Structure of Human Brain

Brain

- The brain is the central information processing organ of our body and acts as the '**command and control centre**'.
- It can be divided into 3 major parts:
  - **Fore-brain**: plays a **central role** in the **processing of information related to complex cognitive activities**, **sensory** and **associative functions**, and **voluntary motor activities**.
  - **Mid-brain**: It serves important functions in **motor movement**, particularly **movements of the eye**, and **in auditory and visual processing**. It is **smaller compared to other regions**.
  - **Hind-brain**: It is the region composed of the **medulla oblongata**, **the pons**, and **the cerebellum** and coordinates functions **that are fundamental to survival** (including **respiratory rhythm**, **motor activity**, **sleep**, and **wakefulness**).
- The brain covered by meninges is well protected by the skull.

Musculoskeletal System

Muscles [UPSC 2013]

- Muscles are **specialised tissue of mesodermal origin** (**contributing 40-50 % of body weight in adults**).
- Have special properties like **excitability**, **contractility** (**involves ions like Ca++**, **Na+**), **extensibility** and **elasticity**.

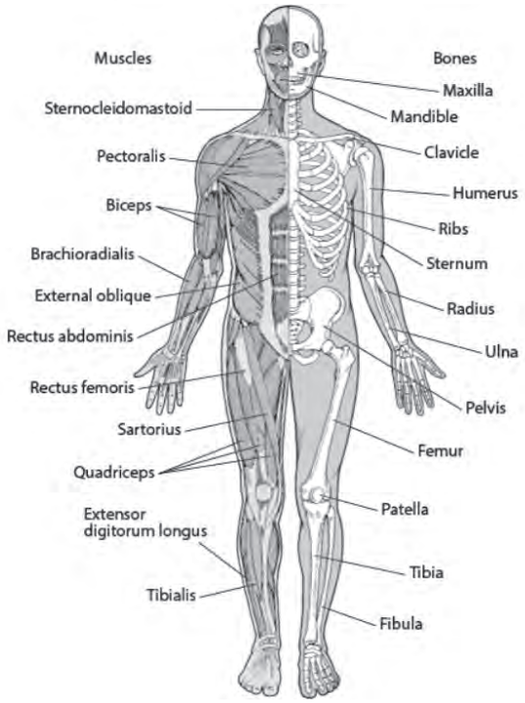


Fig: Human Musculoskeletal System

- **Types of muscles**:
  - **Skeletal muscles**: These are **attached to bones** (**responsible for skeletal movements**) and **are controlled by the peripheral portion of the central nervous system** (**CNS**) [**Hence, are voluntary/consciously controlled**]. The **muscle fibre with many nuclei** (**the basic unit of these muscles**) is **striated** (**has transverse streaks**), and **each fibre acts independently of the neighbouring fibre.**

- **Smooth muscle:** It is found in the walls of the **hollow internal organs** such as **blood vessels, the gastrointestinal tract**, **bladder**, and **uterus**, and **is under the control of the autonomic nervous system** [**is involuntary, slow** and **rhythmic**]. The **non-striated** (**smooth**) **muscle cell** is **spindle-shaped** and **has one central nucleus**.
- **Cardiac muscle**: It (**found in the walls of the heart**) is also **under the control of the autonomic nervous system**. The **cardiac muscle cell** has **one central nucleus**, **like smooth muscle**, but **it also is striated**, **like skeletal muscle**. The contraction of cardiac muscle is **involuntary**, **strong**, and **rhythmical**.

Skeleton

- The Human skeleton (**an internal skeleton**) serves as a **framework for the body** and **consists of many individual bones** and **cartilage along with bands of fibrous connective tissue- the ligaments** and **the tendons**.
- **The human skeleton consists of two principal subdivisions**:
  - **The axial skeleton-** comprising the vertebral column (spine and much of the skull.
  - **The appendicular skeleton-** to which the **pelvic** (**hip**) and **pectoral** (**shoulder**) **girdles** and **the bones and cartilages of the limbs** belong.
- **Joints:** Joints are points of contact between bones, or between bones and cartilages essential for movement and are **classified into three major structural forms**:
  - **Fibrous joints do not allow any movement** and are **shown by the flat skull bones** which fuse end-to-end to form **the cranium**.
  - **Cartilaginous joints** (**joints between the adjacent vertebrae**), the bones involved are **joined together with the help of cartilages permitting limited movements.**
  - **Synovial joints help in locomotion and many other movements** and are **characterised by the presence of a fluid-filled synovial cavity between the articulating surfaces of the two bones** allowing **considerable movement**. The **ball and socket joint** (**between the humerus** and **pectoral girdle**), **hinge joint** (**knee joint**), **pivot joint** (**between atlas** and **axis**), **gliding joint** (**between the carpals**) and saddle joint (**between carpal** and **metacarpal of thumb**) are some examples.
- An infant's body has about **300 bones at birth**, which eventually **fuse to form the 206 bones that human adults have.**

DISEASE

It is a **harmful deviation from the normal structural or functional state of an organism**, generally **associated with certain signs** and **symptoms** and **differing in nature from physical injury**.

The **study of disease** is called **pathology**. It involves the **determination of the cause** (**aetiology**) of the disease, the **understanding of the mechanisms of its development** (**pathogenesis**), the **structural changes associated with the disease process** (**morphological changes**), and the **functional consequences of those changes**. Based on **distinctions in the mode of acquiring diseases**, they can be classified as:

- **Idiopathic-** The initial cause (**unknown or spontaneous**) of the diseased state lies **within the individual organism itself**.
- **Iatrogenic-** It results from **a course of medical treatment**, either as an **unavoidable side effect** or as **a result of an ill-advised treatment**.
- **Non-communicable-** It may be caused by some **external agent** (e.g. **toxic compound**), and **it affects only the individual organism exposed to it.**
- **Communicable diseases-** These are **transmitted from one organism to another. Infectious diseases are diseases caused in the host by infection with living**, and **therefore replicating**, **microorganisms**, such as **animal parasites**, **bacteria**, **fungi**, **or viruses.**
- **Congenital disorders (birth defects, congenital anomalies or congenital malformations)- structural or functional anomalies** that **occur during intrauterine life.**
- **Genetic Diseases:** It **is a disease caused in whole** or **in part by a change in the DNA sequence away from the normal sequence**. Genetic disorders can be caused by **monogenic disorder- a mutation in one gene**, **multifactorial inheritance disorder- mutations in multiple genes**; combination **of gene mutations** and **environmental factors**; damage **to chromosomes- changes in the number/structure of entire chromosomes**.

Homeostasis: The **normal state of an organism which represents a condition of delicate physiological balance** (in terms of **chemical**, **physical**, and **functional processes**) maintained by **a complex of mechanisms.**

Communicable Diseases

Infectious diseases are a **leading cause of death in children** and **young adults worldwide**. **Lower respiratory infections**, **diarrhoeal diseases**, and **tuberculosis** are among the **most common and deadliest types of infectious diseases**. These are caused by **viruses** or **bacteria** (**and other microbial agents**) that people spread to one another **through contact with**

contaminated surfaces, **bodily fluids**, **blood products**, **insect bites**, or **through the air**. Based on the causative agents, these diseases can be classified as:

- **Bacterial**
- **Viral**
- **Parasitic**
- **Fungal**

Bacterial Diseases

Bacteria are **unicellular organisms** that **reproduce sexually** or **asexually** and c**an exist in an environment with oxygen** (**aerobic**) or in **a situation lacking oxygen** (**anaerobic**). Some may enter **a dormant state** and **form spores where they are protected from the environment** and **may remain viable for years**.

They include both **indigenous flora** (**normal resident**) **bacteria** and **pathogenic** (**disease-causing**) bacteria. Pathogenic bacteria cause disease by **invading, overcoming natural or acquired resistance, and multiplying in the body**.

Disease	Agent	Vector/ Transmission	Treatment/Prevention
Tuberculosis	Mycobacterium tuberculosis (**usually attacks lungs but can affect any part of body**)	Air-Borne	Bacille Calmette-Guérin (BCG) Vaccine
Diphtheria [UPSC 2014]	Corynebacterium diphtheriae	Person to person- usually through respiratory droplets	Diphtheria, tetanus, and pertussis (DTaP/DTP) vaccine
Cholera	Vibrio cholerae	Contaminated water or food	Dukoral Vaccine Adequate Sanitation
Leprosy (Hansen's Disease)	Mycobacterium leprae	Droplets (from nose and mouth)	Multidrug therapy (MDT)
Whooping cough (Pertussis)	Bordetella pertussis	Air-borne	Diphtheria, tetanus, and pertussis (DTaP/DTP) vaccine
Tetanus	Clostridium tetani	Through spores in environment	Diphtheria, tetanus, and pertussis (DTaP/DTP) vaccine
Plague	Yersinia pestis	• Flea bites • Direct Contact • Infectious Droplets	Sanitaion and rodent control
Gonorrhea	Neisseria gonorrhoeae	Sexually transmitted disease (STD)	Intramuscular ceftriaxone
Syphilis	Treponema pallidum	Sexually transmitted disease (STD)	Benzathine penicillin G
Typhoid (Enteric Fever)	Salmonella typhi	Contaminated drinking water and food	• Oral Vaccine • Injectable Vaccine
Pneumococcal Disease [UPSC 2020]	Streptococcus pneumoniae	Direct Contact-Respiratory Secretions	Pneumococcal Conjugate Vaccines (PCV13, PCV15, and PCV20)

Table: Bacterial Diseases

Viral Diseases [UPSC 2021, 2016,2013]

A virus is a **nucleic acid molecule** (**RNA** or **DNA**) **encapsulated in a protein coat or capsid**. **The virus is not a complete cell** and **can only replicate inside a living cell (bacteria**, **plants**, **fungi** etc.). The **capsid may have a protective lipid-containing envelope**. The **capsid and envelope facilitate attachment and penetration into host cells** (e.g., via **attachment to receptors like ACE 2**) **and often contain virulence factors**. Inside the **host cell**, **the nucleic acid molecule** utilises **cellular proteins** and **processes for virus replication**. Based on the **type of nucleic acids**, **viruses can be classified** as:

- **DNA viruses** (**e.g., Adenovirus**) contain usually double-stranded **DNA** (**dsDNA**) and rarely **single-stranded DNA** (**ssDNA**). These viruses replicate using **DNA-dependent DNA polymerase**.
- **RNA viruses** have typically **ssRNA** (**single-stranded RNA**) but may also contain **dsRNA**.
- **Retrovirus** [**e.g., Human Immunodeficiency Virus (HIV)**] **core** contains **several copies of reverse transcriptase bound to two identical single-stranded RNA molecules**.
- The key difference between **RNA Viruses** and **retroviruses** is that RNA viruses are **viruses that have single-stranded or double-stranded RNA as their genetic material,** while **retroviruses are viruses that have single-stranded RNA as their genetic material but use DNA intermediates in their life cycle.**

Disease	Agent	Vector/ Transmission	Treatment/Prevention
Dengue	Dengue virus (RNA Virus)	Aedes aegypti or Aedes albopictus female mosquitoes	Dengvaxia
Chikungunya **[UPSC 2013]**	Chikungunya virus (RNA Virus)	Aedes aegypti or Aedes albopictus female mosquitoes	Ixchiq
Poliomyelitis(Polio)	Polio virus (RNA Virus)	• Person to person: faecal-oral route. • Contaminated water/ food.	• Inactivated poliovirus vaccine (IPV) • Oral poliovirus vaccine (OPV)
AIDS **[UPSC 2019, 2013]**	Human Immunodeficiency Virus (HIV) [RNA Virus]	Exchange of body fluids (**excluding saliva**)	Anti Retroviral Therapy (ART) with: • Fostemsavir • Ibalizumab-uiyk • Lenacapavir • Lamivudine • Cabotegravir • Zidovudine etc.
Hepatitis- A, **B, C, D, E, G** **[UPSC 2019, 2013]**	Hepatitis- A, B, C, D, E, G Viruses [All are RNA viruses **except Hepatitis B- a DNA virus**]	• Hepatitis A and E- contaminated food or water • Hepatitis B, C, D, G- Parenteral contact with body fluids/blood	• HAV Vaccine • HBV Vaccine- also for Hepatitis D • **No Vaccines- Hepatitis C, E, G**
Chickenpox **[UPSC 2014]**	Varicella-Zoster Virus	Air-borne Direct Contact	Varivax, ProQuad (MMRV)
Ebola	• Zaire ebolavirus (**deadliest strain**) • Sudan ebolavirus • Taï Forest ebolavirus • Bundibugyo ebolavirus • All are RNA Viruses	Zoonosis & Body fluids	• Ervebo • Zabdeno+Mvabea
Nipah	Nipah virus (NiV) [RNA Virus]	Zoonosis, Direct contact and Food contaminated by body fluid of infected animals	No approved Vaccines

COVID-19	SARS-CoV-2 (many strains) [RNA Virus]	• Contact and droplet transmission • Air-borne • **Fomite transmission**	Covaxin, Covishield, Sputnik-V, **GEMCOVAC-OM** (**mRNA vaccine**)
Japanese encephalitis	Japanese encephalitis virus [RNA Virus]	Culex tritaeniorhynchus mosquitoes	Inactivated Vero cell culture-derived Vaccine (IXIARO)
Zika Fever	Zika Virus [RNA Virus]	Aedes aegypti or Aedes albopictus female mosquitoes	No approved Vaccines

Table: Viral Diseases

Prions: discovered in recent years (**Stanley Prusiner, Nobel Prize 1997**)**- are proteins**, which can induce disease [**Degenerative central nervous system** (**CNS**) **diseases**, including **spongiform encephalopathy in livestock** (**mad cow disease** and **scrapie in sheep**) and humans {**variant Creutzfeldt–Jakob Disease** (**vCJD**)}].

Parasitic Diseases

These are diseases caused by **protozoa**, **helminths**, and **arthropods** (**live within**, **on**, or **at the expense of a host**). Protozoa include unicellular organisms, such as the flagellates- **Giardia** and **Trichomonas**, and **amoebae-Entamoeba** (causing **enteric** and **gynaecological disorders**). **Sporozoa** are parasites with complex life cycles in different hosts, such as **Cryptosporidium** or **malarial parasites**. Helminths are worms that infest humans. Arthropods include **lice**, **fleas**, **sandflies**, **blackflies**, and **ticks**, and **they serve as important disease vectors**. Arthropods can live on the body's surface (**ectoparasites**) and transmit **bacterial**, **viral**, **rickettsial**, and **other diseases**.

Disease	Agent	Vector/ Transmission	Treatment/Prevention
Sleeping Sickness (Trypanosomiasis)	Trypanosoma brucei	Tsetse fly	Pentamidine
Chagas Disease	Trypanosoma cruzi	Triatomine bugs	No Vaccine
Ascariasis	Ascaris lumbricoides (Hookworm)	Soil-Transmitted Helminths (STH) [Worm Eggs- Faecal Route]	• Albendazole and Mebendazole
Elephantiasis (Lymphatic filariasis)	Wuchereria bancrofti, Brugia malayi, Brugia timori	Mosquitoes (various)	Diethylcarbamazine (DEC)
Kala-azar (Leishmaniasis)	Leishmania species (protozoans)	Phlebotomine Sand flies	Miltefosine
Malaria	• 5 **Plasmodium parasites- P. falciparum**, **P. vivax**, **P. malariae**, **P. ovale** and **P. knowlesi**. • **P. falciparum** is the **deadliest malaria parasite (common in Africa)** • **P. vivax** is dominant-**outside sub-saharan Africa.**	Anopheles mosquitoes	R21/Matrix-M and RTS, S against **P. Falciparum** (**not for other strains**)

Primary Amebic Meningoencephalitis (PAM)	Naegleria fowleri	Water containing Naegleria fowleri enters the nose (not by drinking)	Combination of Drugs
River Blindness (Onchocerciasis)	Onchocerca volvulus	Blackflies (Simulium)	Ivermectin

Table: Parasitic Diseases

Fungal Diseases

- **Mycoses** are **infections caused by moulds (molds) and yeasts**.
- **Clinical manifestations** of fungal disease range from **relatively mild superficial infection** to **systemic**, **life-threatening conditions**.
- **Immunocompromised individuals** (e.g. **those receiving chemotherapy** and **radiation for cancer treatment**) are at elevated risk.
- **Cryptococcus**, **Candida**, **Aspergillus**, and **Mucor moulds** or **fungi are among the leading causes of morbidity in HIV-positive patients.**
- **Pneumocystis jiroveci** (**formerly P. carinii-** causes **Pneumocystis pneumonia**), once t**hought to be a protozoan**, **is now classified a fungus**.
- **Common dermatophytic infections**, known as **tinea**, are caused by **fungi invading the hair**, **skin**, or **nails**, and **they occur in nearly all living organisms**.

Wolbachia Method [UPSC 2023]: Wolbachia are safe, **naturally occurring bacteria**, which have **evolved to live inside the cells of many insect species**. The **World Mosquito Program(WMP)** discovered that **Wolbachia blocks viruses like dengue, chikungunya and Zika from growing in the bodies of Aedes aegypti mosquitoes**. This means that **if Wolbachia is established in a mosquito population, it results in a decreasing incidence of dengue, Zika, and chikungunya**. **WMP** has been releasing **Wolbachia mosquitoes** in 14 countries for the last 12 years. When **Wolbachia mosquitoes are released, they breed with wild mosquitoes until, over 6-12 months, Wolbachia mosquitoes replace the local mosquito population.** Once Wolbachia is established in the population, **it stays there for many years, making Wolbachia a safe, one-time intervention**.

Non-communicable Diseases

These diseases generally are long-lasting and progress slowly, and **thus they are sometimes also referred to as chronic diseases**. They can arise from **environmental exposures** or f**rom genetically determined abnormalities**, which **may be evident at birth** or **which may become apparent later in life**. The **World Health Organization** (**WHO**) has identified four major types of noncommunicable diseases:

- **Cancer**
- **Cardiovascular disease** (e.g., **heart attack**, **stroke**)
- **Chronic respiratory diseases** [e.g., **Asthma**, **COPD** or **Emphysema** (**Chronic obstructive pulmonary disease- smoking is one of the causes**)]
- **Diabetes mellitus**
- Of all **NCD deaths**, **77% are in low- and middle-income countries**.
- **Cardiovascular diseases** account for most NCD deaths **(17.9 million annually**), followed by **cancers** (**9.3 million**), chronic respiratory diseases (**4.1 million**), and diabetes (**2.0 million- including kidney disease deaths caused by diabetes**).
- **Tobacco use**, **physical inactivity**, **the harmful use of alcohol**, **unhealthy diets** and **air pollution** all **increase the risk of dying from an NCD**.

WHO estimates that, combined, **these four groups of conditions account for 82 % of all deaths** from **non-communicable diseases**.

Nutritional Diseases

'**Nutritional inadequacy**' involves an **intake of nutrients that is lower than the estimated average requirement**, whereas '**nutritional deficiency**' consists of **severely reduced levels of one or more nutrients**, making **the body unable to normally perform its functions** and **thus leading to an increased risk of several diseases**. **Malnutrition** could be caused by **environmental factors**, **like food scarcity**, as well **as disease conditions**, like **anorexia nervosa**, **fasting**, **swallowing inability**, **persistent vomiting**, **impaired digestion**, **intestinal malabsorption**, or **other chronic diseases**.

- **Macronutrient deficiencies** could cause **kwashiorkor**, **marasmus**, **ketosis**, **growth retardation**, **wound healing**, and **increased infection susceptibility**.
- **Micronutrient** (like **iron**, **folate**, **zinc**, **iodine**, and **vitamin A** etc.) **deficiencies** lead to **intellectual impairment**, **poor growth**, **perinatal complications**, and **degenerative diseases.**

Preventing macro- and **micronutrient deficiency** is crucial, and **this could be achieved through supplementation and food-based approaches**.

Macronutrient Deficiency

Protein-Energy Malnutrition (PEM): It is a condition in which individuals have **very little dietary intake of proteins, energy** or **both**; it is **thus prevalent in developing countries** because of insufficient dietary intake. The two major diseases linked with this condition:

- **Marasmus:** It is **complete food deprivation** with **exceptionally limited quantities of protein** and **energy. Infants** with **marasmus are exceptionally underweight** (as they have lost almost all their subcutaneous fat)and **their body appears to be a combination of only bones and skin.**
- **Kwashiorkor:** It is characterised by **extreme protein deficiency** and appears in children that, after **being weaned from breast milk** (**containing high-protein**), are **fed carbohydrate-rich diet sources without sufficient protein intake**. The **main characteristic of kwashiorkor** is **swollen belly** caused by **fluid retention** (**edema**). Kwashiorkor **suppresses the production of insulin**, causing a reduced protein synthesis which leads to **hypoproteinemia**, **immunosuppression**, and **diarrhoea**.
- **Anthropometric Indicators for Child Malnutrition:**
  - **Stunting:** is **low 'height for age'.**
  - **Wasting:** is **less 'weight for height'.**
  - **Underweight:** is **less** '**weight for age'.**
- **Ketosis: Long-term insufficiency of carbohydrate intake** leads to ketosis (increased ketone production), which is **characterised by the peculiar sweet odour of the patient's breath**.
- **Essential Fatty Acid Deficiency: Omega-3** and **Omega-6** are **polyunsaturated** and **essential fatty acids** (**EFA**). Clinical symptoms of **EFA deficiency** include **diminished growth in children** and **infants**, **scaly dry rash**, **reduced wound healing**, and **increased infection susceptibility**. A **lower omega-3 index** is associated with **a higher risk of mortality by coronary heart disease**. Replacing other **dietary saturated fatty acids** (**SFAs**) with **Omega-6, PUFA decreases the total blood cholesterol.**

Micronutrient Deficiency

A **lower micronutrient consumption** than the **Recommended Dietary Allowance** might lead to **chronic metabolic disorders.** In industrialised and developing countries, **micronutrient deficiencies affect more than 2 billion people of all ages** (**especially pregnant women and children below 5 years of age**) and are linked with almost **10% of child deaths**.

- **Iron**, **folate**, **zinc**, **iodine**, and **vitamin A** are among **the most occurring micronutrient deficiencies** in the world.
- **Vitamin A (Retinol):** Symptoms of **vitamin A deficiency** include **xerophthalmia**, **Bitot spots development**, and **night blindness**. With the progression, **keratomalacia** and **permanent blindness** may take place.
- **Vitamin B1 (Thiamine):** Deficiency of this vitamin causes **Beriberi** which is of two types:
  - **Wet beriberi** affects the cardiovascular system.
  - **Dry beriberi** can **damage the central nervous system** (**CNS**) and **disrupt motor functioning** (**the movement of the muscles**). It can also cause **impaired reflexes** and **numbness in the extremities.**
- **Vitamin B3 (Niacin):** Its deficiency results in a condition known as **pellagra** (triad of **dermatitis**, **dementia**, and **diarrhoea**)
- **Vitamin B6 (Pyridoxine):** It causes **anaemia**, **peripheral neuropathy**, **seborrheic dermatitis**, **glossitis**, **cheilosis**, **depression**, **celiac disease**, **Crohn's disease**, and **seizures**.
- **Vitamin B12 (Cobalamin):** Its deficiency can lead to **megaloblastic anaemia**, **fatigue**, **weakness** etc.
- **Vitamin B9 (Folic acid, Folate):** Untreated folic acid deficiency can lead to **megaloblastic anaemia**, **pancytopenia**, **glossitis**, **angular stomatitis**, and **oral ulcers.**
- **Vitamin C (Ascorbic acid) [UPSC 2014]:** is considered **an essential nutrient** (**derived from the diet**); its deficiency causes **scurvy** (**gum disease**) and could also lead to **behavioural** and **mood changes**.
- **Vitamin D (Calciferol) [UPSC 2014]:** Its deficiency causes **hypocalcemia** and **hypophosphatemia**, which lead to **osteomalacia among adults** and **rickets among children.**
- **Vitamin E (Alpha-tocopherol) [UPSC 2014]:** The major characteristics of **vitamin E deficiency** (**which is rare**) include **ataxia**, **myopathy,** and **pigmented retinopathy**, like **retinitis pigmentosa** with **vision loss**.
- **Vitamin K (Phylloquinone, Menaquinone):** Its deficiency leads to **coagulation disorder**. In newborns, vitamin K deficiency is called '**hemorrhagic disease of the newborn**'.
- **Calcium:** A **long-standing calcium deficiency** can lead to **cataracts**, **dental changes**, **brain alterations**, **osteoporosis**, and **rickets**.
- **Iron:** Iron is a major contributor to haemoglobin synthesis, depletion of its reserves leads to **microcytic hypochromic anaemia**, characterised by **smaller red blood cells** containing a **lesser haemoglobin**.
- **Iodine:** Iodine is a trace element that plays **a major role in thyroid hormone synthesis**, and its **deficiency can cause Goiter (Goitre)**.
- **Zinc:** Zinc deficiency symptoms can include **skin lesions**, **increased susceptibility to infection**,

diarrhoea, **poor appetite**, **night blindness**, **reduced taste** and **smell acuity**, **hair loss**, **low sperm count**, **impotence**, and **slow wound healing.**

- **Magnesium:** Its deficiency is linked with **colorectal cancer**, **osteoporosis**, **hypertension**, **metabolic syndrome**, and **diabetes**.
- **Selenium:** Its deficiency can lead to **Keshan disease** (**cardiomyopathy**) and **Kashin-Bek disease** (**deforming arthritis**) and has a negative impact on **spermatogenesis**, **immunocompetency**, **thyroid function**, **cardiovascular diseases**, and **mood swings.**
- **Fluoride:** Its deficiency can lead to **dental caries** and **bone problems.**
- **Biotin:** Its deficiency leads to **metabolic acidosis**, **conjunctivitis**, **ataxia**, **organic aciduria**, **developmental delay**, **encephalopathy**, **sensorineural hearing loss**, **seizures**, **periorificial dermatitis**, and **alopecia.**

Food Fortification

It is **the practice of adding vitamins and minerals to commonly consumed foods during processing to increase their nutritional value** and **is a proven, safe and cost-effective strategy for improving diets** and **for the prevention and control of micronutrient deficiencies**. The main fortification vehicles are as follows:

- **Large-Scale Food Fortification** (**LSFF**): It is the addition of micronutrients during processing to commonly consumed foods such as **salt** (**folic acid**), **flour** (**folic acid**), **oil** (**vitamin A**), **sugar** (**vitamin A**), **milk** (**vitamin A & D, iron, calcium and folic acid**), and **condiments**. These can be categorised as:
  - **Mandatory:** initiated and regulated by the government- fortified flour and iodised salt.
  - **Voluntary:** Food processors **add nutrients to the foods of their own volition** but are governed by regulatory limits.
- **Biofortification:** It is the process in which food crops with improved nutritional value are grown, and these projects mainly concentrate on **boosting iron**, **zinc**, **amino acids** and **provitamin A carotenoid** in different food crops. Examples include **iron biofortification of rice, beans, maize and sweet potato**; **zinc biofortification of wheat, rice, beans, sweet potato and corn**; and **Vitamin A biofortification of sweet potatoes, corn and cassava**.
- **Point-of-Use or Home Fortification:** It is the addition of **vitamins** and **minerals** to **food that has been cooked and is ready to be eaten** achieved by sprinkling **micronutrient powders** (**MNPs**). **MNPs are single-dose packets containing multiple vitamins and minerals** in powder form that can be sprinkled onto food **without affecting the taste or colour.**

Indian Council of Agricultural Research (ICAR) has developed more than **20 varieties of biofortified crops,** including **wheat, rice, maize, millet, mustard, and groundnut,** having **1.5 to 3 times higher levels** of **nutrients compared to the traditional varieties**. It is **worth noting that these varieties are not genetically modified- they have been developed through conventional crop breeding techniques.**

Probiotics are **foods/ supplements** that contain **live microorganisms** (**Bacteria**, **Yeast**) intended to maintain or improve the '**good**' **bacteria** (**normal microflora**) in the body. **[UPSC 2022]**

Prebiotics are **non-digestible food components** that selectively **stimulate the growth or activity of desirable microorganisms** in the human body.

Synbiotics are **products that combine probiotics** and **prebiotics**.

IMMUNITY

It is the **means by which the body recognises and resists infection resulting from the presence of specific foreign antigens on the surface of bacteria, viruses, fungi, or other toxins, chemicals, drugs or foreign objects**, e.g., a splinter, which may be harmful.

- **Humoral** (**blood**) **immunity** is activated by **B lymphocytes**, which produce antibodies (**complement proteins, or cells that act on the microorganism associated with a specific disease, toxin, or foreign body**). **[UPSC 2022]**
- The **body also reacts to infective antigens with cellular responses, including those that directly defend against invading organisms and other cells which produce antibodies**. **T lymphocytes** attack antigens directly and assist with chemicals controlling the **immune response** (**cytokines**). **[UPSC 2022]**
- **Inflammation** attracts **white cells** (**macrophages** and **neutrophils**), which act as **phagocytes to kill germs** and **dead** or **damaged cells**.

Terms in Immunology of Infectious Diseases

- **Infectious agent**: a pathogenic organism (e.g., **virus**, **bacterium**, **rickettsia**, **fungus**, **protozoa**, **helminth**, **pollen**, or **chemical**) is one capable of producing infection or infectious disease in humans.
- **Infection**: the **process of entry, development, and proliferation of an infectious agent in the body tissue of a living organism overcoming the host's defence mechanisms, resulting in a non-apparent or clinically manifest disease.**
- **Antigen**: any substance (e.g., **protein**, **polysaccharide**) which causes the immune system to produce antibodies against it.

- **Antibody**: A **protein molecule produced by the body's immune system** in response to a **harmful foreign substance** (**an antigen**) or acquired by passive transfer. Antibodies bind **to the specific antigen that elicits their production, causing the infective agent to be susceptible to immune defence** mechanisms against infections (e.g., humoral and cellular). A**ntibodies may also form against one's own tissue, producing an autoimmune disorder.**
- **Innate immunity**: Includes the **cough reflex**, **skin**, **mucus**, and **stomach acidity** as **barriers** which protect the body against infection.
- **Acquired immunity**: It is **developed as a result of natural exposure or deliberate exposure by immunisation to an infectious agent or its antigenic components,** which **protects against later exposure to the active live agent**.
- **Passive immunity**: The **transfer of antibodies produced in another body**, such as **maternal antibodies transferred from the mother to her fetus via the placenta to provide protection for part of the first year of life** or by **antiserum** or **antitoxin of antibodies from another person to give short-term protection against an antigen** such as **serum globulin against hepatitis infection** or **tetanus antiserum**.
- **Immunoglobulins**: Molecules **produced by plasma cells in response to an antigen challenge** and are **present in blood or other body fluids**. There are **five major classes** (**IgG**, **IgM**, **IgA**, **IgD**, and **IgE**) and **subclasses based on molecular weight**. They **can cross from a mother to a fetus in utero to provide passive immunity to the fetus.**
- **Antisera or Antitoxin**: Materials **prepared in animals for use in passive immunisation against infection or toxins**.
- **Cellular immunity (cell-mediated immunity)**: Immunity acquired with **T lymphocyte cells producing chemicals which activate natural killer cells** (**macrophages**).
- **Herd immunity: Resistance of a group to an infectious disease** when **a large percentage of the population at risk is immune through previous exposure to the disease or by immunisation**.
- **Immunotherapy**: It is **a type of cancer treatment that helps your immune system fight cancer.**
- **Monoclonal Antibodies:** These are **antibodies** (**looking for a certain antigen**) that **have been generated artificially to help the body's natural immune system**. In the lab, monoclonal antibodies are made by **exposing white blood cells to a specific antigen**. To enhance the amount of antibodies produced, a single white blood cell is cloned, and identical copies of the antibodies are created.

VACCINE

It is a suspension of **weakened**, **killed**, or **fragmented microorganisms** or **toxins** or **other biological preparations** [such as **those consisting of antibodies**, **lymphocytes**, or **messenger RNA** (**mRNA**)] that is administered **primarily to prevent disease**. Vaccines may confer:

- **Active immunity** against a specific harmful agen**t by stimulating the immune system to attack the agent. Once stimulated by a vaccine**, **the antibody-producing cells** [**called B cells** (**or B lymphocytes**)] **remain sensitised** and **ready to respond to the agent should it ever gain entry to the body**.
- **Passive immunity** by **providing antibodies or lymphocytes already made by an animal or human donor.**

Vaccines are usually administered by **injection** (**parenteral administration**)**,** but some are **given orally** or **even nasally** (**e.g. flu vaccine**)**.** Various types of vaccines developed till now include:

- **Weakened or Attenuated vaccines:** These **consist of microorganisms that have lost the ability to cause serious illness but retain the ability to stimulate immunity** (**may produce a mild or subclinical form of the disease**). Attenuated vaccines include those for **measles**, **mumps**, **polio** (**the Sabin vaccine**), **rubella**, and **tuberculosis**.
- **Inactivated vaccines:** These are those that contain organisms **that have been killed or inactivated**. Inactivated **vaccines elicit an immune response which is less complete than with attenuated vaccines**; hence **greater quantities of inactivated vaccines are administered**. Vaccines against **rabies**, **polio** (**the Salk vaccine**), some **forms of influenza**, and **cholera** are made from inactivated microorganisms.
- **Subunit vaccine:** It **is made from proteins found on the surface of infectious agents**. Toxins (the metabolic by-products of infectious organisms) are inactivated to form toxoids and used to stimulate immunity against **tetanus**, **diphtheria**, and **whooping cough** (**pertussis**).
- **Recombinant DNA technology [UPSC 2021]:** It has also proven useful in **developing vaccines for viruses** that cannot be **grown successfully** or **that are inherently dangerous**. **Genetic material that codes for a desired antigen is inserted into the attenuated form of a large virus**, such as **the vaccinia virus**, **which carries the foreign genes 'piggyback'.** The **altered virus is injected into an individual to stimulate antibody production to the foreign proteins** and **thus confer immunity**. Vaccines against **human papillomavirus** (HPV) are

made from **viruslike particles (VLPs) prepared via recombinant technology.**

- **Naked DNA therapy:** It involves **injecting DNA that encodes a foreign protein into muscle cells.** The **cells produce the foreign antigen, which stimulates an immune response.**
- **Messenger RNA vaccine (mRNA vaccine): mRNA is a molecule that contains the instructions or recipe that directs the cells to make a protein** using its natural machinery. To **enter cells smoothly, mRNA travels within a protective bubble called a Lipid Nanoparticle.** Once inside, **our cells read the mRNA as a set of instructions, building proteins that match up with parts of the pathogen called antigens**. The **immune system sees these foreign antigens as invaders- dispatching defenders called antibodies and T-cells**- and **training the immune system for potential future attacks** conferring immunity. **GEMCOVAC-19** is **India's first home-grown mRNA Covid-19 vaccine.**

ANTIMICROBIAL RESISTANCE (AMR)

Antimicrobials (including **antibiotics**, **antivirals**, **antifungals**, and **antiparasitics**) are **medicines used to prevent and treat infectious diseases in humans, animals and plants.**

- **Antimicrobial Resistance** (**AMR**) occurs when **microbes** (**bacteria**, **viruses**, **fungi** and **parasites**) no longer respond to **antimicrobial medicines**.
- As a result of **drug resistance**, **antibiotics and other antimicrobial medicines become ineffective, and infections become difficult or impossible to treat.**
- **AMR is a natural process** that happens over time **through genetic changes in pathogens.**
- **However, its emergence and spread is accelerated by human activity, mainly the misuse and overuse of antimicrobials. [UPSC 2019]**
- **Superbugs are strains of bacteria that are resistant to several types of antibiotics.**
- **Each year, these drug-resistant bacteria infect more than 2 million people nationwide and kill at least 23,000, according to the U.S. Centers for Disease Control and Prevention (CDC).**
- Drug-resistant forms of **tuberculosis**, **gonorrhoea**, and **staph infections** are just a few of the dangers we now face.
- Other examples of **superbugs** include **resistant bacteria** that can cause **pneumonia**, **urinary tract infections** and **skin infections**.
- **Vaccines can contribute to the fight against AMR** by **preventing microbial diseases** and **their transmission reducing antibiotic misuse**.

ONE HEALTH APPROACH

It calls for a holistic, integrated and systems-based approach **that recognises the interconnection between the health of humans, animals and the environment.** Focus on the **one health initiative has increased to address the complex health challenges such as ecosystem degradation**, **food system failures**, **zoonotic diseases** and **antimicrobial resistance** (**AMR**) faced by our society today.

One Health Joint Plan of Action (2022-26)

- Recently, four multilateral agencies, **FAO, UNEP, WHO and World Organisation for Animal Health,** have launched a One Health Joint Plan of Action (2022-26) (**OH JPA**).
- The plan is aimed at mitigating the health challenges at global, regional, and country levels.
- It will create a framework and integrate systems and capacity to collectively better prevent, predict, detect and respond to health threats to all living beings as well as the environment.

National One Health Mission(India)

India envisaged **'National One Health Mission'** under **the Office of the Principal Scientific Advisor.**

- **Objective:** To coordinate, support, and integrate all existing **One Health initiatives in the country.**
- The government launched the **" Animal Pandemic Preparedness Initiative (APPI)"** as well as the **World Bank-funded Animal Health System Support for One Health (AHSSOH) project** under the aegis of the National One Health Mission

Zoonosis is an infectious disease **that has jumped from a non-human animal to humans**. Zoonotic pathogens may be **bacterial**, **viral** or **parasitic**, or **may involve unconventional agents** and **can spread to humans through direct contact or through food, water or the environment**.

- It's estimated that **60% of known infectious diseases** and up to **75% of new or emerging infectious diseases are zoonotic in origin**.
- Some of the **most dangerous zoonotic diseases worldwide** include **COVID-19**, **avian flu**, **salmonellosis** and the **Ebola virus disease** (**Ebola**).
- Zoonotic diseases common in India include **Nipah virus infection**, **rabies**, **anthrax**, **brucellosis**, **plague**, **bovine tuberculosis**, **leptospirosis** and **salmonellosis**.
- **Deforestation and other land use changes**, **Intensified agriculture and livestock production**, **Illegal or poorly regulated wildlife trade**, **Climate change**, and **Antimicrobial Resistance** are some of the factors which have **contributed to an increase in the emergence of zoonotic diseases**.

3 Information and Communication Technology and Electronics

DEVELOPMENTS IN THE FIELD OF ICT

- **The Metaverse**: It is a collective virtual shared space that can be accessed by different devices and platforms.
  - It is a fusion of augmented reality (AR), virtual reality (VR), and the internet, creating immersive and interactive experiences for users.
  - It has many potential applications, such as entertainment, education, social networking, e-commerce, and digital art.
- **Software 2.0**: It is a term that refers to machine-written code, which is generated by artificial intelligence (AI) models based on data and specifications.
  - It can automate the development process, reduce errors, and optimize performance. It can also enable new services and products, such as autonomous vehicles, smart homes, and natural language processing.
- **Blockchain**: It is a distributed ledger technology that enables secure and transparent transactions without intermediaries. **[UPSC 2020]**
  - Application: Digital identity, smart contracts, supply chain management, and decentralized finance.
- **Internet of Things (IoT)**: It is the network of physical objects that are embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems. **[UPSC 2018]**
  - Applications: smart cities, smart agriculture, smart manufacturing, and smart healthcare.
- **Quantum Computing**: It is a new paradigm of computation that uses quantum mechanical phenomena, such as superposition and entanglement, to perform operations on quantum bits (qubits). **[UPSC 2022]**
  - It can potentially solve problems that are intractable for classical computers, such as optimization, cryptography, machine learning, and simulation.
  - It can also accelerate scientific discovery and innovation in various fields, such as physics, chemistry, biology, and medicine.
- **Facial Recognition System (FRS)**
  - FRS is part of the Digi Yatra initiative (Ministry of Civil Aviation) to promote seamless and hassle-free experience at airports and simultaneously, improving the security.
  - Digi Yatra Foundation (DYF) has been set up as a joint venture company for creating the Digi Yatra Central Ecosystem.
  - FRS is a way of identifying or confirming an individual's identity using their face. It can be used to identify people in photos, videos, or in real-time.
  - First phase of Facial Recognition System (FRS) is planned at Kolkata, Varanasi, Pune, Vijayawada, Bangalore, Delhi and Hyderabad Airports by March 2023.
- **Wearable Devices:** These are electronic devices that are worn as accessories, embedded in clothing, or even implanted in the body to monitor and collect data related to health, fitness, location, and other aspects. **[UPSC 2019]**

Wearable Devices

Fitness Trackers: To monitor physical activity, track steps, measure heart rate, and estimate calorie expenditure. **E.g.,** Fitbit, Garmin, Apple Watch.

Smartwatches: Combine features of traditional watches with additional functionalities like notifications, apps, and health tracking. **E.g.,** Apple Watch, Samsung Galaxy Watch, Garmin Venu.

Health Monitoring Devices: Track vital signs and health metrics for medical purposes. **E.g.,** Wearable heart rate monitors, continuous glucose monitoring (CGM) devices, ECG monitors.

Smart Clothing: Embed sensors and technology directly into clothing for various applications, including fitness tracking and health monitoring. **E.g.,** Smart shirts, sports bras with built-in heart rate monitors.

Augmented Reality (AR) Glasses[UPSC 2019]: Overlay digital information onto the user's physical environment, enhancing their perception of reality. **E.g.,** Google Glass, Microsoft HoloLens.

Virtual Reality (VR) Headsets [UPSC 2019]: Immerse users in virtual environments for entertainment, gaming, training, or therapy. **E.g.,** Oculus Rift, HTC Vive, PlayStation VR.

Smart Jewelry: Combine fashion accessories with technology, often providing notifications and health tracking features. **E.g.,** Smart rings, bracelets, and necklaces.

GPS Trackers: Provide location tracking and navigation assistance. **E.g.,** GPS-enabled smartwatches, fitness trackers with GPS capabilities.

Wearable Cameras: Capture photos and videos from the user's perspective. **E.g.,** GoPro cameras, Snap Spectacles.

Brain-Computer Interface Devices: Monitor brain activity or enable communication between the brain and external devices. **E.g.,** EEG headsets, neuroprosthetics.

Supercomputers in India

- As of June 2023, the **AIRAWAT supercompute**r is the fastest supercomputer in India, having been ranked **75th fastest** in the world in the TOP 500 supercomputer list. It has been installed at the Centre for Development of Advanced Computing (C-DAC) in Pune.
- India has a **National Supercomputing Mission** that aims to increase the country's research capability and skills by connecting various institutions with a supercomputer network.

BharOS

- It is an Indian government-funded project to develop a free and open-source operating system (OS) for use in government and public systems.
- It is an Android Open Source Project based operating system which is developed by JandK Operations Private Limited. (The JandKops is a non-profit organization incubated at IIT Madras).

Displays

It is a device that displays text and graphics on a screen, allowing the user to see the output of a computer or another device.

Some Popular Displays

- **LED (light-emitting diodes) Display:** It is a type of flat-panel display that uses light-emitting diodes (LEDs) as pixels to create images or text.
  - They are bright, energy-efficient, and durable, and they can be used for various applications such as outdoor signs, billboards, video walls, and stage lighting.
  - They can produce a wide range of colors and contrast levels by adjusting the intensity and color of the LEDs.
- **OLED (Organic Light-Emitting Diode) Display**: This type of display uses a **layer of organic materials** that emit light when an electric current is applied. **[UPSC 2017]**
  - Unlike LCDs, OLEDs do not need a backlight, as each pixel can produce its own light. This allows OLEDs to have better contrast, wider viewing angles, and thinner designs.
  - These are used in some TVs, monitors, laptops, and smartphones. These can produce vivid and realistic colors, but they may have issues with brightness, lifespan, and burn-in.
- **Plasma Display**: This type of display uses a **layer of gas** that is ionized by an electric current to create plasma. The plasma then excites phosphors that emit light to create an image.
  - They are mainly used in large TVs.
  - It can produce high contrast, wide viewing angles, and fast response times, but they may have issues with power consumption, heat generation, and image retention.
- **CRT (Cathode Ray Tube)**: This type of display uses a **vacuum tube** that shoots electrons at a phosphor-coated screen to create an image.
  - They are the **oldest and most traditional type of display**, and they are mostly used in old TVs and monitors.
  - They can produce high contrast, wide color gamut, and low input lag, but they may have issues with size, weight, resolution, and radiation.
- **MicroLED Display**: This type of display uses **microscopic LEDs** that can emit light individually to create an image.
  - These are similar to OLED displays, but **they use inorganic materials** instead of organic ones.
  - These are still in development, and they are expected to offer better brightness, efficiency, and durability than OLED displays.
- **Quantum Dot Display:** It is a type of LCD that **uses tiny semiconductor nanocrystals,** known as quantum dots, to produce more accurate and vibrant colors than traditional LCDs.
  - Quantum dots are excited by the blue light from the display panel to emit pure red, green, and blue light, which reduces light losses and color crosstalk in color filters, improving display brightness and color gamut.
  - They present a favorable **alternative to super-premium Organic LED displays (OLEDs),** but usually at less cost, and with none of the technical issues and limitations that OLED introduces.

Types of Communication

- **Wired Telecommunication**
  - **Copper Wires:** Traditional telephone networks often use copper wires to transmit analog signals. These wires have been widely used for landline telephony.
  - **Fiber Optic Cables:** They use light signals to transmit data over long distances at high speeds. They are commonly used for high-speed internet connections, telephone networks, and cable television.
  - **Coaxial Cables:** They are used for transmitting cable television signals and internet data. They consist of a copper conductor surrounded by insulation and a metallic shield.
- **Wireless Telecommunication**
  - **Radio Waves:** Wireless communication often relies on radio waves to transmit information. This includes technologies like radio broadcasting, walkie-talkies, and mobile phones.
  - **Microwaves:** These are used for point-to-point communication over long distances, such as in satellite communication.
  - **Infrared Communication:** Infrared signals are used for short-range communication, such as in remote controls for TVs and other electronic devices.
  - **Bluetooth:** It is a short-range wireless communication technology used for connecting devices like smartphones, headphones, and other peripherals.
  - **Wi-Fi:** It enables wireless local area networking (WLAN) and is widely used for internet access in homes, businesses, and public places.

Fiber Optic Cables

They are made of glass fibers that carry data as pulses of light. These fibers are incredibly thin and are surrounded by protective layers to prevent damage.

Advantages:

- **High Bandwidth:** Fiber optic cables offer significantly higher bandwidth than copper cables, enabling faster data transmission speeds.
- **Long Transmission Distances:** Signals can travel over longer distances with minimal signal degradation.
- **Lower Attenuation:** Fiber optic cables experience less signal attenuation than copper cables, resulting in clearer and more reliable data transmission.
- **Immunity to Interference:** They are less susceptible to electromagnetic interference than copper cables, making them ideal for use in environments with electrical noise.
- **Security:** Fiber optic cables are more difficult to tap into than copper cables, providing enhanced security for sensitive data transmission.

Digital Terrestrial Television Transmission System

It is a system for transmitting television signals using digital coding, as opposed to the analog signals used in the past. It offers several advantages over analog television, including:

- **More Efficient use of the Radio Spectrum:** DTT signals can be compressed more efficiently than analog signals, which means that more channels can be transmitted using the same amount of spectrum.
- **Better Picture and Sound Quality:** DTT signals are less susceptible to interference than analog signals, which results in a clearer picture and better sound quality.
- **More Programming Options**: DTT allows broadcasters to offer more channels and services, such as high-definition television (HDTV) and interactive television**.**

Networks

- **Fifth Generation (5G):** The ongoing development and deployment of the fifth generation (5G) of cellular networks involve the use of **millimetre wave** (mmWave) or sub-6 GHz frequencies, enabling massive multiple-input multiple-output (MIMO) and beamforming within a cell.
  - Promising ultra-fast data speeds, low latency, and massive connectivity, 5G networks target a maximum data rate of 10 Gbps.
  - Their goal is to enhance the efficiency, flexibility, and diversity of 4G networks.
- **Sixth Generation (6G):** As the successor to 5G cellular technology, the sixth-generation wireless (6G) is currently under development.
  - 6G networks are expected to utilise **terahertz** (THz) frequencies or optical wireless communication (OWC) to achieve extremely large aperture terminal (ELAT) and intelligent reflecting surface (IRS) within a cell.

- Offering significantly higher capacity and lower latency than 5G networks, 6G aims for a maximum data rate of 1 Tbps.
- The aspirations for 6G include enabling immersive reality, quantum communication, and applications of artificial intelligence.

Difference between LTE and VoLTE [UPSC 2019]

Long Term Evolution(LTE)	Voice over LTE (VoLTE)
A data communication system	A data communication system to overcome LTE
A type of network	A service offered on the network
May or may not support data and voice call together	Always supports data and voice call together
The quality of voice calling is not good	The quality of voice calling is HD
Turns off the data connection while making voice calls	Does not turn off the data connection while making voice calls
Call connection between two users is slower (almost takes 7 seconds)	Call connection is faster if both users are on VoLTE
External applications are required to make video calls	No external applications are required to make video calls. Gives better battery life than LTE

Satellite Phones

A satellite phone or satphone, is a phone that works by connecting to a telecommunications satellite in space.

Satellite Phones vs Normal Phones

Feature	Satellite Phones	Normal Phones
Connectivity	Connect to satellites orbiting the earth	Connect to cell towers on the ground
Coverage	Better in remote areas where there are no cell towers	Better in urban areas where there are many cell towers
Durability	More Durable	More fragile and can be damaged by water, dust, or impacts
Functions	Mostly used for voice calls and text messages	Have many more features and functions, such as internet access, mobile apps, cameras, etc

India Semiconductor Mission

It is a specialized and independent Business Division within the Digital India Corporation that aims to build a vibrant semiconductor and display ecosystem to enable India's emergence as a global hub for electronics manufacturing and design.

Components of the Mission

- **Scheme for setting up of Semiconductor Fabs in India:** This scheme provides fiscal support of up to 50% of the project cost to the eligible applicants for setting up of semiconductor wafer fabrication facilities in the country.
- **Scheme for setting up of Display Fabs in India:** This scheme provides fiscal support of up to 50% of the project cost, subject to a ceiling of INR 12,000 crore per fab, to the eligible applicants for setting up of TFT LCD/AMOLED based display fabrication facilities in the country.
- Scheme for setting up of **Compound Semiconductors/ Silicon Photonics/ Sensors Fab and Semiconductor Assembly, Testing, Marking and Packaging (ATMP)/ OSAT facilities in India:** This scheme provides fiscal support of 30% of the capital expenditure to the eligible applicants for setting up of compound semiconductors/silicon photonics/sensors (including MEMS) fab and semiconductor ATMP / OSAT facilities in India.
- **Design Linked Incentive (DLI) Scheme:** This scheme offers financial incentives, design infrastructure support across various stages of development and deployment of semiconductor design for integrated circuits (ICs), chipsets, system on chips (SoCs), systems and IP cores and semiconductor linked design.

Different Types of Computer Networks

Personal Area Network (PAN)

- A PAN is the smallest and most personal type of network. It is typically used for communication among devices like smartphones, tablets, laptops, and personal computers within the range of an individual person, typically within a range of about 10 meters (33 feet).
- Personal Area Networks are classified into two types:
  - **Wireless Personal Area Network**: They are created by utilizing wireless technologies such as WiFi and Bluetooth. It is a network with a short range.
  - **Wired Personal Area Network:** The USB is used to create a wired personal area network.

Local Area Network (LAN)[UPSC 2022]

- It is a network that is limited to a small geographic area, such as a single building, a campus, or a group of nearby buildings.
- Thay are often used for connecting computers and devices within a home or office to share resources and information. **E.g.,** An office network where computers are connected to a shared printer and server.

Metropolitan Area Network (MAN)

- It has a larger geographic scope than a LAN but is smaller than a WAN. It typically covers a city or a large campus, connecting multiple buildings within a city or a large campus area. **E.g.,** A university campus network connecting various departments and buildings.

Wide Area Network (WAN)

- It covers a broad area, often spanning across cities, countries, or even continents. It connects multiple LANs and MANs, allowing for the exchange of data over long distances. **[UPSC 2022] E.g.,** The Internet itself is a global WAN, connecting networks worldwide.

Storage Area Network (SAN)

- It is a dedicated high-speed network that provides access to consolidated, block-level data storage. It enables multiple servers to access a shared pool of storage resources.
- These are commonly used in enterprise environments to enhance storage management and improve accessibility.

Virtual Private Network (VPN)

- It is a technology that allows secure and encrypted communication over an untrusted network, such as the internet.
- It enables users to connect to a private network (like a corporate network) from a remote location securely. These are often used to ensure the confidentiality and integrity of data transmitted over public networks.

Intranet

It is a private network within an organization that uses internet technologies but is isolated from the public internet. It is used for internal communication, collaboration, and sharing of resources among employees within the organization.

Extranet

It is a controlled extension of an organization's intranet that provides limited access to external parties, such as customers, suppliers, or partners. It allows for secure collaboration and information sharing between the organization and its authorized external users.

Various Wireless Communication Technologies

- **Bluetooth:** Short-range wireless technology for connecting devices, commonly used for data transfer between devices like smartphones, headphones, and speakers.
- **Wi-Fi Direct:** Allows devices to connect to each other directly without the need for a traditional Wi-Fi network. It's useful for peer-to-peer communication between devices.
- **Cordless Phone:** Typically uses DECT (Digital Enhanced Cordless Telecommunications) technology for short-range wireless communication between a phone and its base station.
- **Hotspot:** A physical location where people can access the internet, typically using Wi-Fi, through a wireless local area network (WLAN) with a router connected to an internet service provider.
- **Wi-Fi:** Wireless local area networking technology that allows devices to connect to the internet and communicate with each other within a certain range of a Wi-Fi router or access point.
- **WiMAX (Worldwide Interoperability for Microwave Access):** A wireless communication standard that provides high-speed, long-range broadband connections. It's designed for wireless metropolitan area networks (WMANs).
- **Li-Fi:** A wireless communication technology that uses light to transmit data. It is a form of visible light communication (VLC) and can provide high-speed, bi-directional communication.

Difference between LiFi and WiFi [UPSC 2016]

Feature	LiFi	WiFi
Data transmission medium	Light (visible light spectrum)	Radio waves (electromagnetic spectrum)
Speed	Potentially much faster (theoretical speeds up to 224 Gbps)	Limited by the radio spectrum (typical speeds up to 10 Gbps)
Security	High, data cannot penetrate walls or travel far from the light source	Moderate, data can be intercepted by devices within range
Coverage	Limited to the area illuminated by the LiFi light source	Can cover larger areas with appropriate infrastructure
Energy efficiency	More energy efficient, uses existing LED lights	Less energy efficient, requires separate routers and antennas
Applications	Ideal for high-density environments like offices, classrooms, airplanes, and hospitals	Well-suited for general wireless connectivity in homes, businesses, and public spaces

- **Zigbee:** It is a low-power, low-data-rate wireless communication protocol commonly used for short-range communication between devices in applications like home automation, industrial control, and sensor networks.
- **Infrared (IR):** It involves the use of infrared light for wireless data transfer. It's **commonly found in TV remote** controls and some short-range communication applications.
- **NFC (Near Field Communication):** It is a short-range wireless communication technology that enables data exchange between devices when they are in close proximity (typically within a few centimeters). It's often used for contactless payments, file sharing, and access control. **[UPSC 2015]. E.g.,** cardless payments through Samsung Pay, Google Pay
- **RFID (Radio-Frequency Identification):** It **uses radio waves** to identify and track objects. It is used in logistics, inventory management, and access control systems. **[UPSC 2022]**

RFID

It is a technology that uses electromagnetic waves to identify and track tags attached to objects. An RFID system consists of a tag, which contains a microchip and an antenna, and a reader, which emits radio signals and receives the tag's response. RFID tags can store various kinds of data, such as serial numbers, product information, or personal identification. **Example:** FASTag.

Working of RFID

- RFID works by using radio waves to communicate between a tag and a reader. A tag is a small device that contains a microchip and an antenna.
- A reader is a device that emits radio signals and receives the tag's response.
- The tag can store and transmit data, such as an identification number or product information, to the reader.
- The reader can then process the data or send it to a computer system for further analysis.

Comparison of ITU and ICANN

International Telecommunication Union (ITU) and Internet Corporation for Assigned Names and Numbers (ICANN) are two key organizations involved in the governance of the Internet.

ITU	ICANN
• A specialized agency of the United Nations (UN) • Focuses on information and communication technologies (ICTs) • Fosters international cooperation and development in the ICT sector • Sets global technical standards for telecommunications • Facilitate allocation and management of global radio spectrum and satellite orbits • Promote the development of ICTs in developing countries	• A non-profit organization responsible for coordinating the Domain Name System (DNS) and other internet identifiers • Manages the top-level domains (TLDs) such as .com, .net, and .org • Oversees the allocation and assignment of IP addresses • Develops and implements policies related to the DNS and other internet identifiers • Promotes competition and innovation in the internet domain name industry

Satellite Network

It is a system of satellites that are used to communicate with each other and with ground stations. Satellite networks can be used for a variety of purposes:

- **Telecommunications:** Satellite networks are used to provide telecommunications services, such as telephone, internet, and television.
- **Navigation:** Satellite networks are used for navigation, such as GPS and GLONASS.
- **Earth observation:** Satellite networks are used to observe the Earth, such as for weather forecasting and environmental monitoring.
- **Military:** Satellite networks are used for military purposes, such as command and control, intelligence, and surveillance.

Starlink: A space-based internet system developed and operated by SpaceX.

- It aims to provide high-speed internet access to underserved areas around the world through a network of thousands of low-orbit satellites.
- Starlink has already launched over 3,000 satellites and is operational in over 65 countries.
- It has been praised for its ability to connect remote areas and its role in disaster relief and wartime communication.

Space Based Internet: Space-based internet can provide connectivity in areas where land networks can't reach, such as remote areas, at sea, and during disasters.

Benefits	Challenges
• **Global Coverage:** Ensures high-speed internet worldwide, reaching even areas lacking modern connectivity. • **Fiber Replacement:** Replaces costly fiber connections used by traditional internet providers. • **Stable Signals:** Eliminates dropped calls and signal loss issues associated with conventional internet. • **Future-Ready:** Enables seamless connection for upcoming innovative devices and technologies. • **Improved Performance:** Utilizes low earth orbit satellites to minimize latency for better overall performance.	• **Latency Concerns:** Potential latency issues compared to fiber optic internet, especially with uncertain impacts on communication. • **Space Junk Risks:** Deployment of numerous satellites raises concerns about increased space debris, posing collision risks. • **Technical Hurdles:** Involves addressing challenges in satellite positioning and mass production of thousands of satellites simultaneously. • **Environmental Concerns:** Carbon footprint of launches and impact on astronomy. • **Cybersecurity:** Vulnerability to cyber threats and the need for secure communication. • **Global Coverage and Equity:** Challenges in providing universal access and affordability.

Evolution of Web (Web 1.0, 2.0, 3.0, and 5.0)

- **Web 1.0**: Often referred to as the "read-only web," was the first stage of the World Wide Web. It existed roughly from the mid-1990s to the early 2000s.
- **Web 2.0**: Refers to the second generation of the World Wide Web, characterized by a shift from static web pages to dynamic and interactive content. The term was popularized around the early 2000s.
- **Web 3.0**: It is the idea of a new internet that gives **users more control over their data** and privacy, using decentralization, blockchain, and tokenomics. It aims to offer a personalized and interactive experience but is still in development and not fully implemented. **[UPSC 2022] E.g.,** Siri, Alexa, Google Assistant, and Ethereum.
- **Web 4.0**: This is the future stage of the web, expected to emerge by 2025. It is also called the **symbiotic web**, as it envisions a seamless integration of the web with the physical world, human biology, and consciousness.
- **Web 5.0**: This is the ultimate stage of the web, expected to emerge by 2030. It is also called the emotional web, as it anticipates a web that can understand and respond to the emotions, values, and preferences of the users.

Cryptography

It plays a vital role in securing information and communication within the vast realm of Information and Communication Technology (ICT). It's like a digital shield, protecting sensitive data from prying eyes and ensuring its integrity during transmission or storage. Here's how cryptography permeates the ICT landscape:

- **Secure Communication**
  - **Encryption:** Messages are transformed into unreadable code using mathematical algorithms and secret keys. Only authorized recipients with the corresponding key can decipher the message. This safeguards confidential information exchanged over email, online banking, and even video conferencing.

- **Digital Signatures:** Cryptography allows to create a unique digital fingerprint of the data, ensuring its authenticity and preventing tampering. This is crucial for contracts, financial transactions, and software updates.

- **Data Protection**
  - **Data at Rest:** When storing sensitive data on hard drives or in cloud servers, encryption scrambles it into an unreadable format. Even if hackers gain access to the storage, they'll face a formidable wall of complex code.
  - **Data in Transit:** As data travels across networks, it's vulnerable to interception. Encryption secures data transmission, protecting credit card information during online purchases or medical records during transfer between hospitals.
- **Identity and Access Management**
  - **Authentication:** Cryptography verifies the identity of users trying to access systems or information. This can involve password encryption, digital certificates, or even biometric authentication like fingerprints or facial recognition.
  - **Authorization:** Once authenticated, users are granted specific access levels to data and systems. Cryptography plays a role in defining and enforcing these access controls, ensuring only authorized individuals can perform certain actions.

Digital Signature

It is a secure way to electronically sign documents and other digital files. It's like a traditional handwritten signature, but it's created using cryptography, a branch of mathematics that deals with secure communication in the presence of adversaries. **[UPSC 2019]**

How it works

- **Creating the Signature:** The signer uses a private key to create a unique code that is mathematically linked to the document. This code is like a digital fingerprint of the document and the signer's identity.
- **Verifying the Signature:** The recipient uses a public key, which is mathematically paired with the private key, to verify the signature. The public key is like a lock that only the private key can open. If the signature is valid, it means that the document has not been tampered with and that it was signed by the person who claims to have signed it.

Digital signatures are used in a wide variety of applications such as: **E-commerce:** Digital signatures are used to secure online transactions; **Software distribution:** Digital signatures are used to verify the authenticity of software downloads; **Contract signing:** Digital signatures are used to sign contracts electronically; **Healthcare:** Digital signatures are used to secure patient records.

Digital Signature Certificates (DSCs) and their Legality in India

In India, digital signature certificates (DSCs) are legally valid and recognized as equivalent to handwritten signatures under the Information Technology Act, 2000 (IT Act, 2000).

Cloud Computing

- It is a technology that allows users to **access and use computing resources**, such as storage, servers, applications, and databases, **over the internet,** without having to manage them directly.
- It has many advantages, such as **cost reduction, scalability, availability, reliability, and agility**. **E.g.,** Google Cloud, IBM Cloud, Amazon Web Services, and Microsoft Azure.

Edge Computing

- It refers to the movement of data-handling activities or other network operations away from centralized and always-connected network segments (such as Dropbox, Gmail, and so on) and towards individual sources of data capture, such as endpoints such as laptops and tablets.
- It is a type of cloud computing that differs in the amount of time it takes to process information. The data is analyzed in real-time, close to where it is stored, and without latency.

MeghRaj

It is a cloud computing initiative of the Government of India. It is a set of discrete cloud computing environments spread across multiple locations, built on existing or new (augmented) infrastructure, following a set of common protocols, guidelines and standards issued by the Government of India.

Objective

- To provide a secure, reliable, and affordable cloud computing platform for government agencies and organizations.
- It is designed to meet the specific needs of the Indian government, including data sovereignty, security, and compliance.

Malware or Malicious Software [UPSC 2018]

- **Viruses:** It is a type of malicious software that attaches itself to legitimate programs and files, spreading from one computer to another when the infected files are shared. **E.g.,** WannaCry.
- **Ransomware:** It is a type of malware that encrypts a user's files or the entire system, rendering them inaccessible. The attacker then demands a ransom, usually in cryptocurrency, in exchange for providing the decryption key. **E.g.,** Locky, Petya, Ryuk.

- **Trojan Horses:** They disguise themselves as legitimate software but contain malicious code. They rely on social engineering to trick users into installing them. **E.g.,** Zeus, Backdoor.Net.
- **Bugs:** They are programming errors or flaws in software code that can lead to unexpected behavior or issues in the functioning of a program. **E.g.,** Heartbleed, Spectre/Meltdown, Y2K bug.
- **Worms:** It is a type of malware that spreads copies of itself from computer to computer, often using a network. **E.g.,** Stuxnet, Melissa, I Love You worm
- **Spyware:** It secretly monitors and collects information about a user's activities without their knowledge. It can record keystrokes, capture screenshots, and collect personal information. **E.g.,** Pegasus, FinFisher.
- **Adware:** It displays unwanted advertisements on a user's device. It is usually bundled with free software and can be challenging to remove. **E.g.,** Superfish, MyWebSearch.
- **Rootkits:** They are designed to hide the presence of malware on a system by modifying or replacing system files. They often give attackers privileged access to a compromised system. **E.g.,** Stuxnet, Flame, Sony BMG Rootkit.

Cyber Security

It is the practice of protecting systems, networks, and data from digital attacks. These attacks can come in many forms, including:

- **Malware:** Malicious software designed to harm or exploit a system.
- **Phishing:** A scam that attempts to trick users into giving up personal information.
- **DDoS attacks:** An attempt to overwhelm a system with traffic so that it becomes unavailable.
- **Zero-day attacks:** Attacks that exploit vulnerabilities that are unknown to the software vendor.
- **Juice jacking:** A type of cyberattack that involves compromising a charging station or cable in order to steal data from a device that is plugged into it.
- **Whaling Attack:** Also known as CEO fraud or whale phishing, is a targeted cyberattack aimed at high-profile individuals within an organization, such as CEOs, CFOs, or other executives.
- **Skimming:** It refers to the clandestine theft of payment and personal information during online transactions.

Government Initiatives for Cyber Security

- **Cyber Swachhta Kendra:** It is a botnet cleaning and malware analysis center set up by the Indian Computer Emergency Response Team (CERT-In) under the Ministry of Electronics and Information Technology (MeitY).
  - It is a part of the Government of India's Digital India initiative to create a secure cyberspace by detecting botnet infections in India and to notify, enable cleaning and securing systems of end users so as to prevent further infections.
- **Indian Cyber Crime Coordination Centre (I4C):** It is a crucial government initiative established by the Ministry of Home Affairs to tackle cybercrime in India in a coordinated and comprehensive manner.
- **Indian Computer Emergency Response Team (CERT-In):** It is the national agency responsible for cybersecurity in India. It functions under the Ministry of Electronics and Information Technology (MeitY) of the Government of India.
- **National Cyber Coordination Center: It** is an operational cybersecurity and e-surveillance agency in India. It was established in 2017 by the Ministry of Electronics and Information Technology (MeitY).

Digital Personal Data Protection Act, 2023

- It aims to regulate the processing of digital personal data in a manner that recognizes both the right of individuals to protect their personal data and the need to process such data for lawful purposes.
- It was based on the recommendations of Justice **B.N. Srikrishna Committee.**

Salient features

- **Applicability:**The processing of digital personal data within India applies to data collected in both digital and non-digital forms, or data that is digitized subsequently. Processing personal data outside India is applicable if it involves offering goods or services within India.
- **Consent:** Personal data may only be processed for lawful purposes with the consent of the Data Principal, who can withdraw consent at any time.For children or persons with disabilities, consent will be provided by the parent or legal guardian.
- **Data Protection Board of India (DPBI):** The Central government establishes the DPBI with key functions including monitoring compliance, imposing penalties, directing data fiduciaries in case of data breaches, and hearing grievances.
- **Rights and Duties of Data Principal:** Data principals ("Data Principal" means the individual to whom the personal data relates and where such individual is a child includes the parents, or lawful guardian of such a child) have the right to obtain information about processing, seek correction and erasure of personal data, grievance redressal, and the right to nominate a person to exercise rights in case of death or incapacity.
- **Obligations of Data Fiduciaries:** Data fiduciaries (entities determining the purpose and means of processing) must ensure accuracy and completeness

of data, implement reasonable security safeguards, inform DPBI and affected persons in case of a breach, and erase personal data when the purpose is met and retention is not necessary for legal purposes.

- **Significant Data Fiduciaries (SDF):** The Central Government may notify any data fiduciary as SDF based on factors like volume and sensitivity of data processed, risk to the rights of the data principal, potential impact on India's sovereignty and integrity, security of the State, risk to electoral democracy, and public order.
  - SDFs have additional obligations, including appointing a data protection officer and an independent data auditor, and undertaking impact assessments.

Exemptions:

- Certain exemptions apply in specified cases, including for notified agencies in the interest of security, sovereignty, public order, etc., for research, archiving, or statistical purposes, for startups or other notified categories of data fiduciaries, to enforce legal rights and claims, prevention and investigation of offenses, performing judicial or regulatory functions, and processing personal data of non-residents under a foreign contract.

- **Processing of Personal Data of Children:** While processing the personal data of a child, data fiduciaries must avoid processing likely to cause detrimental effects on the child's well-being and tracking, behavioral monitoring, or targeted advertising.
- **Cross-border Transfer:** The bill allows the transfer of personal data outside India, except to countries restricted by the government.
- **Penalties:** Penalties for various offenses are specified, such as up to Rs 200 crore for non-fulfillment of obligations for children and Rs 250 crore for failure to take security measures to prevent data breaches.

Critical Information Infrastructure (CII)

- It refers to the physical and virtual systems and assets that are essential for the functioning of a country's vital societal functions, health, safety, security, economic or social well-being of people. Disruption or destruction of these infrastructures would have serious consequences.
- **The National Critical Information Infrastructure Protection Centre (NCIIPC):** It is the nodal agency in India for taking all measures to protect the nation's critical information infrastructure. It was created in January 2014 under Section 70A of the Information Technology Act, 2000.
- **National Intelligence Grid (NATGRID)**: It is an integrated intelligence master database structure connecting the databases of various core security agencies under the Indian government. It aims to collect and collate comprehensive patterns of intelligence data readily accessible to security agencies 24/7 for counter-terrorism purposes.

Net neutrality

- It is the principle that Internet service providers (ISPs) should treat all data on the Internet the same way, without discrimination or preferential treatment.
- It ensures that ISPs don't block or throttle (slow down) access to specific websites, content, or services, and they cannot create "fast lanes" for certain data.
- The goal of net neutrality is to maintain an open and equal Internet, allowing users to access all legal content without interference or bias from ISPs.

Government Initiatives to Boost Information & Technology in the Country

- **Digital India:** This **program, started in 2015**, aims to create a digital and knowledge-based society and economy in India. It covers aspects such as broadband networks, mobile connectivity, public Wi-Fi, digital literacy, and e-governance.
- **National Optical Fibre Network (NOFN):** This project aims to connect all gram panchayats (village councils) in India with high-speed broadband internet.
- **BharatNet:** This initiative aims to offer affordable internet access to all citizens through a network of optical fiber cables.
- **Common Service Centres (CSCs):** These are digital service points in rural areas that offer e-governance services, digital literacy training, and access to government schemes.
- **Skill India:** This program aims to provide skill development opportunities to youth in various sectors, including IT and ITES.
- **Digital Skills Development Initiative:** This initiative aims to train 10 million individuals in digital skills by 2022.
- **Startup India Standup India:** This initiative aims to foster entrepreneurship and innovation across the country, especially in the IT sector.
- **MeitY Startup Hub:** This initiative provides incubation support and mentorship to startups in the IT sector.
- **Electronics Development Fund (EDF):** This fund provides financial assistance to companies engaged in the development and production of electronic components.
- **IndiaAI:** Launched in 2020, this initiative aims to make India a global leader in Artificial Intelligence (AI). It includes setting up research centers, developing AI-powered solutions for social good, and fostering

collaboration between government, academia, and industry.

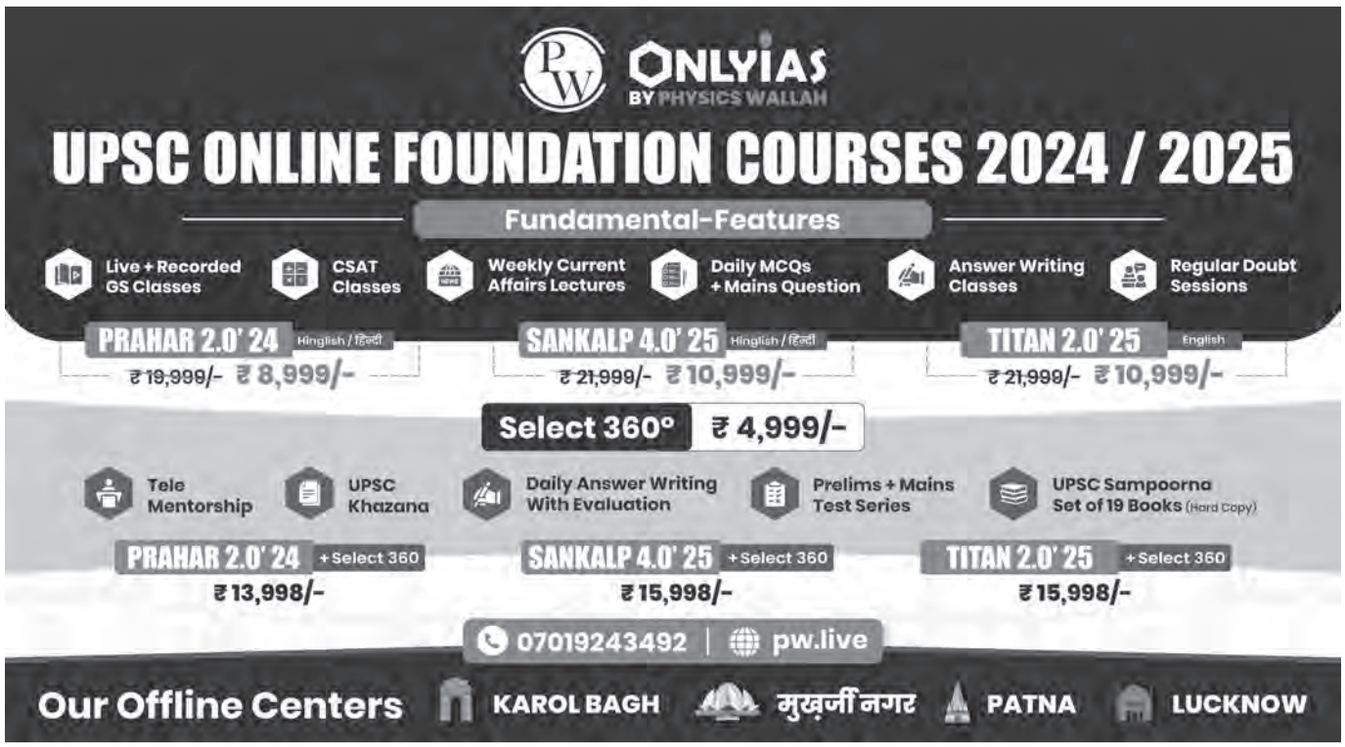
- **National Centre for Robotics and Automation (NCRA):** This center focuses on research and development in robotics and automation technologies.
- **National Mission on Quantum Technologies & Applications (NMQTA):** This mission aims to develop quantum technologies in areas like communication, computing, and sensing.

India Stack: A Digital Infrastructure Revolution

It refers to a set of open APIs (Application Programming Interfaces) that facilitates building digital solutions for various purposes. It aims to create a unified digital infrastructure that simplifies service delivery for India's citizens and businesses.

Key Components of India Stack

- **Aadhaar:** A unique 12-digit identification number assigned to residents of India based on their biometric and demographic data. It enables identity verification and authentication for various purposes.
- **Unified Payments Interface (UPI):** An interoperable payment network that allows users to send and receive money using their mobile phones and bank accounts. It supports multiple payment modes, such as QR codes, mobile numbers, virtual payment addresses, etc.
- **e-KYC:** An electronic Know Your Customer service that allows users to share their identity and address proofs digitally with service providers, such as banks, telecom operators, etc. It reduces the cost and time of verification and enhances customer convenience.
- **e-Sign:** An electronic signature service that allows users to digitally sign any document using their Aadhaar number and biometrics or OTP. It eliminates the need for physical signatures and paper documents and ensures legal validity and security.
- **DigiLocker:** A digital locker service that allows users to store and access their documents, such as certificates, licenses, etc., in a secure cloud-based platform. It also enables users to share their documents with authorized entities, such as government agencies, employers, etc. **[UPSC 2016]**
- **Account Aggregator:** A framework that allows users to share their financial data, such as bank statements, tax returns, etc., with third-party service providers, such as lenders, insurers, etc., with their consent. It enables users to access various financial products and services in a seamless and transparent manner.



4 Emerging Technologies

ARTIFICIAL INTELLIGENCE

Artificial Intelligence (AI) refers to the development of computer systems that can perform tasks that typically require human intelligence. These tasks include learning, reasoning, problem-solving, perception, speech recognition, and language understanding.

Some Examples of AI

- **Google Search**, which uses AI to understand your queries and provide relevant results.
- **YouTube, Amazon, and Netflix**, which use AI to recommend videos, products, and shows based on your preferences.
- **Google Assistant, Bixby, Siri, and Alexa,** which use AI to recognize your voice and answer your questions.
- **Waymo**, which uses AI to drive self-driving cars.
- **ChatGPT and AI art**, which use AI to generate creative content such as text and images.

Key Components and Techniques in AI

AI weaves its magic through five vital threads: learning, reasoning, problem-solving, perception, and language. Imagine machines absorbing knowledge, making decisions, navigating landscapes, interpreting images, and even understanding you – that's the breathtaking symphony of AI.

- **Machine Learning (ML):** A subset of AI, machine learning involves the development of algorithms that allow computers to learn from data and improve their performance over time without being explicitly programmed. Types of machine learning include supervised learning, unsupervised learning, and reinforcement learning.
- **Deep Learning:** A subfield of machine learning, deep learning involves neural networks with multiple layers (deep neural networks). It has been particularly successful in tasks such as image and speech recognition.
- **Neural Networks:** They are a fundamental component of artificial intelligence (AI) and machine learning (ML), particularly in the subfield of deep learning. They are computational models inspired by the structure and function of the human brain, consisting of interconnected nodes (artificial neurons) organized in layers.
- **Natural Language Processing (NLP):** NLP focuses on the interaction between computers and human languages. It enables computers to understand, interpret, and generate human-like text, making it crucial for applications like chatbots and language translation.
- **Computer Vision:** This field enables machines to interpret and make decisions based on visual data, such as images or videos. Object recognition and image classification are common applications.
- **Robotics:** AI is often integrated into robotic systems to enable them to perform tasks autonomously. This includes both physical robots and software-based robots.
- **Expert Systems:** These are computer systems designed to mimic the decision-making abilities of a human expert in a particular domain. They use rule-based systems to make decisions based on a set of predefined rules.

From robots aiding surgery to algorithms predicting your next song, AI's future brims with endless possibilities. This journey requires continuous learning, ethical integration, and a responsible exploration of the potential that lies within machines that think.

Applications of AI

Artificial intelligence (AI) is a rapidly evolving field that aims to create intelligent machines capable of performing tasks that typically require human intelligence. This includes tasks such as learning, reasoning, problem-solving, perception, and decision-making.

AI has numerous applications across various industries and sectors, including:

- **Healthcare:** AI is used for medical diagnosis, drug discovery, personalized medicine, and robotic surgery.
- **Finance:** AI is used for fraud detection, risk assessment, algorithmic trading, and chatbots for customer service.
- **Manufacturing:** AI is used for predictive maintenance, quality control, and automation.
- **Transportation:** AI is used for self-driving cars, traffic management, and logistics optimization.

- **Retail:** AI is used for personalized recommendations, product search, and dynamic pricing.
- **Customer service:** AI is used for chatbots, virtual assistants, and sentiment analysis.
- **Entertainment:** AI is used for game development, special effects, and virtual reality.

AI Regulation

Bletchley Summit

- The Bletchley Summit in November 2023 marked a significant step towards global AI regulation, although it's still early days.
- **Outcomes**
  - **Bletchley Declaration:** This document outlined shared principles for safe, responsible, and human-centric AI development and use. It emphasizes transparency, accountability, and respect for human rights and fundamental freedoms.
  - **International Collaboration:** The summit brought together government officials, tech leaders, and researchers from over 30 countries, fostering dialogue and collaboration on AI governance.
  - **Concrete Proposals:** Discussions at the summit explored specific areas for regulation, including:
    - **Risk assessment and mitigation**: Developing frameworks for identifying and addressing potential risks of AI systems.
    - **Bias and fairness:** Ensuring AI systems are free from bias and discrimination.
    - **Transparency and explainability:** Making AI systems' decision-making processes more transparent and understandable.
    - **Human oversight and control:** Ensuring humans remain in control of AI systems.

MACHINE LEARNING

Machine learning is a fascinating and rapidly evolving field within AI, focusing on building computer systems that can learn from data without being explicitly programmed.

Applications of Machine Learning

- **Recommendation Systems:** Recommend products, music, or movies you might like.
- **Fraud Detection:** Identify suspicious activity in financial transactions.
- **Image Recognition:** Self-driving cars, facial recognition software.
- **Medical Diagnosis:** Assisting doctors in analyzing medical images and predicting disease progression.
- **Natural Language Processing:** Powering chatbots and virtual assistants, improving machine translation.

Deep Learning

It is a subset of machine learning that uses artificial neural networks (ANNs) inspired by the structure and function of the human brain. ANNs are organised in layers, with each layer learning more complex features from the data. This "deep" architecture allows for high accuracy in tasks like image recognition, natural language processing, and speech recognition.

Hence, "Machine learning is the foundation, and deep learning is a powerful technique built on top of it. Machine learning is more general-purpose, while deep learning excels at specific tasks like image and language processing."

GENERATIVE AI: A DEEP DIVE

Generative AI, a branch of artificial intelligence, is making waves with its ability to create new content across various media, including text, images, audio, and even code. While its potential for revolutionizing industries and creative fields is undeniable, it also raises critical questions about learning curves, authenticity, copyright, human rights, and the ethical implications of technologies like deepfakes.

Example : Chatgpt by OpenAI, Bard by Google etc.

Applications of Gen AI

Content Creation

- **Text Generation:** Generative AI models like GPT-3 can generate coherent and contextually relevant text. This is utilized in content creation, including article writing, social media posts, and creative writing.
- **Code Generation:** Developers use generative models to automatically generate code snippets, aiding in software development and reducing coding time.
- **Automated Storytelling:** Generative AI can create narratives, scripts, and storylines for various media, contributing to the entertainment industry.

Media Production and Design

- **Image Synthesis:** Models like DALL-E by OpenAI can generate images from textual descriptions. This is valuable in graphic design, conceptualizing ideas, and creating visual content.
- **Style Transfer:** Generative AI can apply artistic styles to images, videos, or other media, enhancing creativity in visual production.
- **Video Game Design:** Generative models assist in creating characters, landscapes, and scenarios in video games, providing a dynamic and immersive gaming experience.

Healthcare

- **Drug Discovery:** Generative models aid in predicting molecular structures and generating potential drug compounds, accelerating the drug discovery process.
- **Medical Imaging:** Generative AI enhances medical image interpretation, assisting in the diagnosis of diseases and abnormalities through automated analysis and report generation.

Entertainment

- **Music Composition:** Generative AI can compose music, generating melodies, harmonies, and even entire pieces. This has applications in the music industry for creating original compositions.
- **Virtual Characters:** In the film and animation industry, generative models contribute to the creation of virtual characters, bringing new possibilities to special effects and animation.

Business and Marketing

- **Content Personalization:** Generative AI helps personalize marketing content, creating tailored messages and advertisements based on user preferences and behavior.
- **Chatbots and Virtual Assistants:** Natural language generation allows for the creation of intelligent chatbots and virtual assistants that can understand and respond to user queries effectively.

Education

- **Automated Tutoring:** Generative AI facilitates the creation of interactive educational content, including automated tutoring systems that adapt to individual learning styles.
- **Content Summarization:** Generative models can summarize large volumes of text, making it easier for students and researchers to grasp key information.

Simulation and Training

- **Virtual Environments:** Generative AI contributes to the development of realistic virtual environments for training purposes, such as flight simulations, medical procedures, and military training.

DEEPFAKES

A deepfake is a synthetic media in which a person's face or voice is digitally altered to make it appear as if they are saying or doing something they never did. This is done by using a type of artificial intelligence called deep learning, which can learn to mimic a person's appearance and voice with remarkable accuracy.

Benefits

- **Film Dubbing:** Deepfake tech enhances global film accessibility with realistic lip-syncing for actors speaking different languages.
- **Entertainment and education**: Deepfake technology can be used to create immersive and engaging content for movies, games, documentaries, or online courses.
  - For example, deepfake technology can bring back deceased actors or actresses, create more realistic scenes, or allow learners to interact with famous historical figures or experts. You can listen and enjoy various songs in the voices of legendary singers like KK and Kishore Kumar which were sung by someone else.
- **Healthcare and research**: Deepfake technology can be used to generate synthetic data for medical diagnosis, treatment, or analysis.
  - For example, deepfake technology can create virtual patients with realistic symptoms, conditions, or responses, without compromising the privacy of real patients.
- **Autonomy and Expression:** Deepfake apps, like Reface, empower users to control their digital identity by swapping faces with celebrities for fun or personalization.
- **Amplification of the Message:** Deepfake tech amplifies voices, like a journalist's final message created posthumously, aiding those facing discrimination, censorship, or violence.
- **Digital Reconstruction and Public Safety:** Deepfake tech reconstructs missing data, restoring photos or videos, and enhances public safety through realistic training materials.

Challenges

Deepfakes, or synthetic media created using deep learning techniques, present a range of challenges that have implications for privacy, security, and trust. Some of the key challenges associated with deepfakes include:

- **Misinformation and Disinformation:** Deepfakes can be used to create convincing fake videos or audio recordings that spread false information. This poses a significant risk to public discourse, as deepfakes can be maliciously employed to manipulate opinions or deceive the public.
- **Privacy Concerns:** Deepfakes can be used to create fake content featuring individuals, raising concerns about unauthorized use of personal images or videos for malicious purposes. This can lead to privacy violations and damage to a person's reputation.
- **Political Manipulation:** Deepfakes have the potential to be used for political manipulation, where videos of political figures are manipulated to make them appear

to say or do things they never did. This can influence elections and public perception.

- **Fraud and Scams:** Deepfakes can be employed in various forms of fraud, including impersonation scams. For instance, criminals might create convincing voice or video recordings to deceive individuals into believing they are communicating with someone they know or trust.
- **Ethical Concerns:** The creation and distribution of deepfakes raise ethical questions about the responsible use of artificial intelligence. It can be challenging to establish guidelines and regulations that balance the potential benefits of AI with the risks associated with deepfake technology.
- **Security Threats:** Deepfakes can be used as part of cyber threats, such as impersonation attacks on individuals or organizations. For example, an attacker could use a deepfake to mimic a company executive's voice and request unauthorized actions.
- **Detection Challenges:** As deepfake technology advances, so does the sophistication of the methods used to create them. This makes it challenging to detect deepfakes reliably. The cat-and-mouse game between deepfake creators and detection technologies is ongoing.
- **Impact on Trust:** The prevalence of deepfakes erodes trust in visual and auditory information. People may become more skeptical of the authenticity of media content, leading to challenges in confirming the veracity of information.
- **Legal and Regulatory Challenges:** The legal landscape around deepfakes is evolving, and there are challenges in defining and enforcing regulations. Different jurisdictions may have varying approaches to addressing the creation and dissemination of deepfakes.

Curbing the Menace of Deepfakes

- **Learning from International Experiences:** The life cycle of deepfakes comprises three key phases – creation, dissemination, and detection. Utilizing AI regulations can be instrumental in curbing the illicit or non-consensual development of deepfakes.
  - Various nations, including China, are adopting regulatory approaches that mandate consent from individuals featured in deepfake videos. Additionally, they require technology providers to authenticate user identities and provide avenues for recourse in case of misuse.
- **Integrating Watermarks into All AI-Generated Videos:** Incorporating watermarks into AI-generated videos is crucial for efficient detection and attribution. These marks disclose the content's origin and ownership, serving multiple purposes. They facilitate attribution by clearly identifying the content's creator or source, especially when shared across diverse contexts.
  - Visible watermarks also serve as a deterrent against unauthorized use, signaling that the content can be traced back to its origin.
  - Furthermore, watermarks contribute to accountability by furnishing evidence of the original creator's rights, simplifying the enforcement of copyright and intellectual property protections for AI-generated content.
- **Preventing Users from Uploading Inappropriate Content:** Online platforms should take proactive measures to educate users about content policies and potentially implement deterrents against uploading inappropriate content.
- **Advancing Deepfake Detection Technologies:** This involves deploying more advanced algorithms and exploring innovative methods capable of identifying deepfakes based on contextual cues, metadata, or other relevant factors.
- **Strengthening Digital Governance and Legislation:** This entails formulating clear and consistent laws and policies that define and prohibit the malicious use of deepfakes. Effective remedies and sanctions for victims and perpetrators of digital harm should also be outlined.
- **Promoting Ethical and Responsible Use of Deepfake Technology:** This involves establishing and enforcing codes of conduct and standards for creators and users of deepfake technology. Encouraging positive and beneficial applications of the technology is also crucial.

Rules to Curb Deepfakes

- The IT Act of 2000 and the IT Rules of 2021 both contain explicit directives assigning responsibility to social media intermediaries for the prompt removal of deep-fake videos or photos.
  - Failure to comply may result in imprisonment for up to three years or a fine of Rs 1 lakh.
- According to **Section 66D of the IT Act**, individuals engaging in cheating through impersonation using communication devices or computer resources can face imprisonment for up to three years and a fine of up to one lakh rupees.
- **Rule 3(1)(b)(vii)** stipulates that social media intermediaries must ensure that their platform users do not host any content that impersonates another person. Additionally,
- **Rule 3(2)(b)** mandates the removal of such content within 24 hours upon receiving a complaint against it.

Prominent AI Platforms

- **ChatGPT:** It is an artificial intelligence language model created by OpenAI, proficient in generating text that closely resembles human language based on context and previous interactions. It excels at responding to inquiries, engaging in conversations on diverse subjects, and crafting imaginative written pieces.
- **Bing:** A web search engine that furnishes pertinent and dependable information drawn from various sources like web pages, images, videos, news, and more. Additionally, it provides artificial intelligence services, encompassing capabilities such as image recognition, natural language processing, and machine learning.
- **Bard:** A virtual chatbot, offers assistance in an array of tasks, including learning, writing, coding, planning, and more. It harnesses the power of Google's Gemini, a versatile and multimodal AI model capable of reasoning across text, images, audio, video, and code.
- **Gemini:** Google's latest and most advanced AI model, is engineered for adaptability and multimodality. Available in three sizes—Ultra, Pro, and Nano—to operate on various devices and platforms, Gemini surpasses human experts in challenging AI endeavors, such as Massive Multitask Language Understanding (MMLU) and HumanEval (Python code generation).

ARTIFICIAL INTELLIGENCE IN INDIA

The field of artificial intelligence is undergoing rapid advancement, and India stands as a prominent player in AI research and development.

India has great potential for a big AI revolution. It's the third-largest hub for AI talent globally, and investments in India's AI capabilities are growing fast at a rate of 30.8%, expected to hit $881 million in 2023.

The growth of India's semiconductor industry will be crucial for its AI market, projected to reach $7.8 billion by 2025. By then, about 60% of AI's impact on India's economy will come from four main sectors: Industrials & Automotive, Healthcare, Retail, and Consumer Packaged Goods.

- **National Strategy on Artificial Intelligence (NSAI):** The National Strategy on Artificial Intelligence (NSAI) is a 2018 document released by NITI Aayog. The NSAI focuses on using AI to achieve inclusive growth and solve social challenges in areas like education, health, and agriculture. The NSAI is also known as "AI For All".
- **INDIAai:** It is the National Artificial Intelligence Portal of India, launched by the Ministry of Electronics and Information Technology (MeitY) in May 2020. It is a single central knowledge hub on artificial intelligence and allied fields such as, Machine Learning, Computer Vision, Deep Learning etc., for aspiring entrepreneurs, students, professionals, academics, and everyone else.
  - **INDIAai aims to:**
    - Bridge the gap between theory and practice on AI by supporting cutting-edge research and applied activities on AI-related priorities.
    - Build a strong AI ecosystem in India by providing a platform for collaboration and innovation.
    - Promote the responsible use of AI for the benefit of society.
- **Global Partnership on AI (GPAI):** India is also a founding member of the Global Partnership on AI (GPAI), a multi-stakeholder initiative that aims to bridge the gap between theory and practice on AI by supporting cutting-edge research and applied activities on AI-related priorities.
  - The GPAI has four working groups: data governance, future of work, innovation and commercialization, and responsible AI.
  - India is co-leading the data governance working group along with the UK and Canada.

BLOCKCHAIN TECHNOLOGY

Blockchain technology is a decentralized and distributed ledger system that enables secure and transparent record-keeping. It was initially developed as the underlying technology for the cryptocurrency Bitcoin, but its applications have expanded beyond cryptocurrencies to various industries. **[UPSC 2020]**

- **Decentralization:** Unlike traditional centralized systems, blockchain operates on a decentralized network of computers (nodes).
  - Each node on the network has a copy of the entire blockchain, and there is no central authority controlling the system.
- **Distributed Ledger:** The blockchain is a distributed ledger that records transactions across a network of computers.
  - Each transaction is added to a block, and these blocks are linked together in chronological order, forming a chain of blocks—hence the name "blockchain."

Applications of Blockchain Technology

Blockchain technology's potential applications are vast and constantly evolving, spanning across numerous industries and sectors. Here's a glimpse into its diverse possibilities:

Financial Services

- **Cryptocurrencies and Digital Assets:** Secure, transparent transactions without intermediaries and Democratizing access to high-value assets like real estate or art.

- **Fractional Ownership:** Democratizing access to high-value assets like real estate or art.
- **Trade Finance and Cross-Border Payments:** Increased efficiency and reduced costs.
- **Fraud Prevention and Anti-Money Laundering:** Enhanced traceability and immutability of transactions.

Supply Chain and Logistics

- **Track and Trace:** Monitoring the movement of goods for transparency and authenticity.
- **Inventory Management:** Optimizing stock levels and reducing waste.
- **Counterfeit Prevention:** Ensuring the authenticity and origin of products.
- **Smart Contracts:** Automating logistics processes and payments.

Healthcare

- **Secure Medical Records:** Providing patients with control over their data and improving accessibility.
- **Drug Supply Chain Management:** Combating counterfeiting and ensuring drug quality.
- **Personalized Medicine:** Tailoring treatments based on individual genetic data.
- **Clinical Trials and Research:** Streamlining data collection and analysis.

Governance and Voting

- **Secure and Transparent Elections:** Reducing fraud and increasing voter confidence.
- **Identity Management:** Securely storing and verifying personal information.
- **Property Registration and Land Titles:** Streamlining land ownership and reducing disputes.
- **Contract Management:** Ensuring tamper-proof records of agreements.

Other Applications

- **Internet of Things (IoT):** Securing communication between devices and managing data streams.
- **Intellectual Property Protection:** Protecting copyrights, patents, and trademarks.
- **Energy Trading and Renewable Energy Management:** Facilitating peer-to-peer energy transactions and tracking renewable energy credits.
- **Voting Systems for Organizations and Communities:** Ensuring transparency and fairness in decision-making processes.

Blockchain's adaptability reshapes industries, securing transactions, ensuring transparency, and optimizing processes across financial services, supply chain, healthcare, governance, and various applications.

Non-Fungible Token (NFT)[UPSC 2022]

- A non-fungible token (NFT) is a unique digital identifier that is recorded on a blockchain, which is a type of distributed ledger that stores transactions across a network of computers.
- An NFT can represent a digital or physical asset, such as an artwork, a song, or a property.
- An NFT can be used to certify the ownership and authenticity of the asset, and can be traded and sold on online platforms.
- Unlike cryptocurrencies, which are fungible and interchangeable, NFTs are not identical and cannot be replaced by another token of the same type.

Some examples of NFTs are

- A collage of digital artworks by Beeple, which sold for over $69 million at an auction in 2021.
- A tweet by Jack Dorsey, the founder of Twitter, which was sold as an NFT for $2.9 million in 2021.

NFTs are created by a process called minting, which involves uploading a digital file to a platform that supports NFTs and paying a fee in cryptocurrency to record the token on the blockchain.

CRYPTOCURRENCY

Cryptocurrency is a type of digital currency that uses cryptography to secure and verify transactions, and to control the creation of new units. Cryptocurrencies operate on decentralized networks of computers, without the need for a central authority like a government or a bank.

- Some of the most popular cryptocurrencies are **Bitcoin, Ethereum, Tether, Binance Coin,** and **Cardano.**
- Cryptocurrencies can be used for various purposes, such as online payments, remittances, investments, and innovation. However, cryptocurrencies also face many challenges, such as volatility, regulation, security, and environmental impact.

How is Cryptocurrency different from NFT

Feature	Cryptocurrency	NFT
Fungibility	Fungible (interchangeable)	Non-fungible (unique)
Purpose	Medium of exchange and store of value	Ownership of digital assets
Value	Derived from market demand and supply	Subjective, based on underlying asset and market sentiment
Trading	Traded on cryptocurrency exchanges	Traded on NFT marketplaces
Examples	Bitcoin, Ethereum, Litecoin	CryptoPunks, Bored Ape Yacht Club, NBA Top Shot

RBI's Central Bank Digital Currency - CBDC (e₹)

The e₹ is a digital form of Indian rupee issued by the RBI. It's not a cryptocurrency like Bitcoin, as it's not mined and is centrally controlled by the RBI. The e₹ is intended to complement, not replace, physical currency.

The RBI launched a pilot program for the e₹ in December 2022, with a limited rollout to select banks and financial institutions. The pilot is currently in two phases:

- **Wholesale CBDC (e₹-W):** This is for use in settling interbank transactions, such as government securities.
- **Retail CBDC (e₹-R):** This is for use by individuals and businesses for everyday payments.

The e-rupee is not a cryptocurrency, as it is not based on a public blockchain network, but on a private and permissioned distributed ledger technology (DLT).

Central Bank Digital Currency (CBDC)

- A central bank digital currency (CBDC) is the digital form of a country's fiat currency, such as the rupee, dollar, euro, or yen.
- It is issued and regulated by the central bank of that country, and can be used for online and offline transactions.
- Unlike cryptocurrencies, CBDCs are backed by the sovereign authority and legal tender status of the central bank.

ROBOTICS

Robotics is the field of engineering and computer science that involves the design, construction, operation, and use of robots. Robots are machines that can perform physical tasks on behalf of a human, either autonomously or semi-autonomously.

Types of Robots

- **Industrial Robots**
  - **Articulated Robots:** These robots have rotary joints and can move in multiple planes. They are commonly used in manufacturing and assembly lines.
  - **SCARA Robots (Selective Compliance Assembly Robot Arm):** These robots have rigid arms and are often used for tasks that require precision, such as electronics assembly.
- **Service Robots**
  - **Medical Robots:** Used in healthcare settings for tasks such as surgery (surgical robots), rehabilitation, and patient assistance.
  - **Cleaning Robots:** Robotic vacuum cleaners and floor scrubbers fall into this category, performing automated cleaning tasks.
  - **Personal Assistant Robots:** Designed to assist individuals with various tasks, such as communication, reminders, and information retrieval.
- **Autonomous Vehicles**
  - **Unmanned Aerial Vehicles (UAVs or Drones):** Used for surveillance, photography, agriculture, and various other applications.
  - **Autonomous Cars:** Self-driving vehicles that use sensors and AI to navigate roads safely.
- **Space Robots**
  - **Rovers:** Designed to explore the surface of planets and moons. Examples include NASA's Mars rovers.
  - **Satellite Servicing Robots:** Used for maintenance and repair of satellites in orbit.
- **Military Robots**
  - **Unmanned Ground Vehicles (UGVs):** Used for reconnaissance, bomb disposal, and other military applications.
  - **Unmanned Aerial Vehicles (UAVs):** Drones used for surveillance, reconnaissance, and sometimes for offensive operations.
- **Humanoid Robots**
  - **Humanoid Assistants:** Robots with a human-like appearance designed to assist humans in various tasks.
  - **Research and Development Robots:** Used in labs and research institutions to explore human-robot interaction and advance robotics technology.

- **Telepresence Robots**
  - **Remote Presence Robots:** Equipped with cameras and displays, these robots allow users to remotely navigate and interact with a distant environment.
- **Social Robots**
  - **Companion Robots:** Designed to provide companionship and assist with social interactions.
  - **Educational Robots:** Used in educational settings to teach programming and robotics concepts.
- **Bio-Inspired Robots**
  - **Robots Inspired by Animals:** Mimic the movement and behaviour of animals for specific applications, such as exploration or search and rescue.
- **Soft Robots**
  - A subfield of robotics that uses compliant materials like silicone, hydrogels, and textiles instead of rigid metal or plastic parts.
  - This makes them more adaptable and safer for interacting with humans and delicate environments.
  - Potential applications include surgery, prosthetics, search and rescue, and even food handling.
- **Gelbots**
  - A type of soft robot made primarily of hydrogel, a soft, water-based material.
  - Hydrogels can be designed to be responsive to stimuli like temperature, light, or chemicals, giving gelbots unique capabilities.
  - For example, some gelbots can change their shape or stiffness on demand, while others can sense and react to their surroundings.

Applications of Robots

- **Manufacturing and Assembly:** Robotic arms and automated systems are commonly used in manufacturing for tasks such as assembly, welding, painting, and quality control. They can enhance efficiency and precision in production lines.
- **Healthcare:** Surgical robots assist surgeons in performing minimally invasive surgeries with greater precision. Robots are also used for tasks like medication dispensing, patient care, and rehabilitation therapy.
- **Agriculture:** Agricultural robots, known as agribots, are used for tasks like planting, harvesting, and monitoring crop health. Drones equipped with sensors are also employed for crop surveillance.
- **Logistics and Warehousing:** Autonomous mobile robots (AMRs) are used in warehouses for tasks such as picking and packing, inventory management, and material handling. They can navigate through environments and collaborate with human workers.
- **Exploration:** Robots are used in space exploration to explore planets, moons, and other celestial bodies. Rovers like NASA's Mars rovers, for example, have been sent to gather data and conduct experiments on other planets.
- **Defense and Security:** Unmanned Aerial Vehicles (UAVs) or drones are used for surveillance, reconnaissance, and sometimes combat. Bomb disposal robots are employed to handle and dispose of explosive devices safely.
- **Education:** Educational robots are used to teach programming and problem-solving skills to students. These robots are often designed to be easily programmable and can be used in STEM (science, technology, engineering, and mathematics) education.
- **Entertainment:** Robots are used in the entertainment industry, ranging from animatronics in theme parks to robotic characters in movies. They can simulate human movements and interactions.
- **Domestic and Personal Use:** Robotic vacuum cleaners, lawn mowers, and other household robots assist with daily chores. Social robots, designed for companionship, are also being developed.
- **Environmental Monitoring:** Robots equipped with sensors are used for environmental monitoring in areas such as oceans, forests, and disaster-stricken regions. They can collect data on temperature, pollution, and other environmental factors.
- **Construction:** Construction robots can assist in tasks like bricklaying, concrete pouring, and demolition. They can enhance efficiency and safety in construction sites.

Biorobotics

Biorobotics is an interdisciplinary science that draws inspiration from nature to design and build robots. It blends principles from biology, engineering, and computer science to create robots that are more efficient, adaptable, and robust than traditional machines.

Two main approaches:

- **Biomimicry**: This involves directly mimicking the structures, functions, and control systems of biological organisms. Examples include:
  - **Cheetah-inspired robots:** Running robots with flexible spines and legs, mimicking the energy-efficient locomotion of cheetahs.
  - **Gecko-inspired grippers:** Robots with adhesive surfaces inspired by gecko feet, allowing them to climb walls and handle delicate objects.
  - **Fish-inspired underwater robots:** Undulating robots inspired by fish swimming, offering efficient and maneuverable underwater movement.
- **Bio-inspired algorithms and control:** This focuses on developing robot control systems inspired by biological processes like learning, adaptation, and evolution. Examples include:

- **Evolutionary algorithms:** Optimizing robot behavior through simulated evolution, mimicking the Darwinian process.
- **Swarm intelligence:** Robots collaborating and making decisions based on local interactions, similar to ant colonies or bird flocks.
- **Neural networks:** Robot control systems inspired by the structure and function of the brain, enabling learning and adaptive behavior.

India's Advancement in Robotics

India is one of the emerging countries in the field of robotics and artificial intelligence. The Indian government, startups, and research institutes are working on various initiatives and projects to develop and deploy humanoid robots, autonomous mobile robots, and AI-based solutions for various sectors and domains.

India's Strides in Robotics

- **Manav**: India's first 3D-printed humanoid robot, developed by A-SET Training and Research Institute. Manav can walk, talk, dance, and perform various activities in response to human commands.
  - It uses an open-source code and has WiFi and Bluetooth connectivity.
- **Mitra**: A humanoid robot that can interact with humans smartly, developed by Invento Robotics. Mitra can greet customers, use facial and speech recognition, and understand multiple languages. It also has a touchscreen on its chest for interaction.
  - Mitra was launched by Prime Minister Narendra Modi and Ivanka Trump at the Global Entrepreneurship Summit (GES) conference in 2023.
- **Robocop**: A police robot that can assist in handling law and order, developed by H-Bots Robotics. Robocop can salute, shake hands, recognise faces, and identify suspects.
  - It can also communicate with the police control room and alert them in case of emergencies.
- **AI Centers of Excellence**: The national Artificial Intelligence (AI) Mission will include creating Centres of Excellence (CoE) for AI-related research and development. There will be a National Centre for Transformation AI and several domain-specific CoEs for healthcare, agriculture, education, smart cities, etc.
- **US-India AI Initiative**: A flagship program launched by the Indo-US Science and Technology Forum (IUSSTF) to foster AI innovation and collaboration between India and the USA.
  - The initiative will bring together key stakeholders from both countries to share ideas and experiences, identify new opportunities, and address common challenges in AI.

OTHER PROMINENT EMERGING TECHNOLOGIES

3D Printing [UPSC 2018]

3D printing, also known as additive manufacturing, is the process of creating three-dimensional objects from a digital file. The process works by laying down successive thin layers of a material, such as plastic, metal, or ceramic, until the object is complete.

QR Technology

- QR technology is a type of two-dimensional barcode that can store a large amount of information, such as text, URLs, contact information, images, and videos.
- QR codes can be scanned by a digital device, such as a smartphone or a camera, and processed using error correction algorithms to retrieve the encoded data.
- QR technology has many applications in various fields, such as product tracking, item identification, time tracking, document management, and general marketing.
- QR codes can also be used to encode cryptocurrency wallet addresses, connect to wireless networks, or compose an email or text message.

Neuromorphic Computing

Neuromorphic computing mimics the human brain's structure to create devices using artificial neurons for calculations. The aim is to be powerful, energy-efficient, and capable of learning like our brains.

- This field combines biology, physics, math, computer science, and electronics.
  - It's used in vision systems, auditory processors, and robots.
- Challenges include making reliable designs, efficient learning methods, and understanding neural networks.
- Neuromorphic computing doesn't replace regular computing; it's an extra approach offering new possibilities for artificial intelligence.
- Though it's early in development, it could revolutionize how we compute and understand things in the future.

Bharat GPT

- India's first indigenous Generative AI platform developed by CoRover.ai.
- Aims to provide conversational AI solutions in 12+ Indian languages across various channels like text, voice, and video.
- Focuses on being human-centric, meaning it prioritizes natural and engaging interactions with users.
- Targets a wide range of potential applications, including customer service, education, healthcare, and entertainment.

Bharat QR

- Interoperable QR code-based payment system launched by the National Payments Corporation of India (NPCI).
- Enables seamless digital transactions between merchants and customers across various banks and payment networks.
- Aims to promote cashless transactions and financial inclusion in India, particularly among small businesses and rural communities.
- Offers advantages like convenience, security, and affordability for both merchants and customers.

LASER (LIGHT AMPLIFICATION BY STIMULATED EMISSION OF RADIATION)

It's a technology that utilizes the principles of quantum mechanics and optics to produce a highly focused and coherent beam of light. Here are key aspects of LASER technology:

Basic Principle: The fundamental principle behind LASER technology is the process of stimulated emission of photons. Atoms or molecules are stimulated to emit photons (light particles) with the same energy, phase, and direction when they are exposed to external energy.

Components of a LASER

- Gain Medium: This is the material (solid, liquid, or gas) that amplifies light through the process of stimulated emission.
- Excitation Source: It provides the energy required to excite the atoms or molecules in the gain medium.
- Optical Cavity/Resonator: It consists of mirrors at both ends, allowing the light to bounce back and forth, amplifying it further.
- Output Coupler: It allows a portion of the amplified light to exit the cavity, forming the LASER beam.

Coherence and Monochromaticity

- LASER light is characterized by its coherence, which means that the waves are in phase with each other. This coherence leads to a highly focused and narrow beam.
- LASER light is also monochromatic, meaning it consists of a single color or wavelength.

Applications

- Communication: LASERs are used in fiber-optic communication systems for data transmission.
- Surgery: In medical applications, LASERs are used for precision surgeries, such as eye surgeries and skin treatments.
- Material Processing: LASERs are employed for cutting, welding, and engraving various materials in industries.
- Research: LASERs play a crucial role in scientific research, including spectroscopy, microscopy, and particle acceleration.
- Entertainment: LASERs are used in various entertainment applications, such as laser light shows.

Types of LASERs

- Semiconductor LASERs: Commonly used in consumer electronics, including DVD players and laser pointers.
- Gas LASERs: Helium-neon (HeNe) LASERs are a common example used in educational and research settings.
- Solid-State LASERs: Utilize solid materials such as crystals or glass as the gain medium. Nd:YAG and Ruby LASERs fall into this category.
- Fiber LASERs: Use an optical fiber as the gain medium, commonly employed in telecommunications and material processing.

Safety Considerations

- LASERs can be hazardous to the eyes and skin. Protective measures, such as safety goggles, are essential when working with LASERs.
- Different classes of LASERs are defined based on their potential for harm, and safety regulations are in place to mitigate risks.

SUPERCONDUCTIVITY

Superconductivity is a phenomenon observed in certain materials where they can conduct electricity with zero electrical resistance and expel magnetic fields. Here are key aspects of superconductivity technology:

Zero Electrical Resistance

- The most distinguishing feature of superconductors is their ability to conduct electricity without any resistance. This means that once a current is established in a superconducting loop, it can persist indefinitely without any loss of energy.

Critical Temperature (Tc)

- Superconductivity is typically observed below a critical temperature unique to each material. Above this critical temperature, the material behaves like a normal conductor, but below it, the superconducting state emerges.

Types of Superconductors

- Type I Superconductors: Exhibit a sharp transition to the superconducting state at a specific critical temperature. Examples include lead and mercury.
- Type II Superconductors: Have a more gradual transition and can exist in a mixed state where some parts are superconducting and others are not.

Examples include niobium-titanium and yttrium-barium-copper oxide.

Applications

- Magnetic Levitation: Superconductors expel magnetic fields, leading to applications like magnetic levitation (Maglev) trains. The lack of resistance allows Maglev trains to travel at high speeds with minimal energy loss.
- MRI (Magnetic Resonance Imaging): Superconducting magnets are used in medical imaging devices like MRI machines, providing strong and stable magnetic fields for detailed imaging.
- Electric Power Transmission: Superconductors can be used in power cables to transmit electricity with minimal loss, increasing the efficiency of power distribution.
- Quantum Computing: Superconducting materials are being explored for use in quantum computers, where the qubits can be implemented as superconducting circuits.

High-Temperature Superconductors (HTS)

- Early superconductors required extremely low temperatures (near absolute zero), but HTS materials can exhibit superconductivity at higher temperatures, although still below room temperature.
- Yttrium-barium-copper oxide (YBCO) is an example of a high-temperature superconductor.

Challenges and Limitations

- Cooling Requirements: Many superconductors require extremely low temperatures to maintain their superconducting state, which can be a technological challenge.
- Material Cost: Some superconducting materials, especially high-temperature superconductors, can be expensive.
- Current Limitations: Practical applications are often limited by the current-carrying capacity and stability of superconductors.

Ongoing Research and Developments

- Ongoing research aims to discover new superconducting materials with higher critical temperatures and better properties for various applications.
- Scientists are exploring ways to overcome existing challenges and make superconductivity more practical for widespread use.

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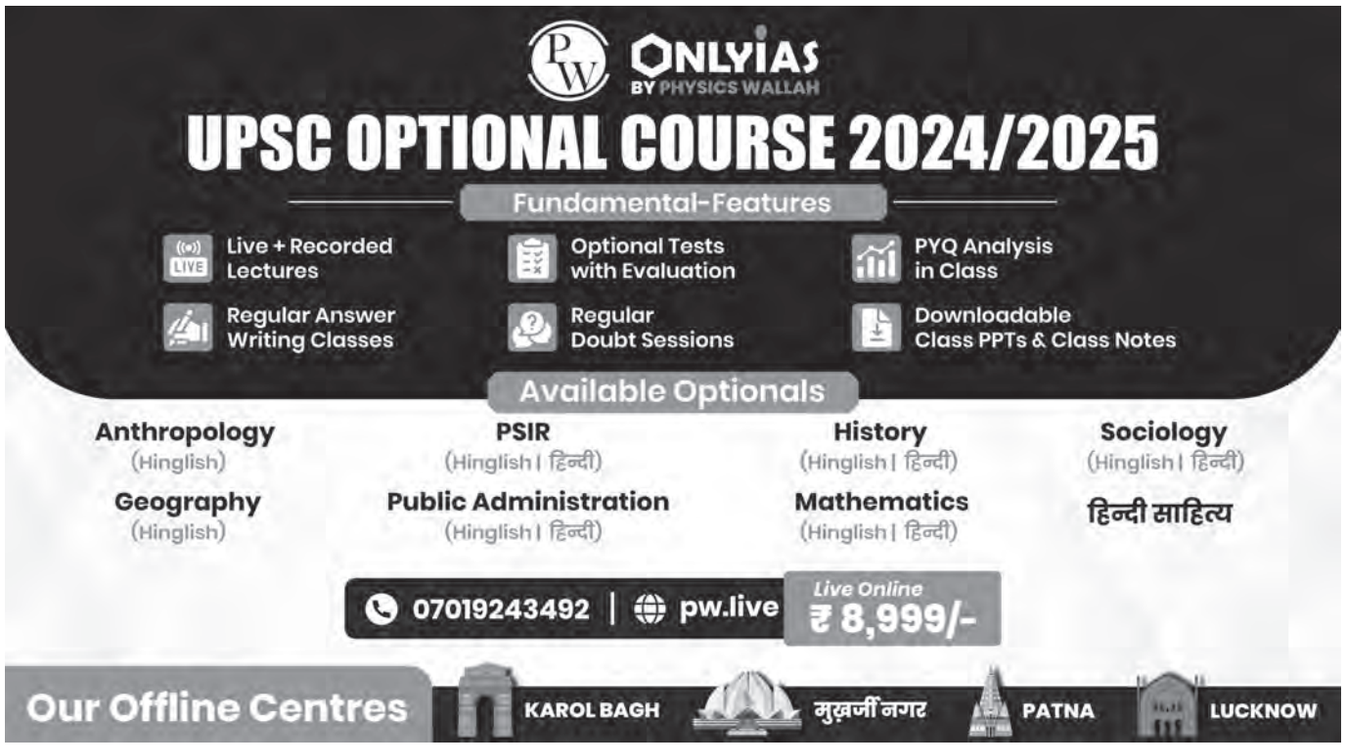


5 Energy: Renewable and Non-Renewable

NON-RENEWABLE (CONVENTIONAL) ENERGY RESOURCE

Non-renewable energy sources are those that **cannot be replenished or take a very long time to form.** They are **finite** and include fossil fuels like coal, petroleum, and natural gas, as well as other forms such as asphalt, bioasphalt, LPG (Liquefied Petroleum Gas), PNG (Piped Natural Gas), CNG (Compressed Natural Gas), LNG (Liquefied Natural Gas), and different types of natural gas like sweet and sour gas.

Following are the Non-Renewable Sources of Energy:

- **Coal:** Coal is a **solid fossil fuel** formed from ancient plant matter over millions of years. It is primarily used for electricity generation and in industrial processes that require heat.
- **Petroleum:** This liquid fossil fuel, also known as **crude oil**, is extensively used for transportation fuels such as gasoline and diesel and as a raw material for chemicals and plastics.
- **LPG (Liquefied Petroleum Gas):** LPG is a byproduct of natural gas processing and petroleum refining and is widely used as fuel in heating appliances, cooking equipment, and vehicles.
- **PNG (Piped Natural Gas):** PNG is **mainly methane,** with a small percentage of other hydrocarbons. It is mainly supplied through mild steel (MS) and polyethylene (PE) pipes to cater to the natural gas demand for domestic cooking and heating, as well as in various industrial applications.
- **CNG (Compressed Natural Gas):** CNG is **methane** stored under high pressure. It is used as a cleaner alternative to gasoline and diesel in vehicles.
- **LNG (Liquefied Natural Gas):** LNG is **natural gas** (The largest component of natural gas is methane. It also contains smaller amounts of natural gas liquids and nonhydrocarbon gases such as carbon dioxide and water vapour) that have been cooled to a liquid state for ease of storage and transportation. It is used in heating, cooking, and as fuel for trucks and ships.
- **Sweet and Sour Gas:** These are types of natural gas. **Sweet gas has a low sulphur content,** making it less corrosive and more environmentally friendly, while **sour gas contains higher amounts of hydrogen sulphide** and requires more processing to make it safe to use.

RENEWABLE (NON-CONVENTIONAL) ENERGY RESOURCES

Renewable energy sources are diverse and sustainable. They are used to generate energy through natural processes. Its forms include solar, wind, geothermal, hydropower, and ocean energy (including ocean thermal energy conversion (OTEC) and tidal energy), biomass energy (biofuels), and wave energy. Each of these sources has distinct characteristics and types:

Category	Details
Renewable Energy Target	• Increase renewables capacity to 500 GW by 2030. • Meet 50% of energy requirements from renewables.
Progress Made by India	• Achieved 40% of its installed electricity capacity from non-fossil fuel sources. • World's third-largest producer of renewable energy.

Solar Energy

Solar energy is the harnessing of the sun's energy and converting it into electricity or heat. **[UPSC 2020]**

Types of Solar Energy Systems in India:

- **Photovoltaic (PV) Systems:** These systems convert sunlight directly into electricity using solar cells. They are widely used for both residential and commercial purposes.
  - **Working:** In PV systems, photovoltaic cells, typically made of semiconductor materials like silicon, absorb sunlight. This sunlight dislodges electrons in the semiconductor material, creating

a flow of electric current. This process is known as the photovoltaic effect.

- **Concentrated Solar Power (CSP):** It uses mirrors or lenses to concentrate a large area of sunlight onto a small area, generating heat that drives an engine connected to an electrical power generator.
  - **Working:** CSP systems concentrate sunlight using mirrors or lenses onto a small, targeted area. This concentrated solar energy is then used to heat a fluid, which produces steam. The steam drives a turbine, generating electricity in a manner similar to traditional power plants.

Difference Between Solar PV Panels and Solar Thermal Panels

- Solar PV (photovoltaic) panels convert sunlight directly into electricity using photovoltaic cells, primarily for electricity generation in residential and commercial settings.
- In contrast, solar thermal panels absorb sunlight to heat a fluid, which is then used for heating purposes such as domestic hot water and space heating. While PV panels are focused on electrical energy production, solar thermal panels are dedicated to providing thermal energy.

- **Solar Rooftop Systems:** They are installed on the rooftops of residential or commercial buildings. These systems generate electricity for onsite use and can feed excess power back to the grid.
- **Solar Parks:** These are large-scale solar installations, often developed in collaboration with state governments or big private firms.
- **Current Capacity and Growth: Installed Capacity:** India has a solar energy target of 280 GW by 2030. As of August 2023, India's solar power installed capacity was **71.61 GWAC** (Gigawatt Alternating Current).
- **Areas of Presence:** Solar energy projects are spread across various states in India. The ranking of states according to current solar energy installations is **Rajasthan (17.8 GW), Gujarat (10.13 GW), Karnataka (9.05 GW), Tamil Nadu (6.8 GW), and Maharashtra (4.8 GW).**

Wind Energy

Wind energy involves generating electricity by converting the kinetic energy of wind using wind turbines.

Current Capacity and Growth

- **Installed Capacity:** As of August 2023, India's total installed wind power capacity was **44 gigawatts (the target for year 2030 is 140 GW),** making it the **fourth** largest in the world in terms of wind power capacity.

Areas of Presence

- **Geographical Spread:** Major wind energy installations are found in states like **Tamil Nadu, Gujarat, Maharashtra, and Karnataka,** which have favourable wind conditions.
- **Wind Parks:** India has developed several large wind parks. Examples include **Jaislmer Wind Park (1064 MW), Muppandal Wind Farm (1500 MW),** etc.

Geothermal Energy

Geothermal energy is derived from the natural heat of the Earth, typically from areas with volcanic or tectonic activity.

- **Properties:** It provides a constant and reliable energy source with minimal environmental impact.
- **Current Capacity and Potential**
  - **Installed Capacity:** As of 2023, India has not yet started commercial power production from geothermal energy. However, the potential is significant. Site exploration is currently going on in **Puga Valley of Ladakh**. India is also exploring sites in the state of Arunchal Pradesh.
  - **Potential Capacity:** Estimates suggest that India has the capacity to generate around **10 GW** of geothermal energy.
- **Areas of Presence**
  - **Geothermal Sites:** India has identified several geothermal fields, with notable ones in the Himalayan region, Gujarat, and Chhattisgarh.
  - **Hot Springs:** There are about 340 identified geothermal hot springs across the country, mostly in regions with volcanic activity.

Hydropower

Hydropower uses the energy of flowing water, typically from rivers or streams, to generate electricity.

- **Properties:** It is a renewable and clean source of energy, though large dams can have significant environmental and social impacts.
- **Current Capacity and Growth:**
  - **Installed Capacity:** As of May 2023, the installed hydropower capacity in India was **46,850 MW,** accounting for 11.2% of the total installed generation capacity.
- **Areas of Presence**
  - **Geographical Spread:** Hydropower plants are predominantly located in the northern and northeastern regions of India, including states like **Himachal Pradesh, Uttarakhand, and Arunachal Pradesh.**
  - **Major Projects:** Notable hydropower projects include the **Bhakra Nangal Dam, Tehri Dam, and Nathpa Jhakri Dam.**

Ocean Energy

Ocean energy encompasses various methods of harnessing energy from the ocean, including thermal gradients, tides, and waves.

- **Properties:** Ocean energy is a vast, largely untapped renewable resource, offering significant potential for coastal regions.
- **Current Capacity and Potential:**
  - **Installed Capacity:** As of 2023, India has not yet realised significant commercial capacity in ocean energy.
  - **Potential Capacity:** India is estimated to have a theoretical potential of about **54 gigawatts (GW)** of ocean energy, including tidal and wave energy.
- **Areas of Presence:**
  - **Potential Sites:** The Gulf of Kutch and the Gulf of Cambay are identified as potential sites for tidal energy. The long coastline of India offers numerous locations for wave energy and OTEC.

Biomass Energy (Biofuels)

It is energy that is produced from organic materials such as wood, agricultural crops, or waste and is used for heating, electricity generation, or as biofuels.

- **Properties:** Biomass can be a sustainable energy source when managed responsibly, though it does produce some emissions when burned.
- **Types of Biomass Energy Systems in India:**
  - **Biomass Power Plants:** These plants use organic materials like agricultural residues, wood, and bagasse to produce electricity.
  - **Biomass Cogeneration:** This involves the simultaneous production of electricity and heat using biomass, commonly practiced in sugar mills.
  - **Waste-to-Energy Plants:** These facilities convert municipal and industrial waste into energy.
  - **Biomass Gasification:** A process where biomass is converted into a gas (syngas), which can be used for power generation or as a fuel.
  - **Biofuels:** Biomass can be processed into biofuels like ethanol and biodiesel, which can be used as substitutes for gasoline and diesel in vehicles.
- **Current Capacity and Growth:** The installed capacity for biomass production in India reached 10 GW in FY22, growing at a compound annual growth rate (CAGR) of 4%.
- **Areas of Presence:**
  - **Geographical Spread:** Biomass energy facilities are widely distributed across India, with a higher concentration in agricultural states like Punjab, Haryana, and Uttar Pradesh.
  - **Major Projects:** Many sugar mills in India have adopted biomass cogeneration, and there are numerous waste-to-energy projects in urban areas.

Gas Hydrates

These are crystalline, ice-like compounds composed of water molecules that **trap gas molecules within their structure**. They form under specific conditions of **low temperature and high pressure, typically in deep-sea sediments and permafrost regions.** The most common gas hydrates contain methane, but other gases like ethane, propane, and carbon dioxide can also be present.

Key points about gas hydrates:

- **Formation:** Gas hydrates form when water molecules create a cage-like structure around gas molecules under low temperatures and high pressures. These conditions are often found in deep-sea sediments and permafrost regions.
- **Composition:** The most prevalent gas hydrate is methane hydrate, where methane molecules are encased in a lattice of water molecules. However, other gases can form hydrates under appropriate conditions.
- **Locations:** Gas hydrates are found in marine sediments along continental margins and permafrost regions. The majority are located in deep-sea environments where low temperatures and high pressures prevail. **[UPSC 2019]**
- **Energy Resource:** Methane hydrates are of interest as a potential future energy resource. The methane trapped within hydrates is abundant, and some estimates suggest that it could represent a vast reservoir of natural gas.
- **Environmental Concerns:** While gas hydrates hold potential as an energy resource, their extraction poses significant technical and environmental challenges. The process of extraction could lead to the release of methane, a potent greenhouse gas, into the atmosphere. **[UPSC 2019]**
- **Technological Challenges:** Extracting gas hydrates poses engineering challenges due to their stability conditions. Developing safe and efficient extraction methods is crucial for the potential commercialization of this resource.
- **Geohazard Potential:** Gas hydrates can destabilise, leading to the release of gas and causing geological hazards such as submarine landslides. Understanding these processes is essential for assessing potential risks in regions where gas hydrates are present.

SOME RECENT AND ADVANCED ENERGY GENERATION SOURCES

Fuel Cells

Fuel cells are devices that generate electricity through electrochemical reactions. Fuel cells, including hydrogen fuel cells and microbial fuel cells (MFCs), represent a significant advancement in energy technology, offering cleaner alternatives to traditional combustion-based power sources.

Hydrogen Fuel Cells

- **Basic Principle:** Hydrogen fuel cells generate electricity through a chemical reaction between hydrogen and oxygen. The key components of a hydrogen fuel cell include an anode, a cathode, and an electrolyte membrane.
- **Operation:** At the anode, hydrogen molecules are split into electrons and protons. The electrons travel through an external circuit, creating an electric current. The protons move through the electrolyte to the cathode, where they combine with oxygen and the electrons to produce water and heat.

Applications

- **Transportation:** Hydrogen fuel cells are used in vehicles like cars, buses, and trucks. They are particularly advantageous for heavy-duty and long-range transportation, including trains and potentially aeroplanes.
- **Stationary Power Generation:** Fuel cells can provide electricity for residential, commercial, and industrial buildings. They are useful for both primary power sources and backup power in case of grid failures.
- **Portable Power:** Hydrogen fuel cells are ideal for portable power applications, providing energy for devices like laptops, mobile phones, and remote sensors, especially in areas without grid access.
- **Specialised Vehicles**: They are used in forklifts and other warehouse vehicles, offering quick refuelling and longer operating times compared to battery-powered alternatives.
- **Power for Remote Locations:** In remote areas, hydrogen fuel cells can be a reliable source of power, replacing diesel generators.
- **Integration with Renewable Energy:** Hydrogen fuel cells can store excess energy generated from renewable sources like wind and solar, helping to balance the grid.

Microbial Fuel Cells (MFCs)

A microbial fuel cell (MFC) is a device that converts chemical energy to electrical energy through the action of microorganisms.

- **Basic Principle:** MFCs generate electricity through the action of bacteria that can oxidise organic and inorganic matter.
- **Operation:** In MFCs, bacteria are used as the biocatalyst at the anode. These bacteria oxidise organic compounds, releasing electrons and protons. The electrons travel through an external circuit to generate electricity, while the protons move to the cathode and combine with oxygen, forming water.
- **Types:** MFCs vary based on the type of bacteria used and the design of the cell, including single-chamber and dual-chamber designs.

Applications

- **Wastewater Treatment:** MFCs are used in wastewater treatment plants to degrade organic pollutants while simultaneously generating electricity, offering a dual benefit of waste management and energy production.
- **Biosensors:** They can be employed as biosensors for detecting pollutants or biochemical oxygen demand (BOD) in water, providing a cost-effective and efficient monitoring tool.
- **Remote Power Sources:** MFCs are suitable for powering remote sensors and low-power devices, especially in areas where conventional energy sources are unavailable.
- **Research Tool:** In scientific studies, MFCs serve as a tool for understanding microbial metabolism and interactions in various environments.

Lithium Ion (Li-Ion)

Lithium-ion cells, a cornerstone of modern battery technology, have revolutionised the way we store and use energy in various applications. These rechargeable batteries are known for their high energy density, low self-discharge rate, and long lifespan, making them ideal for use in everything from portable electronics to electric vehicles.

- **Basic Principle:** Lithium-ion cells operate on the principle of moving lithium ions between the anode and cathode during charging and discharging.
  - When the cell is charging, lithium ions move from the cathode to the anode and are stored there.
  - During discharge, these ions move back to the cathode, releasing electrical energy.
- **Components:**
  - **Anode:** Typically made of graphite, the anode stores lithium ions during the charging process.
  - **Cathode:** Made from lithium metal oxides, the cathode releases lithium ions during discharge.
  - **Electrolyte:** The lithium salt solution in an organic solvent facilitates the movement of lithium ions between the anode and cathode.

- **Separator:** It is a porous membrane that prevents physical contact between the anode and cathode while allowing ion transfer.

- **Status of Lithium Resource in India**
  - India has recently made significant discoveries in its lithium resources.
  - As of the latest reports, these findings place India among the top 1o countries globally in terms of lithium resources.
  - A notable discovery in the **Reasi district of Jammu and Kashmir** has been highlighted, with estimates of around **5.9 million metric tonnes of lithium reserves.**
  - This discovery has elevated India's position in the global lithium market, making it a potentially major player in the electric vehicle and battery manufacturing sectors.

Sodium-ion battery

Sodium-ion batteries are emerging as a promising alternative in the field of energy storage, offering several advantages over traditional lithium-ion batteries.

- **Basic Principle:** These batteries operate on a similar principle to lithium-ion batteries, where sodium ions move between the cathode and anode during the charging and discharging cycles.
- **Components:** The anode in sodium-ion batteries is typically made from carbon materials like hard carbons, while the cathode can be composed of various materials, including layered oxides, polyanionic compounds, and Prussian blue analogues. The electrolyte is usually a sodium salt dissolved in an organic solvent.

Waste to Power Energy

Waste-to-power energy, also known as waste-to-energy (WtE) or energy-from-waste (EfW), is a process that converts waste materials into electricity, heat, or fuel through various treatment methods. This approach not only helps in managing waste but also contributes to energy production, thereby addressing two significant environmental challenges.

Key Points of Waste-to-Power Energy

- **Conversion Processes:** The primary methods include thermal technologies like incineration, pyrolysis, and gasification, as well as non-thermal technologies such as anaerobic digestion and fermentation.
- **Incineration:** Incineration is the process of burning waste materials at high temperatures to reduce their volume, generating ash, flue gas, and heat, often used for energy production.
- **Pyrolysis:** Pyrolysis is the thermal decomposition of organic materials at high temperatures in the absence of oxygen, producing char, liquid bio-oil, and syngas. **[UPSC 2019]**
- **Gasification:** Gasification is a process that converts organic or fossil-based materials into syngas, a mixture of carbon monoxide, hydrogen, and carbon dioxide, by reacting them at high temperatures with a controlled amount of oxygen and/or steam.
- **Anaerobic Digestion:** This biological process breaks down organic waste in the absence of oxygen, producing biogas (mainly methane and carbon dioxide), which can be used to generate electricity and heat.

Polycrack Technology

Polycrack technology is an innovative approach in the fields of waste management and energy production. It represents a significant advancement in converting various types of waste into usable forms of energy. Here's a brief overview covering all aspects of polycrack technology:

- **Basic Principle:**
  - **Heterogeneous Catalytic Process:** Polycrack technology utilises heterogeneous catalytic processes.
  - This process allows for the conversion of multiple feedstocks, including a wide range of waste materials, into hydrocarbon liquid fuels, gas, carbon, and water.
- **Process and operation:**
  - **Conversion of Multiple Feedstocks:** The technology is capable of processing a variety of waste materials, including plastic, rubber, and organic waste.
  - **Output Products:** The process efficiently converts waste into several valuable outputs, including hydrocarbon liquid fuels (which can be used as a substitute for fossil fuels), gas (which can be used for heating or electricity generation), carbon (which has industrial applications), and water.
- **Environmental Impact:**
  - **Reduction in Landfill Waste:** By converting waste into energy, Polycrack technology significantly reduces the amount of waste that ends up in landfills.
  - **Lower Greenhouse Gas Emissions:** The technology offers an environmentally friendly solution by minimising the release of greenhouse gases compared to traditional waste disposal methods.
- **Applications:**
  - **Waste Management:** Polycrack technology is primarily used for the treatment of various types of waste, including municipal solid waste, plastic waste, and industrial waste.

- **Fuel Production:** It converts waste materials into hydrocarbon fuels, which can be used as a substitute for conventional fossil fuels.
- **Energy Recovery:** The process is capable of recovering energy from waste, contributing to sustainable energy initiatives.

Biomass

Biomass energy involves using organic materials as fuel to produce electricity, heat, or transportation fuels. These materials include wood, agricultural residues, and other plant-based materials. Biomass is considered renewable because it can be replenished over a relatively short period of time, unlike fossil fuels.

- **Conversion Processes:**
  - **Direct combustion** is the burning of biomass to produce heat, which is then used to generate electricity.
  - **Anaerobic Digestion:** This technique uses microorganisms to break down organic matter in the absence of oxygen, producing biogas.
  - **Fermentation** is the process of converting biomass into ethanol, a type of biofuel.
  - **Gasification and Pyrolysis:** In this technique, biomass is transformed into synthetic gas or bio-oil at high temperatures.

Biofuel

Biofuels are a type of renewable energy that comes from living materials. They are considered renewable because the feedstock material can be replenished easily. Biofuels, particularly ethanol and methanol, are increasingly recognised as sustainable alternatives to conventional fossil fuels. Their blending with petrol is a significant step towards reducing emissions and dependency on oil imports.

- **Ethanol Blending in Petrol:**
  - **Source and Production:** Ethanol, a type of alcohol, is typically produced through the fermentation of sugars found in crops like sugarcane, corn, and beet.
  - **Blending Process:** Ethanol is blended with petrol to create E10 (10% ethanol and 90% petrol), E15, or even E85 (85% ethanol) blends, depending on the country and regulations.
  - **Benefits:** Ethanol blending reduces greenhouse gas emissions, as ethanol burns cleaner than gasoline. It also helps in diversifying energy sources and supports agricultural sectors.
  - **Challenges:** High ethanol blends may require modifications to traditional petrol engines and fuel infrastructure. There's also a debate over the food vs. fuel issue, concerning the use of food crops for fuel production.
- **Methanol Blending in Petrol:**
  - **Source and Production:** Methanol, also known as wood alcohol, can be produced from natural gas, coal, or biomass.
  - **Blending Process:** Methanol is blended with petrol in various proportions, commonly as M5 (5% methanol and 95% petrol) or M15 blends.
  - **Benefits:** Methanol blending reduces carbon emissions and is cost-effective compared to pure petrol. It also offers higher octane ratings, improving engine performance.
  - **Challenges:** Similar to ethanol, methanol can be **corrosive and may require engine and infrastructure adjustments**. It also has toxicity concerns if mishandled.

Flex-Fuel Vehicles (FFV)

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

- **Engine Design:** The engines in FFVs are similar to those in conventional vehicles but are equipped with modified components that can handle different fuel blends, including high ethanol or methanol content.
- **Fuel Compatibility:**
  - **Ethanol Blends:** FFVs are capable of using E85, a blend containing 85% ethanol and 15% gasoline, as well as other ethanol blends like E15. This flexibility allows drivers to choose between biofuel blends and traditional gasoline based on availability and preference.
  - **Methanol Blends:** Some FFVs are also designed to operate on M85, which consists of 85% methanol and 15% gasoline, along with other methanol blends.
  - **Gasoline Use:** These vehicles can seamlessly switch to running on 100% gasoline, offering versatility in fuel choice, especially in areas where biofuel blends are not readily available.
- **Technological Features:**
  - **Advanced Fuel Systems:** FFVs are equipped with sophisticated fuel injection and engine management systems that can detect the type of fuel blend being used and adjust the fuel injection and combustion processes accordingly.
  - **Durable Materials:** The use of corrosion-resistant materials and components in FFVs ensures longevity and reliability, even with high biofuel blend usage.

Hydrogen Fuel

It is a versatile and clean form of energy that has the potential to play a crucial role in a sustainable and low-

carbon energy future. It can be classified into different types based on its production methods and sources. The three main types are:

Grey Hydrogen

- Production Method: Grey hydrogen is produced through a process called steam methane reforming (SMR) or other methods that use fossil fuels, such as natural gas.
- Environmental Impact: This method releases carbon dioxide (CO2) as a byproduct, making grey hydrogen less environmentally friendly compared to other types.
- Usage: Grey hydrogen has been historically the most common type of hydrogen produced, but its environmental impact has led to increased interest in cleaner alternatives.

Blue Hydrogen

- Production Method: Blue hydrogen is also produced through steam methane reforming (SMR) or other methods using fossil fuels, but the carbon emissions are captured and stored using carbon capture and storage (CCS) technologies.
- Environmental Impact: While it still relies on fossil fuels, the integration of CCS reduces the carbon footprint, making blue hydrogen a cleaner option compared to grey hydrogen.
- Usage: Blue hydrogen is considered a transitional option on the path to a fully renewable hydrogen economy.

Green Hydrogen:

- Production Method: Green hydrogen is produced through the process of electrolysis, using renewable energy sources such as solar, wind, or hydropower to split water into hydrogen and oxygen.
- Environmental Impact: Green hydrogen is considered the most environmentally friendly option since it is produced without emitting carbon dioxide, making it a key component in efforts to achieve a carbon-neutral or low-carbon future. **[UPSC 2023]**
- Usage: Green hydrogen is seen as a sustainable and long-term solution for various applications, including transportation, industry, and energy storage. **[UPSC 2023]**

National Green Hydrogen Mission

On 4th January 2023, the Union Cabinet approved the National Green Hydrogen Mission with an outlay of ₹ 19,744 crore from FY 2023-24 to FY 2029-30. The overarching objective of the Mission is to make India a global hub for production, usage and export of Green Hydrogen and its derivatives. The following components have been announced as part of the Mission:

- Facilitating demand creation through exports and domestic utilization;
- Strategic Interventions for Green Hydrogen Transition (SIGHT) programme, which includes incentives for manufacturing of electrolysers and production of green hydrogen;
- Pilot Projects for steel, mobility, shipping etc.;
- Development of Green Hydrogen Hubs;
- Support for infrastructure development;
- Establishing a robust framework of regulations and standards;
- Research & Development programme;
- Skill development programme; and Public awareness and outreach programme.

The expected outcomes of the Mission, by 2030, are as follows:

- India's Green Hydrogen production capacity is likely to reach 5 MMT per annum, contributing to reduction in dependence on import of fossil fuels. Achievement of Mission targets is expected to reduce a cumulative ₹ 1 lakh crore worth of fossil fuel imports by 2030.
- Nearly 50 MMT per annum of CO2 emissions are expected to be averted through production and use of the targeted quantum of Green Hydrogen.

GREEN ENERGY CORRIDOR

The Green Energy Corridor (GEC) in India is a significant initiative aimed at transforming the country's energy infrastructure to better integrate renewable energy sources. The following information gives a detailed outline of its phases, objectives, and significance:

Objectives of the Green Energy Corridor

- **Evacuation of Renewable Energy:** The primary objective is to facilitate the efficient evacuation of large-scale renewable energy, particularly from solar and wind sources, into the national grid.
- **Strengthening Grid Infrastructure:** The project aims to enhance and expand the grid infrastructure to accommodate the integration of renewable energy.
- **Improving Grid Stability:** Ensuring the stability of the grid is crucial, given the intermittent nature of renewable energy sources.

Green Buildings

Green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment. Leadership in Energy and Environmental Design (LEED) and Green Rating for Integrated Habitat Assessment (GRIHA) are two prominent green building certification systems that assess and certify buildings based on their environmental performance and sustainability. The following is a detailed analysis of LEED and GRIHA:

LEED (Leadership in Energy and Environmental Design)

- **Origin and Development:** LEED was developed by the U.S. Green Building Council, a non-profit organization committed to sustainable building practices.
- **Assessment Criteria:** The LEED certification system evaluates buildings on a range of criteria that include energy efficiency, water usage, indoor air quality, and the use of sustainable building materials.
- **Certification Levels:** Buildings seeking LEED certification can achieve different levels of recognition based on their performance across various sustainability metrics. These levels are LEED Certified, Silver, Gold, and Platinum.
- **Global Applicability:** LEED's framework is applied worldwide, transcending geographical boundaries to provide guidelines for creating healthy, efficient, and cost-saving green buildings. Its global applicability has made it a benchmark for best practices in sustainable building and construction, influencing projects around the world.

GRIHA (Green Rating for Integrated Habitat Assessment)

- **Origin and Development:** GRIHA was conceptualised and developed by the Energy and Resources Institute (TERI), a leading research institute in India focused on sustainable development.
- **Assessment Criteria:** The GRIHA system assesses buildings based on a comprehensive set of parameters that include sustainable site planning, building design optimisation, reduced energy consumption, efficient water usage, sustainable material usage, waste management, and improved indoor air quality. These criteria are designed to ensure that buildings are environmentally sustainable throughout their life cycle.

Renewable Purchase Obligation (RPO)

- **Background:**
  - The concept of RPO was introduced in India as part of the Electricity Act of 2003 and the National Tariff Policy of 2006.
  - However, it gained significant momentum with the launch of the National Action Plan on Climate Change in 2008.
- **Objectives of the Renewable Purchase Obligation:**
  - **Promotion of Renewable Energy:** The RPO is designed to increase the use of renewable energy sources in electricity generation, thereby reducing reliance on fossil fuels.
  - **Environmental Sustainability:** By mandating a certain percentage of electricity to be sourced from renewables, the RPO aims to reduce greenhouse gas emissions and promote environmental sustainability.
- **Current Status and Developments:**
  - **RPO Targets:** The Ministry of Power (MoP) in India sets specific RPO targets for obligated entities, which include distribution licensees, open access consumers, and captive power producers.
  - **Compliance Mechanism:** The Central Electricity Regulatory Commission (CERC) and State Electricity Regulatory Commissions (SERCs) oversee the compliance of these targets. They also regulate the Renewable Energy Certificate (REC) mechanism, which allows obligated entities to meet their RPO targets through the purchase of RECs.
  - **Recent Updates:** The Government of India has been updating RPO targets to reflect its increasing commitment to renewable energy. These targets are crucial for achieving the broader goals of the Paris Agreement and India's own renewable energy targets.

Other Government Initiatives

UJALA Scheme

- The UJALA (Unnat Jeevan by Affordable LEDs and Appliances for All) scheme is a significant initiative by the Government of India aimed at promoting energy efficiency and environmental conservation. It was launched on May 1st, 2015.
- **Ministry responsible: Ministry of power**

KUSUM Scheme

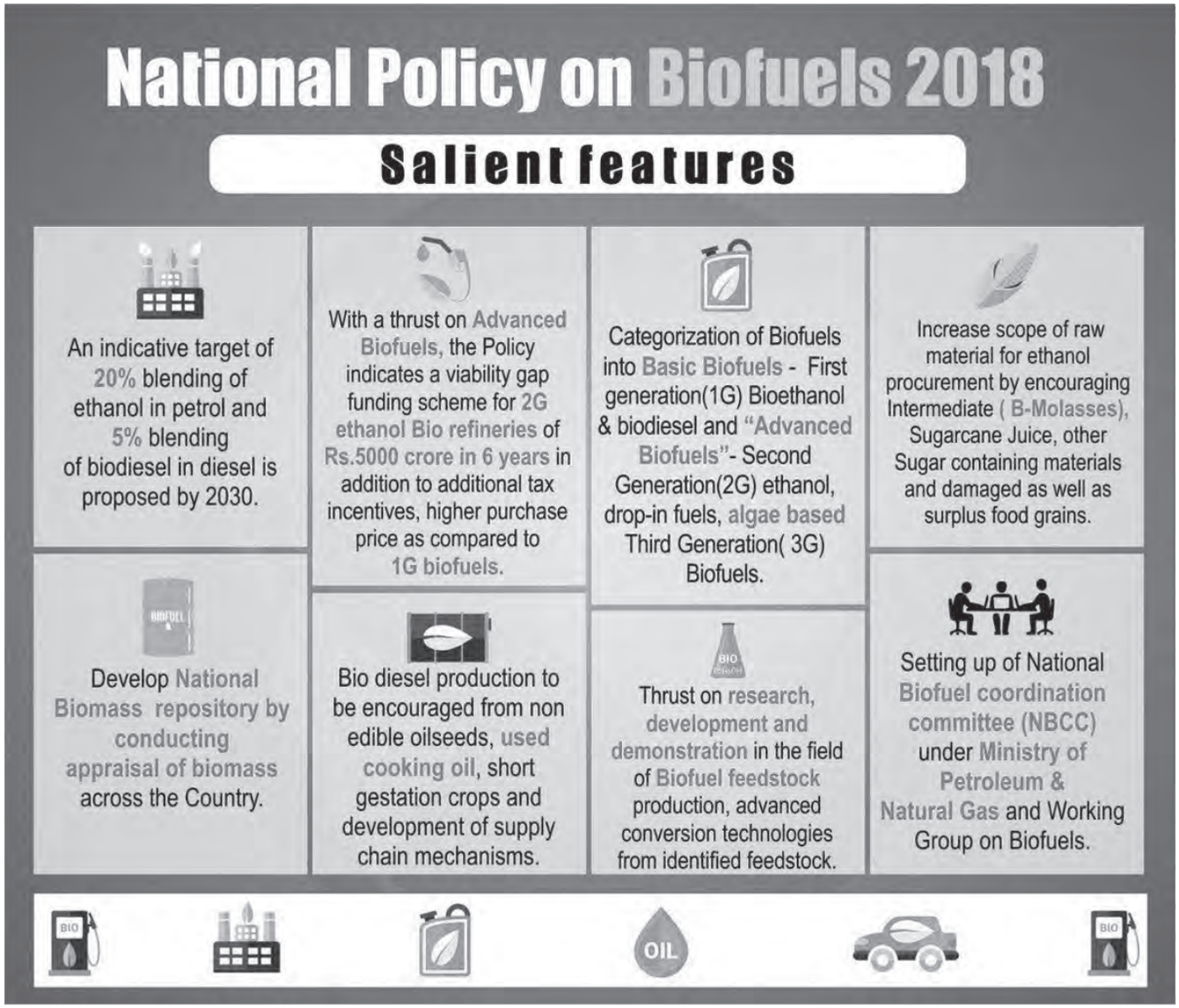
- The PM-KUSUM was launched by the MNRE in 2019 in order to **endow installation of off-grid solar pumps in rural areas** and reduce dependence on grid in grid-connected areas.
- Components:Installation ofgrid-connectedplants; installationn of Off-grid Solar Pumps and Solarization of Existing Grid-connected Agricultural Pumps
- **Ministry responsible: Ministry of New and Renewable Energy**

Atal Jyoti Yojana (AJAY)

- A scheme to provide solar street lighting in areas where grid power is either unavailable or unreliable. It focuses on lighting up streets using solar power, thereby reducing dependence on conventional electricity and promoting renewable energy.
- Ministry responsible: Ministry of New and Renewable Energy

Non-Renewable Energy Policies

- **Hydrocarbon Exploration and Licencing Policy (HELP):**
  - The Hydrocarbon Exploration and Licencing Policy (HELP) is designed to enhance domestic oil and gas production.
  - It offers a uniform licencing system for the exploration and production of all forms of hydrocarbons, including crude oil, natural gas, coal bed methane, and shale gas.
  - HELP aims to attract investment and cutting-edge technology in the hydrocarbon sector, promoting ease of doing business through a revenue-sharing model and marketing and pricing freedom.
- **National Mineral Policy:**
  - The National Mineral Policy focuses on the sustainable development of the mining sector, including minerals and fossil fuels.
  - It emphasises the need for more effective regulation, technological advancements, and environmental sustainability in mining activities.
  - The policy also seeks to ensure that mineral resources are used optimally for the country's economic development while minimising adverse environmental and social impacts.
- **National Policy on Biofuels, 2018 [UPSC 2020]**
  - It promotes the use of biofuels as an alternative to fossil fuels in the transportation sector, aiming to reduce dependence on crude oil imports, enhance energy security, and mitigate greenhouse gas emissions.



6 Nuclear Science and Technology

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

TYPES OF NUCLEAR REACTIONS

There are two primary types of nuclear reactions: nuclear fission and nuclear fusion.

- **Nuclear Fission:** It is the process of splitting a heavy atomic nucleus into two or more lighter nuclei, accompanied by the release of a large amount of energy. The neutrons produced during fission can trigger subsequent fission reactions in nearby fissile nuclei, creating a self-sustaining chain reaction. This is the basis for energy production in nuclear power plants.
- **Nuclear Fusion:** It is the process of combining two light atomic nuclei to form a heavier nucleus, releasing a large amount of energy. Common fusion fuels include isotopes of hydrogen, such as **deuterium** and **tritium**.
  - Experimental projects like **ITER (International Thermonuclear Experimental Reactor)** aim to develop practical and controlled nuclear fusion for energy production.

General differences between nuclear fission and nuclear fusion

Aspect	Nuclear Fusion	Nuclear Fission
Definition	Process of combining light atomic nuclei.	Process of splitting a heavy atomic nucleus
Fuel	Isotopes of hydrogen (e.g.,deuterium)	Fissionable isotopes (e.g., uranium-235)
Temperature and Pressure	Requires extremely high temperatures and pressures	Can occur at lower temperatures and pressures
Controlled vs. Uncontrolled	Achieving controlled reactions is challenging	Reactions can be controlled using control rods
Waste Products	Produces fewer long-lived radioactive waste products	Produces radioactive waste, including spent fuel and fission products
Applications	Potential future energy source (experimental)	Current use in electricity generation, weapons, and propulsion
Natural Occurrence	Naturally occurs in stars (e.g., the Sun)	Does not occur naturally in a sustained way on Earth

Cold Fusion

- It is a type of nuclear reaction that is thought to take place at or near room temperature.
- It would be in sharp contrast to the hot fusion that occurs naturally in stars and artificially in hydrogen bombs and prototype fusion reactors under great pressure and at temperatures of millions of degrees.

Uranium in India

- India has estimated uranium reserves of around **528,000 tonnes,** ranking 15th globally.
- India is the world's **9th largest producer of uranium,** with annual output exceeding 2,200 tonnes.
- India currently relies heavily on uranium imports, primarily from **Russia, Australia, and Kazakhstan.**

Environmental Concerns of Uranium mining: It can contaminate water resources through acid mine drainage, leaching of radioactive elements, and dust containing radioactive particles leading to health risks for communities relying on these water sources for drinking, irrigation, and livestock.

Enriched Uranium

- It is uranium whose concentration of the isotope uranium-235 (U-235) has been increased compared to natural uranium. This makes uranium more suitable for certain applications, such as nuclear power generation or nuclear weapons production.
- Natural uranium typically consists of approximately **99.3%** of Uranium-238(U-238) and **0.7%** of Uranium-235(U-235).
- The low percentage of U-235 in natural uranium limits its suitability for certain applications where a higher concentration of fissile material is required.

Types of enriched uranium

- **Low-Enriched Uranium (LEU):** It refers to uranium with a higher concentration of U-235 than natural uranium but still **below 20%.** It is used as fuel in **commercial nuclear power reactors.**
- **Highly Enriched Uranium (HEU):** It has a U-235 concentration of **over 20%. [UPSC 2023].** It has been historically used in **military applications**, including the production of **nuclear weapons.**

Thorium in India

India possesses unique advantages in the realm of nuclear energy due to its vast reserves of thorium, estimated at over **500,000 tons,** accounting for roughly **25%** of the world's known reserves.

Distribution of Thorium in India

- It is predominantly found associated with minerals like monazite, zircon, and ilmenite.
- **Beach sands** and **placer deposits** along the eastern coast constitute the largest source of thorium.
- Inland deposits, including carbonatite intrusions and pegmatites, contribute to the overall reserves. **[UPSC 2022]**
- **Major Thorium Deposits:** Andhra Pradesh (31%), Tamil Nadu (22%), Odisha (20%), Kerala (12%), Gujarat (3%), Bihar (2%).

Differences between thorium and uranium [UPSC 2012]

Aspect	Thorium	Uranium
Abundance	More abundant in the Earth's crust.	Abundant, but certain isotopes (e.g., U-235) require enrichment.
Nuclear Reactor Use	Used in Advanced Heavy Water Reactors (AHWRs) as part of the Three-Stage Nuclear Power Program.	Used in various types of nuclear reactors, including PWRs and BWRs.
Fertile Material	Thorium-232 is fertile and converted into fissile uranium-233.	Uranium-238 is fertile and converted into fissile plutonium-239.
Fuel Cycle	Involves breeding fissile uranium-233 from thorium. Part of India's Three-Stage Nuclear Power Program.	Involves enrichment of uranium-235 for nuclear reactor use. Spent fuel contains fission products and plutonium.
Proliferation Risks	Associated with fewer proliferation risks.	Traditional fuel cycles have greater proliferation concerns.
Waste Products	Expected to produce less long-lived radioactive waste.	Traditional reactors generate long-lived radioactive waste.
Economic Considerations	Economic viability is still under development.	Established infrastructure for uranium-based nuclear energy.
Safety Features	Thorium reactors are associated with certain safety features.	Modern uranium reactors incorporate safety features. Certain designs may have risks.

Potential benefits of using Thorium

- **Resource abundance:** Thorium is approximately **four times more abundant than uranium** in the Earth's crust, making it a more sustainable long-term fuel source.
- **Fuel breeding:** Although not directly fissile, **thorium-232** can be converted into fissile **uranium-233** through **neutron capture.**
- **Reduced waste:** Thorium-based reactors produce less long-lived radioactive waste compared to uranium reactors. This is because thorium primarily produces uranium-233, which has a **shorter half-life** than the long-lived transuranics generated in uranium reactors.
- **Enhanced safety:** Thorium-based reactor designs can incorporate inherent safety features that make them less susceptible to accidents.This passive safety feature **reduces the risk of meltdowns** and accidents compared to some traditional uranium reactor designs.
- **Diversification of energy sources:** It can serve as a valuable addition to the energy mix, reducing reliance solely on fossil fuels or uranium.

NUCLEAR REACTOR

It is a complex system designed to initiate and control nuclear reactions for the purpose of generating electricity or producing heat. The key principle behind a nuclear reactor is the controlled fission (splitting) of atomic nuclei, releasing a significant amount of energy.

Types of Reactors

Pressurised Heavy Water Reactor (PHWR)

It is a type of nuclear reactor that uses **heavy water (deuterium oxide, D_2O) as both a moderator and a coolant**. PHWRs are commonly employed for electricity generation and are known for their unique characteristics.

Key features and components

- PHWRs typically use natural uranium (uranium-238) as fuel. Unlike enriched uranium used in some other reactor types, natural uranium can sustain a nuclear chain reaction without the need for extensive enrichment.
- Boron control rods are used to regulate the rate of the nuclear chain reaction by absorbing neutrons. By adjusting the position of these control rods, operators can control the reactor's power output.

Small Modular Reactors (SMRs)

- SMRs are **advanced nuclear reactors** that have a power capacity of up to **300 MW(e) per unit**, which is about one-third of the generating capacity of traditional **nuclear power reactors.**
- SMRs, which can produce a large amount of low-carbon electricity:-
  - **Small:** Physically a fraction of the size of a conventional nuclear power reactor.
  - **Modular**: Making it possible for systems and components to be factory-assembled and transported as a unit to a location for installation.
  - **Reactors:** Harnessing nuclear fission to generate heat to produce energy.

NUCLEAR POWER IN INDIA

Nuclear energy is the **fifth-largest** source of electricity in India, contributing about 3% of the country's total electricity generation.

Current Status

- Installed capacity: 6,780 MW (as of November 2023)
- Number of reactors: 22 operating reactors across 7 nuclear power plants
- Types of reactors: Primarily pressurized heavy-water reactors (PHWRs), with some light-water reactors (LWRs)
- Contribution to electricity generation: Approximately 3.11% (as of 2020-21)
- **Plans for expansion:** Increase nuclear power capacity to 22,480 MW by 2031, accounting for nearly 9% of the energy mix by 2047.

India's Nuclear Plan

India's Three-Stage Civil Nuclear Power Programme

The Three-Stage Nuclear Power Program is an initiative introduced by India to develop a self-sustained nuclear power industry. It was proposed by **Dr. Homi J. Bhabh**a, the founder of India's nuclear program, in the 1950s.

Pressurized Heavy Water Reactors	
Input: Uranium Oxide + Deuterium Oxide	**Output:** Plutonium

↓

Fast Breeder Reactors	
Input: Plutonium+Uranium Mixed Oxide	**Output:** Uranium-233

↓

Thorium Based Reactors	
Input: Thorium + Uranium 233	**Output:** Energy

ITER/ARTIFICIAL SUN EXPERIMENT

- The **International Thermonuclear Experimental Reactor (ITER)** is a major international research project focused on **nuclear fusion. [UPSC 2016]**
- ITER represents a collaborative effort involving 35 countries, including the European Union, the United States, Russia, China, **India**, Japan, and South Korea.
- ITER is often referred to as the **"Artificial Sun Experiment"** because it aims to replicate the conditions and processes that occur in the sun to generate energy on Earth.
- India contributes both financially and in terms of expertise. Researchers from Indian institutions collaborate with their international counterparts on various aspects of plasma physics, diagnostics, and other fusion-related fields.

RADIATION TECHNOLOGIES AND APPLICATIONS

Radiation technologies encompass a wide range of applications that leverage the properties of ionizing and non-ionizing radiation for various purposes.

Medical Applications

- **Diagnostic Imaging:** X-rays, a form of ionizing radiation, are extensively used in medical imaging for diagnostic purposes.
- **Radiation Therapy:** Ionizing radiation, such as X-rays and gamma rays, is used in radiation therapy to treat cancer.
- **Nuclear Medicine:** Radioactive tracers, like technetium-99m, are employed in nuclear medicine for imaging and diagnosing diseases. Positron emission tomography (PET) scans use positron-emitting tracers to visualize metabolic processes in the body.

Industrial Applications

- **Non-Destructive Testing (NDT):** X-ray and gamma-ray techniques are applied in NDT for inspecting the integrity of materials and structures without causing damage. This is crucial in industries like aerospace and manufacturing.
- **Food Irradiation:** Ionizing radiation is used to irradiate food products, extending shelf life and preventing the growth of harmful microorganisms. This process enhances food safety and reduces the need for chemical preservatives.
- **Sterilization:** Gamma radiation and electron beams are utilized for sterilizing medical equipment, pharmaceuticals, and certain food products. This process eliminates bacteria, viruses, and other pathogens.
- **Materials Modification:** Ionizing radiation is employed to modify the properties of materials. This includes cross-linking polymers, enhancing the performance of electronic components, and altering the crystalline structure of materials.

Research and Environmental Monitoring

- **Particle Accelerators:** High-energy particle accelerators, such as cyclotrons and synchrotrons, are used in fundamental research, materials science, and medical isotope production.
- **Radiation Monitoring and Dosimetry:** Radiation detectors and dosimeters are crucial for monitoring and measuring radiation levels in various environments, ensuring safety in nuclear facilities, medical settings, and during transportation of radioactive materials.

Agricultural Applications

- **Radiation in Agriculture:** Gamma radiation is used for inducing mutations in plants to develop new crop varieties with desirable traits. Additionally, irradiation is employed for controlling pests and extending the shelf life of certain agricultural products.
- **Soil Moisture Measurement:** Neutron probes and gamma-ray techniques are utilized to measure soil moisture content, aiding in efficient irrigation management.

Space Exploration

- **Radiation for Propulsion:** Nuclear thermal propulsion and radioisotope thermoelectric generators (RTGs) are considered for future space missions. RTGs, for example, provide a long-lasting power source for space probes and rovers.

Environmental Remediation

- **Environmental Decontamination:** Radioactive and hazardous waste cleanup involves techniques such as soil washing and phytoremediation, which use ionizing radiation to decontaminate affected areas.
- **Air Quality Monitoring:** Radioactive aerosols can be used as tracers in atmospheric studies, helping monitor air quality and understand atmospheric circulation patterns.

SAFETY STANDARDS IN NUCLEAR POWER PLANTS

Safety standards in nuclear power plants are of utmost importance to ensure the protection of human health, the environment, and to prevent accidents that could lead to the release of radioactive materials. These standards are developed and enforced by national regulatory bodies, international organizations, and the nuclear industry itself.

Key aspects of safety standards in nuclear power plants

Regulatory Framework

- Each country with nuclear power plants has a regulatory body responsible for overseeing the safety of nuclear facilities. Example: Independent regulatory bodies like the Atomic Energy Regulatory Board (AERB) in India establish and enforce strict safety standards for nuclear power plants.

International Standards

- Organizations such as the International Atomic Energy Agency (IAEA) and the World Association of Nuclear Operators (WANO) play crucial roles in developing and promoting international safety standards.
- The IAEA's safety standards provide guidance and recommendations that member states can adopt to enhance the safety of their nuclear facilities.

Nuclear Winter: It is a theoretical climatic effect that could occur as a result of large-scale nuclear war.

- The concept was first introduced in the early 1980s to understand the potential environmental consequences of a nuclear conflict.

NUCLEAR MEDICINE

It is a medical specialty that uses small amounts of radioactive materials, called radiopharmaceuticals, to diagnose and treat various diseases.

Uses of Imaging Procedure in Varied Areas

Cancer Diagnosis and Staging

- It helps in detecting and staging various cancers by highlighting areas with abnormal cellular activity.
- PET scans are commonly used to identify cancerous lesions, assess tumor metabolic activity, and determine the spread of cancer in the body.

Cardiology

- Myocardial perfusion imaging (MPI) helps evaluate blood flow to the heart muscle, aiding in the diagnosis of coronary artery disease and assessing the extent of heart damage.
- Ventriculography and angiography are used to study the heart's pumping function and blood vessels.

Neurology

- Brain imaging with techniques like **SPECT** (Single Photon Emission Computed Tomography) and PET can aid in diagnosing conditions such as Alzheimer's disease, epilepsy, and brain tumors.
- Cerebral perfusion scans help evaluate blood flow to the brain.

Bone Scans: Whole-body bone scans are used to detect abnormalities in bone metabolism, such as fractures, infections, and bone cancers.

Thyroid Disorders: Radioactive iodine is used in imaging and treatment of thyroid disorders, including hyperthyroidism and thyroid cancer.

Gastrointestinal Disorders: Nuclear medicine studies can help diagnose conditions such as gastrointestinal bleeding, liver disorders, and gallbladder dysfunction.

INDIA'S NUCLEAR POWER & ENERGY POLICY

India's nuclear power and energy policy reflects a complex balancing act between diverse priorities and challenges.

Pillars of India's Nuclear Policy

- **No First Use (NFU):** India's policy commits it to never initiating a nuclear attack, even in the face of conventional aggression.
- **Credible Minimum Deterrence:** This aims to maintain a nuclear arsenal sufficient to deter any potential adversaries from launching a nuclear attack against India.
- **Peaceful Use of Nuclear Energy:** India emphasizes the peaceful use of nuclear energy for power generation and medical applications.

COMMAND AND CONTROL OF NUCLEAR BOMBS

Command and control of nuclear weapons is the authority and direction exercised by the President over nuclear weapon operations.

Nuclear Command Authority (NCA)

- On January 4, 2003, the Nuclear Command Authority (NCA) was established by the **Cabinet Committee on Security (CCS),** comprising two councils: the Executive Council and the Political Council.
- Chaired by the **National Security Advisor (NSA), the Executive Council** works in tandem with the Political Council, which is chaired by the **Prime Minister.**

Strategic Nuclear Command or Strategic Forces Command

- The Strategic Nuclear Command is an integral component of **India's Nuclear Command Authority (NCA),** formally established in 2003.
- The **Joint Services Strategic Nuclear Command (SNC)** serves as the custodian for all of India's nuclear weapons, missiles, and assets. It bears responsibility for the execution of all aspects of India's nuclear policy.

INTERNATIONAL TREATIES AND ARRANGEMENTS FOR NUCLEAR TECHNOLOGY

Treaty on the Non-Proliferation of Nuclear Weapons (NPT): It is a landmark treaty aimed at preventing the spread of nuclear weapons and promoting the peaceful use of nuclear energy.

Comprehensive Nuclear-Test-Ban Treaty (CTBT)

- Aims to ban all nuclear explosions for both civilian and military purposes to prevent the development of new nuclear weapons and contribute to disarmament.
- The CTBT has not yet entered into force, as some key countries, including the United States and China, have not ratified it.

International Atomic Energy Agency (IAEA) Safeguards

- The **"IAEA safeguards"** system ensures that countries use nuclear materials and technology for peaceful purposes and do not divert them for the development of nuclear weapons. **[UPSC 2020]**
- IAEA inspectors conduct inspections and verify the declarations made by member states regarding their nuclear activities.

Convention on Nuclear Safety (CNS)

- Focuses on ensuring the safety of nuclear power plants worldwide.
- Establishes obligations related to design, construction, operation, and decommissioning of nuclear facilities, as well as the management of radioactive waste.

Joint Comprehensive Plan of Action (JCPOA)

- Also known as the Iran Nuclear Deal, the JCPOA was an agreement between Iran and a group of world powers (P5+1) to limit Iran's nuclear program in exchange for the lifting of economic sanctions.
- The JCPOA faced challenges, with the United States withdrawing in 2018.

Zangger Committee

- A group of Nuclear Suppliers Group (NSG) countries that consult on nuclear export controls to prevent the spread of sensitive nuclear technologies.
- Establishes guidelines for controlling the export of nuclear-related equipment, materials, and technology.

Nuclear Suppliers Group (NSG)

- A voluntary association of nuclear supplier countries that aims to prevent the proliferation of nuclear weapons by controlling the export of nuclear materials and technology.
- NSG guidelines include criteria for nuclear exports, with the objective of ensuring that nuclear transfers are for peaceful purposes only. **[UPSC 2020]**

Treaty of Pelindaba: Establishes Africa as a nuclear-weapon-free zone and promotes the use of nuclear energy for peaceful purposes in the region.

Nuclear Non-Proliferation Treaty (NPT)

- The NPT was opened for signature in 1968 and **entered into force in 1970.**
- It is a multilateral treaty designed to prevent the spread of nuclear weapons and weapons technology and promote the peaceful use of nuclear energy.
- The NPT recognizes **five nuclear-weapon states: the United States, Russia, China, France, and the United Kingdom. [UPSC 2015]**
  - These states are acknowledged as possessing nuclear weapons at the time of the treaty's inception.
  - Non-nuclear-weapon states commit not to develop or acquire nuclear weapons and to accept International Atomic Energy Agency (IAEA) safeguards to verify the peaceful nature of their nuclear activities.
- The **International Atomic Energy Agency** plays a crucial role in verifying compliance with the NPT. Non-nuclear-weapon states are required to submit to IAEA safeguards to ensure that their nuclear activities are peaceful.
- **Review conferences** are held every **five years** to assess the implementation of the NPT. These conferences provide a platform for discussions on disarmament, non-proliferation, and the peaceful use of nuclear energy.
- **India didn't sign the NPT** along with the countries like South Sudan, Pakistan, and Israel.

Comprehensive Nuclear-Test-Ban Treaty (CTBT)

- The CTBT was adopted by the United Nations General Assembly in 1996. Its objective is to ban all nuclear explosions for both civilian and military purposes. This includes underground, underwater, and atmospheric testing.
- The CTBT establishes a comprehensive verification mechanism, called **International Monitoring System (IMS)** to monitor compliance. The **IMS** consists of a network of monitoring stations worldwide that detect seismic, hydroacoustic, and radionuclide signals associated with nuclear explosions.
- Several key countries, including the United States, China, and **India, had not ratified the CTBT.**

- The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) was established to promote the treaty's implementation before it enters into force. The CTBTO works on building and maintaining the IMS and preparing for the treaty's verification regime.

India's Emergence as a de Facto Weapons State Under NPT

- India has consistently maintained a position of not signing the NPT, primarily due to its concerns about the discriminatory nature of the treaty, which distinguishes between nuclear-armed states recognized under the treaty and non-nuclear-armed states.
- India's nuclear weapons program dates back to the 1970s, and it conducted its first nuclear test, codenamed **"Smiling Buddha,"** in **1974.**

India's Benefits of NSG Membership

India's pursuit of membership in international export control regimes such as the Nuclear Suppliers Group (NSG), Wassenaar Agreement, and Missile Technology Control Regime (MTCR) is part of its broader strategy to enhance its global standing and access to advanced technologies.

Nuclear Suppliers Group (NSG)

- The NSG is a multinational group of countries that aims to prevent the proliferation of nuclear weapons by controlling the export of nuclear materials, equipment, and technology. It seeks to ensure that nuclear technology is used only for peaceful purposes.
- It was formed in **1974** in response to India's nuclear weapons test.
- The NSG consists of 48 participating governments. **India is currently not a member.**

Benefits of India's membership

- **Access to Nuclear Technology:** NSG membership would provide India with access to advanced nuclear technologies, equipment, and materials for its civilian nuclear program. This includes technologies for power generation, medical applications, and scientific research. **[UPSC 2018]**
- **International Recognition:** Membership in NSG would signify international recognition of India as a responsible nuclear state, acknowledging its adherence to non-proliferation norms and commitments.
- **Economic and Energy Benefits:** Access to nuclear technology can boost India's energy sector by facilitating the expansion of its nuclear power capabilities, helping meet its growing energy demands and mitigating the environmental impact of fossil fuel-based energy.
- **Strengthening Non-Proliferation Commitments:** NSG membership would underscore India's commitment to non-proliferation efforts, as it would be subject to the group's guidelines and controls over the export of nuclear materials and technologies.

INDIA'S NUCLEAR AGREEMENTS

India has signed nuclear energy agreements with various countries as part of its efforts to enhance its nuclear power capabilities and promote civilian nuclear cooperation.

Major Agreements:

- **United States (2008):** The landmark Indo-US Civil Nuclear Agreement **(123 Agreement)** lifted restrictions on nuclear trade with India, allowing access to nuclear fuel and technology for civilian power generation.
- **France (2008):** This agreement covers nuclear fuel supply, technology transfer, and joint research in nuclear energy.
- **Russia (2009):** This agreement covers construction of nuclear power plants, uranium supply, and joint research in nuclear fuel cycle technologies.
- **Russia (2018):** Action Plan for Prioritization and Implementation of Cooperation Areas in the Nuclear Field was signed and by this agreement, Russia will build 12 units of Nuclear Power Plants in the next 20 years **[UPSC 2019]**.
- **Canada (2010):** This agreement focuses on nuclear fuel supply and cooperation in uranium exploration and mining.
- **Australia (2014):** This agreement enables trade in uranium and encourages cooperation in nuclear safety and waste management.
- **Mongolia (2015):** This agreement involves joint exploration for uranium resources in Mongolia.
- **Kazakhstan (2016):** This agreement allows for uranium supply from Kazakhstan to India.
- **Japan (2017):** This agreement focuses on cooperation in nuclear safety research and development.
- **South Korea (2018):** This agreement covers joint construction of nuclear power plants in India.

Benefits of Agreements

- **Fuel Security:** These agreements secure India's access to nuclear fuel for its expanding nuclear power program.
- **Technology Transfer:** Collaboration with advanced nuclear countries provides access to cutting-edge technology and expertise.

- **Research and Development:** Joint research projects promote innovation and technological advancement in nuclear energy.
- **Peaceful Nuclear Cooperation:** These agreements uphold the peaceful use of nuclear energy for power generation and other beneficial applications.

New Start Treaty: The New START Treaty (Strategic Arms Reduction Treaty) is a bilateral arms control agreement between the United States and Russia.
Nuclear Security Summit: The Nuclear Security Summit (NSS) was a series of international summits aimed at addressing the threat of nuclear terrorism and improving the security of nuclear materials worldwide. In April 2009, President Barack Obama proposed the Nuclear Security Summit in a speech in Prague. The first summit was held in Washington, D.C. on April 12–13, 2010. **[UPSC 2017]**

International Panel On Fissile Material (IPFM)
- It is an **independent** group of experts and scholars that focuses on issues related to fissile materials, which are substances capable of sustaining a chain reaction of nuclear fission. **[UPSC 2017**]
- The primary goal of IPFM is to promote international initiatives to control and reduce the use of fissile materials in order to prevent nuclear proliferation and enhance global security.

INSTITUTIONS INVOLVED IN NUCLEAR ENERGY R & D

Department of Atomic Energy

- The Department of Atomic Energy (DAE) is a government agency in India responsible for the development and implementation of nuclear energy programs. The DAE operates under the **Prime Minsiter's Office (PMO),** under the oversight of the **Prime Minister of India.**
- Its function is to harness nuclear power, foster Research and Development and ensure safety and regulations.

Bhabha Atomic Research Centre (BARC)

- Established in 1954, It is a premier multidisciplinary nuclear research facility located in Trombay, Mumbai, India.
- The primary objective of BARC is to harness nuclear energy for peaceful applications and conduct research across various scientific disciplines.

Global Centre For Nuclear Energy Partnership

It serves as a vital platform for international collaboration and innovation in the field of nuclear energy. Established in 2010 by the Department of Atomic Energy (DAE) in India, GCNEP aims to address global energy challenges through research and development in advanced nuclear technologies. GCNEP fosters collaboration through various mechanisms:

- **Joint research projects:** GCNEP collaborates with international research institutions and universities on specific projects.
- **Expert exchanges:** GCNEP facilitates the exchange of experts and knowledge between different countries.
- **Training programs:** GCNEP offers training programs for scientists, engineers, and policymakers from developing countries.
- **Workshops and conferences**: GCNEP organizes international workshops and conferences to share knowledge and discuss emerging trends in nuclear energy.

Atomic Minerals Directorate for Exploration and Research

- The Atomic Minerals Directorate for Exploration and Research (AMD) is an Indian government organisation responsible for exploring, assessing, and researching atomic minerals in the country.
- It operates under the Department of Atomic Energy (DAE), which is a key governmental agency overseeing nuclear energy programs in India.
- AMD has its headquarters in Hyderabad, Telangana, and it operates through regional centers across the country to cover different geological regions.

7 Defence Technology

INDIAN DEFENCE

Defence is protecting the integrity, sovereignty, international borders and geo-economic interests of a nation. Indian Defence system has been organised with the **President as the supreme commander** at the helm and the **Ministry of Defence**, which exercises **administrative control over the armed forces**. Indian Defence has been divided into three services:

- **Indian Army-** 1.3 million active personnel organised under six operational and one training command.
- **Indian Air Force-** over 127000 active personnel organised under five operational, one training and one maintenance command.
- **Indian Navy-** Blue water Navy with strength of 58000 plus active personnel.

Blue Water Navy: A Blue Water Navy is one that has the capacity to project itself over a much bigger maritime area than its maritime borders. In contrast, a navy whose operations are restricted close to the shore, where the water is muddy, signifies **Brown Water Force,** whereas those who can project themselves into the littoral waters are termed **Green Water Force.**

Ministry of Defence

The Ministry of Defence comprises five Departments, viz. **Department of Defence** (DOD), **Department of Defence Production** (DDP), **Department of Defence Research & Development** (DDR&D), **Department of Ex-Servicemen Welfare** and also **Finance Division**.

Defence Acquisition Council

Serves as the paramount decision-making entity within the Defence Ministry; the DAC is responsible for **formulating new policies and overseeing capital acquisitions** for the **Army**, **Navy**, **Air Force**, and the **Indian Coast Guard**.

- **DAC Composition:** The **Defence Minister serves as the Chairperson of the DAC**, which consists of 11 other members, including the **Minister of State for Defence**, **the Chief of Staff of the three wings of the Armed Forces**, the Defence Secretary, the Secretary-Defence Production, the Secretary-Defence R&D, Chief of Integrated Defence, Director General-Acquisition, Chief of Integrated Staff Committees HQ IDS.

DAC Functions:

- Granting approval for **AoN (Acceptance of Necessity)** concerning Capital Acquisition Proposals.
- Categorising acquisition proposals into **'Buy,' 'Buy & Make,' and 'Make' projects:**
- Providing in-principle approval for the **15-year Long-Term Integrated Perspective Plan (LTPP)** for Defence Forces.
- Overseeing the projects(progress) based on feedback from the Defence Procurement Board.

Defence Research and Development Organisation:

Established in **1958** with the objective of **Military research**, achieving **self-reliance** in defence technology and development of **advanced technologies** in diverse areas, including missile systems, aeronautics, electronics etc. The **scientific adviser** of the **Defence Ministry** is the **secretary of DDR&D** and **the chairman of DRDO**.

- **Important Contributions of DRDO**
  - **Missile Systems:** Agni series for deterrence, Prithvi, Akash, Nag for various applications.
  - **Aerospace Technologies:** LCA Tejas, PSLV, GSLV for satellite launches.
  - **Radar and EW Systems:** Arudhra, Rohini radars, electronic warfare advancements.
  - **Naval Systems:** Sonar systems, BrahMos supersonic cruise missile.
  - **Armoured Vehicles:** Arjun tank.
  - **UAVs and Drones:** Surveillance, combat UAVs, advancements in drone tech.

Besides the above, DRDO has also played an important role in the development of Nuclear Capabilities, Cyber Security, Biomedical Technologies, Strategic Technologies (AI, Quantum Tech) etc.

NTRO (National Technical Research Organisation)

- Technical Intelligence Agency under the National Security Advisor in the Prime Minister's Office, which operates as an autonomous organisation
- Primary objective is the acquisition of technical intelligence involving the interception and analysis of communication signals, imagery intelligence, and cyber intelligence.
- National Institute of Cryptology Research and Development functions under it.

Chief of Defence Staff

The **Cabinet Committee on Security** (**CCS**) created (2019) the post of the **Chief of Defence Staff** (CDS) to enhance the quality of military advice to political leadership through the integration of service inputs. The **Chief of Defence Staff is the Permanent Chairman of the Chiefs of Staff Committee and acts as the Principal Military Adviser to Raksha Mantri** on all tri-services matters. The **CCS** also created **the Department of Military Affairs**. The **overarching principle of this arrangement is that work related to Military Affairs is to be done only by the 'Department of Military Affairs', while the Department of Defence will deal with issues related to the defence of the Country**, including defence policy. Former Chief of the Army Staff, **General Bipin Rawat**, was appointed as the country's first Chief of Defence Staff on 31st December 2019.

DEFENCE TECHNOLOGIES IN INDIA

Missile Systems

Considering the importance of guided missile weapon systems in modern warfare, a Special Weapon Development Team (SWDT) was formed in 1958, which was expanded into the **Defence Research & Development Laboratory**(DRDL) in June 1961. Projects under the DRDL include:

- Development of an anti-tank missile system and indigenous rockets initially.
- **Project Devil** (initiated: 1972) for the development of a **medium-range Surface-to-Surface Missile**.
- DRDL (1982 onwards) has undertaken the design and development of various types of missile systems under **the Integrated Guided Missiles Development Programme (IGMDP)**.

Integrated Guided Missiles Development Programme (IGDMP)

IGMDP (**conceived by Dr. A. P. J. Abdul Kalam**) was started in 1983 to develop **Prithvi**, **Trishul**, **Akash**, **Nag** and **a Technology Demonstrator Agni Missile**.

The technology demonstrator missile of the Agni series (**tested in 1989**) was developed under the IGMDP. Afterwards, the **Agni missile program was detached from the IGMDP**.

Prithvi Missile: Prithvi is a nuclear-capable surface-to-surface short-range ballistic missile developed by **DRDO** with three variants:

Variant	Version	Range (km)	Payload (kg)
Prithvi I	Army	150	1000
Prithvi II	Air Force	350	500-1000
Prithvi III	Navy	350	1000

Dhanush: surface-to-surface missile, a naval variant of the indigenously-developed 'Prithvi' missile with a range of 350 km and a payload capacity of 500 kg.

Trishul Missile: It is a quick reaction, **short-range surface-to-air missile** equipped with electronic measures against known **aircraft jammers** with a range of 9-12 km and can also be used as an **anti-sea skimming missile**.

Akash Missile: It is a **short-range surface-to-air** missile system (**with built-in Electronic Counter-Counter Measures (ECCM) features**) configured on a **mobile platform** which can simultaneously engage multiple targets. It weighs 710 kg and has an operational range of 4.5-25 km (altitude: 0.1-20 km).

NAG Missile: NAG is a third-generation **Anti-Tank Guided Missile (ATGM)** with **Fire and Forget** top attack capability and an operational range of 0.5-4 km. Other features-

- **NAG missile carrier NAMICA**, a BMP II based system with amphibious capability, has been developed.
- **HELINA (DHRUVASTRA), an abbreviation for Helicopter Launched NAG, is an air-to-surface missile system** mounted on the **Advanced Light Helicopter** (ALH) with an operational range of 0.5-7 km.

Agni technology demonstrator: The two-stage (first stage: solid-fuel) capable of carrying a payload of 1000 kg was first tested in 1989. Later it evolved into the solid-fuel Agni-1 and Agni-2 missiles.

Agni Missile

Agni Missiles are short-range (medium) to long-range (intercontinental) surface-to-surface nuclear-capable ballistic missiles which provide strategic deterrence to India.

Missile	Description	Range (km)	Payload (kg)	Stages/Fuel
Agni- I	Short-Medium Range Ballistic Missile	700-1200	1000	Single Stage Solid Fuel
Agni- II	Medium Range Ballistic Missile	2000 +	1000	2 Stage Solid Fuel & Post Boost Vehicle
Agni- III	Intermediate Range Ballistic Missile	3000 +	1500	2 Stage Solid Fuel
Agni- IV [UPSC 2014]	Intermediate Range Ballistic Missile	4000	1000	2 Stage Solid Fuel
Agni- V [UPSC 2023]	Intercontinental Range Ballistic Missile	5000 +	1500	3 Stage Solid Fuel
Agni- VI (Under Development)	MIRV capable Intercontinental Range Ballistic Missile	9000-12000	3000	–
Agni- P (Prime)	Medium Range Ballistic Missile	1000-2000	1000	2 Stage canisterised Solid Fuel

Prahar Missile: Prahar is a **short-range** (**150 km**) **single-stage solid-fuel surface-to-surface missile** developed by DRDO. Like **Pinaka missile** (**a multiple-rocket system**) several Prahar missiles can be fired in one salvo. Prahar (**guided: three-element flight-control system**), with **greater accuracy** and **shorter reaction time** than the unguided missiles currently being used by the Indian Army, will fill the gap between **Pinaka** (**multi-barrel rocket system, range-45 km**) and the **Prithvi missile**.

Quick Reaction Surface to Air Missile: QRSAM is a **single-stage solid-fuelled** quick reaction surface-to-air Missile (**range: 5-30 km, altitude: 6 km**) capable of **Search on Move**, **Track on Move** and **Fire on Short halts**. Configured on highly mobile platforms, it is being inducted into the Indian Army (IA).

Medium Range Surface to Air Missile (**MRSAM**): Developed by the DRDO in collaboration with Israel Aerospace Industries (IAI) has a **range of 70 km**. MRSAM is a **high-response**, **quick-reaction**, v**ertically launched supersonic missile** designed to neutralise **enemy aerial threats – missiles**, **aircraft**, **guided bombs**, **helicopters** to be used by all three wings of armed forces.

Project Kusha: Under the project (**shouldered by DRDO**), India is readying its own long-range air defence system, which will be able to detect and destroy incoming **stealth fighters**, **aircraft**, **drones**, **cruise missiles** and **precision-guided munitions** at ranges up to 350 km. **Indigenous LRSAM** will be capable of reliable `area air defence' with a **single-shot kill probability of not less than 80%** (for single missile launch) and **not less than 90% for a salvo launch**.

Shaurya Missile: Shaurya (**land variant of short-range SLBM K-15 Sagarika**) is a **nuclear-capable two-stage solid-fuel short-range hypersonic ballistic missile** (**7.5 Mach**) with a **strike range of around 1,000 km** and a payload capacity up to **1000 kg**.

K Family of missiles

- These missiles are primarily **Submarine Launched Ballistic Missiles** (**SLBMs**), indigenously developed by DRDO and **are named after Dr Kalam.**
- Launched presently from **Arihant class submarines** (**complete India's Nuclear Triad**), these are lighter, smaller and stealthier than their land-based counterparts, the Agni series.
- **K-4 missiles** from the family are **intermediate-range** (**3500 km**) **nuclear-capable SLBMs** with a payload capacity of **2.2 tons**.
- **K-15 Sagarika** (**range: 750 km, payload: 1000 kg**) is two-stage solid-fuel nuclear capable SLBM.
- More members of K-family (**reportedly codenamed K-5 and K-6**) with ranges of 5000 and 6000 km are under development.

Astra Weapon System: ASTRA is an indigenously developed **air-to-air Beyond Visual Range radar homing missile** comprising of Astra Missile and Launcher with a range up to 110 km (altitude up to 20 km).

Mission Shakti: DRDO successfully **neutralised a satellite in space** with its **anti-satellite (ASAT) missile** in **low earth orbit** under Mission Shakti. The successful mission demonstrated DRDO's technical prowess and ability to defend country's assets in space, **the 4th dimension of warfare**.

Cruise Missiles

Cruise missiles are unmanned vehicles that are propelled by jet engines, much like an aeroplane which can be launched from ground, air, or sea platforms.

Brahmos Missile [UPSC 2023]

- **Two-stage missile** with a solid propellant booster engine at first stage which propels it to **supersonic speed.**

- **Liquid ramjet (second stage)** steers missile closer to 3 Mach in cruise phase.
- Has a **range of 450 km** and **speed of 2.8 Mach**
- **Ship-launched** and **land-based missiles** can carry a **200 kg** warhead, whereas the **aircraft-launched** variant can carry a **300 kg** warhead.
- Named after the rivers **Brahmaputra** and **Moskva**, it has been jointly developed by **DRDO(India)** and **NPOM(Russia)**.
- Operates on **Fire and Forget principle** up to a maximum altitude of 15 km (minimum altitude: 5m).

Nirbhay Missile

- All weather long-range **subsonic cruise missile**, which can carry **nuclear warheads** (450 kg) up to **1000 km**.
- Cruise speed of **0.8 Mach** and **designed for all three wings of the armed forces**.

Moskit Missile

- Procured from Russia, it is a **ship-launched/land-based supersonic ramjet cruise missile** with a range of 120 km.

Cruise Missile Propulsion

- **Ramjet**, air-breathing jet engine **(without major moving parts)** relies on the craft's forward motion to draw in air and on a specially shaped intake passage to compress the air for combustion. The combustion that produces thrust in the ramjet occurs at a **subsonic speed** in the combustor. For a vehicle traveling **supersonically**, the air entering the engine must be **slowed to subsonic speeds by the aircraft inlet** resulting in formation of **shock waves that cause performance losses**; as a result, ramjet propulsion above Mach 5 is highly inefficient. Ramjets work best at speeds of Mach 2 and higher. Since ramjets develop **no static thrust**, some **means for launching them at high velocity is required.**
- **Scramjet engine (Supersonic Combustion Ramjet)** is an improvement over the ramjet engine as it efficiently operates at hypersonic speeds and **allows supersonic combustion in the chamber. A dual mode ramjet (DMRJ)** is a type of jet engine where **a ramjet transforms into scramjet over Mach 4-8 range,** operating efficiently both in subsonic and supersonic combustor modes.
- **Solid Fuel Ducted Ramjet (SFDR) Technology** based propulsion enables the missile to intercept aerial threats at very long range at supersonic speeds. The system utilises a solid fuelled air-breathing ramjet engine which enhances efficiency.

Ballistic Missile vs Cruise Missile [UPSC 2023]

- **Ballistic missile**- a **rocket-propelled self-guided strategic weapons system** that follows a **ballistic trajectory** (powered initially by a rocket or series of rockets but then follows **an unpowered trajectory** that arches upwards before descending) to deliver a payload from its launch site to a predetermined target. Ballistic missiles can carry conventional high explosives as well as chemical, biological, or nuclear munitions. They can be launched from aircraft, ships, and submarines in addition to land-based silos and mobile platforms. These missiles have **high flight paths, often extending into space**.
- **Cruise missiles** are unmanned vehicles that are **propelled by jet engines** (**powered throughout the flight**). They can be launched from ground, air, or sea platforms and can deliver all types of payload. Cruise missiles **remain within the atmosphere for the duration of their flight and can fly as low as a few meters off the ground. Flying low to the surface** of the earth expends more fuel but makes a **cruise missile very difficult to detect** (**also due to smaller radar cross-section**). Cruise missiles are **generally self-guided,** with some missiles **allowing manual manoeuvrability**.

Anti Ballistic Missile System

The Indian **Ballistic Missile Defence** (**BMD**) Program is an initiative to develop and deploy a multilayered ballistic missile defence system to protect our country from ballistic missile attacks in two phases.

- **Phase 1-** focuses on intercepting missiles with a range of up to **2000 km**. It includes:
  - **Prithvi Air Defence (PAD)/Pradyumna Ballistic missile Interceptor**- This missile is an **exoatmospheric Anti-Ballistic missile** with a **maximum flight altitude of 80 km** (max speed: 8 Mach) and **a range of 300-2000 km**. It has a two-stage rocket booster with a first stage: dual propellant liquid fuel and a second solid fuel stage.
  - **Advanced Air Defence (AAD)/ Ashwin Ballistic Missile Interceptor:** It is an **endoatmospheric Anti-Ballistic missile** and can intercept and destroy a target in the lower atmospheric layer. It's a single-stage solid-fueled missile with a **maximum range from 150 to 200 km** and **a maximum altitude in interception range of 30 km**.
  - **Prithvi Defence Vehicle:** It is an **exoatmospheric Anti-Ballistic missile** which has the s**ame range as PAD (300-2000 km)** but **enhanced flight altitude of 150 km** with a more accurate guidance system.
  - **Prithvi Defence Vehicle Mk-2 /ASAT**: This missile is an **exoatmospheric Anti-Ballistic missile** which intercepts a missile/satellite out in orbit and has a **maximum flight altitude of 1200 km**. It has a two-stage rocket motor with a **third**

stage added as a kinetic kill vehicle, which helps the projectile to forcefully hit the target with a >10 cm accuracy.

- **Swordfish RADAR:** Swordfish (Brain of ABM) is an Indian **active electronically scanned array (AESA) long-range tracking radar** based on **Israeli EL/M-2080 Green Pine long-range radar.**

- **Phase 2-** will be capable of intercepting missiles up to 5000 km and is under development.
- **Air Defence 1 missile:** The **AD-1** (**Air Defence**) is a **long-range interceptor missile** designed for both **low exoatmospheric** and **endoatmospheric interception** of **long-range ballistic missiles** and aircraft. The missile is propelled by a **two-stage solid motor** and equipped with an **indigenously developed advanced control system.** The **AD-2** capable of neutralising missiles of even higher ranges, is also said to be under development.

National Advanced Surface to Air Missile System-II (NASAMS-II): India is set to get NASAMS II from the USA, which will be used for **New Delhi** along with the **BMD** and the current air defence systems from Russia (**Pechora**) and Israel (**Spyder**). NASAMS-II is a **network-centric short to medium-range ground-based air defence system armed with 3-D Sentinel Radars, launchers, short and medium-range missiles** which quickly detect and shoot down **multiple airborne threats** such as **cruise missiles**, **aircraft** and **drones**.

S-400 Triumf: A long-range surface-to-air missile system developed by **Russia's Almaz Central Design Bureau** (considered way ahead of **US developed-THAAD**), S-400 can engage intruding **aircraft**, **UAVs**, **cruise missiles**, and **ballistic missiles**. Each S-400 unit has two batteries, each of which has a command-and-control system, a surveillance radar, an engagement radar, and four launch trucks. The system comes equipped with **four types of missiles** with a **range up to 400 km** and a **flight altitude of 180 km**. It can simultaneously track **up to 160 objects in a 600 km range** and **target 72 objects in a 400 km range**.

Iron Dome: Developed by Israeli firms (with some US support) is designed to protect against incoming **short-range weapons** and **operates in all weather conditions,** having a **high success rate of 90%**. It can **differentiate between those rockets that are likely to hit built-up areas and those that are not**, interceptor missiles are only fired at rockets expected to strike populated areas. **I-DOME** is the truck-mounted mobile version of the system, while **C-Dome** is the naval version.

RUDRAM Anti-Radiation Missile: RUDRAM is **first indigenous anti-radiation missile** of the country developed by **DRDO**. The missile is integrated into SU-30 MKI fighter aircraft (can be adapted for other aircraft), having a variable range. It is a potent weapon for IAF for the **Suppression of Enemy Air Defence** (**SEAD**) effectively from large stand-off ranges.

Sudarshan Bomb: The LASER-guided bomb was developed by the **Aeronautical Development Establishment** (**ADE-DRDO**) with technological support from the **Instruments Research and Development Establishment** (**IRDE-DRDO**) for the Indian Air Force. Sudarshan has been designed for 450 kg (990 pound) bombs. Current version has a range of 9 km, and a new version has an expected range of 50 km.

RaIDer-X: It is a new explosive detection device used to detect a number of explosives in pure form as well as with contaminants developed by **High Energy Materials Research Laboratory** (**HEMRL-DRDO**) and **Indian Institute of Science**, **Bangalore**.

Fractional Orbital Bombardment System (FOBS): It is a warhead delivery system **having no range limit** (**first developed by the Soviet Union**) that uses a low earth orbit to target its destination. Just before reaching the target, it deorbits through a retrograde engine burn. **[UPSC 2022]**

Aircraft Carriers

INS Vikramaditya: Russia's refurbished Admiral Gorshkov was commissioned into the Indian Navy as INS Vikramaditya at Severodvinsk, Russia. The ship is over 285 m long and 60 m wide, with 23 decks scaling a height of 60 m, **making it the biggest ship in the Indian Navy**. With over 1,600 personnel on board, INS Vikramaditya is literally a '**Floating City**'. With an operational range of over 13000 km, the ship has the ability to carry over 30 aircraft, comprising an assortment of **MiG 29K/Sea Harrier**, **Kamov 31**, **Kamov 28**, **Sea King**, **ALH-Dhruv** and **Chetak helicopters**. Major systems include the **LUNA Landing system** for MiGs, **DAPS Landing system** for Sea Harriers and **Flight deck lighting systems.**

INS Vikrant: The 262-metre-long carrier powered by four Gas Turbines (88 MW-total) has a maximum speed of 28 Knots. The ship is capable of operating 30 aircraft comprising **MIG-29K fighter jets**, **Kamov-31**, **MH-60R multi-role helicopters**, **Advanced Light Helicopters** (**ALH**) and **Light Combat Aircraft** (**LCA**) (**Navy**). It uses a novel aircraft-operation mode known as **STOBAR** (**Short Take-Off but Arrested Landing**) and is equipped with a **ski-jump for launching aircraft** and a set of '**arrester wires**' for their recovery onboard. It has an overall indigenous content of 76%.

Important Vessels of the Indian Navy

INS Astradharini: An **indigenously** (**95%**) built **Torpedo Launch and Recovery Vessel** '**INS Astradharini**' was designed by the **NSTL**, **M/s Shoft Shipyard** and **IIT Kharagpur**. It has a length of 50 m and can operate in high

seas, with a maximum speed of 15 Knots. INS Astradharini (**replacement of INS Astravahini**) is used to carry out the **technical trials of underwater weapons and systems developed by NSTL** (naval systems laboratory of DRDO). **[UPSC 2016]**

INS Kavaratti: It is an indigenous (**90%**) **Kamorta class Anti-Submarine Warfare** (**ASW**) **stealth corvette** built under **Project 28.** It has been designed by the Directorate of Naval Design (DND- Indian Navy's in-house organisation) and built by **Garden Reach Shipbuilders & Engineers** (**GRSE**), Kolkata. Kavaratti is capable of **detecting and prosecuting submarines**, also, **carbon composites** have been used in its construction. Three other ships commissioned under Project 28 include **INS Kamorta**, **INS Kadmatt**, and **INS Kiltan.**

Project 17 A: Under the Project 17A program, a total of four ships [**Guided Missile Frigates- Nilgiri** (**1st ship**), **Udaygiri**, **Taragiri**, **Mahendragiri**] by **M/s MDSL** (**Mazagon Dock Shipbuilders Ltd**) and three ships [**Himgiri**, **Dunagiri** and **Vindhyagiri**] by **M/s GRSE** are under construction. These warships are follow-ons of the **Project 17 Class Frigates** (**Shivalik Class**), with improved features and advanced weapon systems. Project 17 A ships have been designed by the Indian Navy's **Warship Design Bureau,** and a **substantial 75%** of the orders for equipment and **systems are from indigenous firms including MSMEs**.

Project 15 B: Has been launched for building the advanced variants of the Kolkata class **Guided Missile Destroyers** (**built under Project 15 A**: **including INS Kolkata**, **INS Kochi**, **INS Chennai**). **Ships under Project 15 B have been designed by the Warship Design Bureau** and are being built by **M/s MDSL,** and include four ships- **INS Visakhapatnam**(lead ship), **INS Mormugao**, **INS Imphal** and **INS Surat.**

INSV Tarini: It is a 55-foot sailing vessel which was used for **the first-ever Indian circumnavigation of the globe by an all women crew-Navika Sagar Parikrama.** Navy's next project to send a woman to circumnavigate the globe has been christened '**Solo**'.

Submarines

Strategic Strike Nuclear Submarine (**SSBN**)**: INS Arihant** is a 6,000-tonne (**SSBN**) with a length of 110 metres and a breadth of 11 metres and is able to carry **12 Sagarika K 15 SLBMs.** Arihant can dive to 300 metres and is powered by 83 MW pressurised water reactor (PWR) developed by **BARC**. SSBNs powered by a nuclear reactor can **function submerged for months**, with greater stealth. **SSBNs can carry ballistic missiles with nuclear warheads**. **INS Aridhaman** and **INS Arighat,** two other SSBNs of India built under the Advanced Technology Vessel Project.

Nuclear-Powered Attack Submarines (SSN): These are **armed with non-nuclear weapons**. Indian Navy's only SSN, the INS Chakra, is an **Akula class vessel** taken on lease from Russia.

Sub Surface Killer/Diesel-Electric Attack Submarine (SSK): Indian Navy currently has numerous SSKs, including **Sindhughosh class** (**Russian Kilo class**), **Shishumar class** and **Kalvari class** (**Scorpene class**) submarines.

Project 75: Entails indigenous construction of **SSK submarines** of **Scorpene design** by **M/s MDSL**. The project includes the commissioning of six vessels, including **INS Kalvari**, **INS Khanderi**, **INS Karanj**, **INS Vela**, **INS Vagir**, and **INS Vagsheer**.

Project 75 (I): It is a follow-up and improvement over **Project 75. The initiative envisages new SSK submarines** with **fuel cells** and **Air-Independent Propulsion System (AIP)** for the Indian Navy**.**

NETRA Airborne Early Warning and Control System (AWE&C/AWAC)

It is a multi-sensor platform developed by **DRDO** in collaboration with the **Centre for Airborne Systems** (**CABS**). Netra has an indigenous **Active Electronically Scanned Array** (**AESA**) radar system mounted on the **Embraer ERJ 145 aircraft**, which can track and find aircraft, missiles, ships and vehicles. It can receive fuel in flight, which can double its flight time endurance to nine hours. It has electronic scan coverage of 240 degrees up to a range of 500 km.

Unmanned Aerial Vehicles (UAV)/Drone

UAV/Drone is a military aircraft/land-water based vehicle that is guided autonomously, by remote control, or both and that carries sensors, target designators, offensive ordnance, or electronic transmitters designed to interfere with or destroy enemy targets.

Lakshya 2 [Advanced Pilotless Target Aircraft (**PTA**)**]**: Lakshya 2 (developed by DRDO) is an advanced version of Lakshya 1. It has enhanced endurance, autonomous and low-level flight capability, and salvo flying capability. Lakshya **weapon delivery configuration** has also been developed for delivery at known coordinates.

Nishant: It is a multi-mission UAV (developed by DRDO) launched using a **Mobile Hydro-pneumatic Launcher with Day/Night capability** used for battlefield **surveillance** and **reconnaissance**, **target tracking** & **localisation**. Nishant has been inducted into the Indian Army.

Panchi: Panchi is a **variant of Nishant** (launcher-based tactical UAV) with **capability of conventional take-off/ landing** and has improved flight envelope and endurance.

Daksh-Remotely Operated Vehicle (ROV): It is versatile equipment for improvised explosive device identification and handling and can also be utilised to survey and monitor nuclear and chemical contamination levels.

Unmanned Aerial Vehicle (UAV)-NETRA: This mini UAV developed for surveillance applications is silent, battery-operated, and equipped for both day and night operations.

Confined Space Remotely Operated Vehicle (CSROV): DAKSH MINI is a battery-operated tracked vehicle with multiple degrees of freedom manipulator arm (telescopic arm) capable of extracting suspicious objects.

Unexploded Ordnance Handling Robot (UXOR): It is capable of handling, diffusing and detecting Unexploded Ordnance (UXO), i.e. Bombs and Missiles up to 1000 kg remotely from 1km.

Rustom 2: It is part of the Rustom line of UAVs being developed by **DRDO** that includes **Rustom 1**, **Rustom H** and **Rustom C**. It can fly at over 22,000 ft and is a **long-endurance** (**MALE**) UAV that has an approximate flight time of 20 h. It can fly at around 280 km/h and **carry a variety of payloads** like MREO, LREO, Synthetic Aperture Radar (SAR), Electronic Intelligence (ELINT), Communication Intelligence (COMINT) and Situational Awareness Payloads (SAP) that help i**n performing missions even during the night**. It has been developed for use by **all three services of the Indian armed forces**.

INTERNATIONAL ORGANISATIONS AND CONVENTIONS

Biological Weapons Convention (BWC): It effectively prohibits the development, production, acquisition, transfer, stockpiling and use of **biological** and **toxin weapons**. It was the **first multilateral disarmament treaty** banning an entire category of **weapons of mass destruction** (**WMD**). **India has signed and ratified the convention.**

Organisation for the Prohibition of Chemical Weapons (OPCW): It is the i**mplementing body for the Chemical Weapons Convention** based in Hague, Netherlands, which oversees the global endeavour to permanently and verifiably eliminate chemical weapons. **India is a signatory and party to the Chemical Weapons Convention. [UPSC 2016]**

Australia Group: It is an informal forum of countries which seeks to ensure that **exports do not contribute to the development of chemical or biological weapons.** All states participating in the Australia Group are parties to the **Chemical Weapons Convention** (**CWC**) and the **Biological Weapons Convention** (**BWC**) and **do not undertake any legally binding obligations. India** was **admitted into the group in 2018**.

Wassenaar Arrangement: The Wassenaar Arrangement is the first multilateral body focused on **export controls for conventional arms and dual-use goods and technologies**, and it comprises 42 states (**including India**). **It is consensus-based, with decisions taken on a politically binding basis**.

Missile Technology Control Regime: The Missile Technology Control Regime (MTCR) is an informal political understanding among states that **seeks to limit the proliferation of missiles and missile technology.** It places particular focus on missiles capable of delivering a **payload of at least 500 kg** to a distance of **at least 300 km**-so called '**Category I**' or '**MTCR-class**' missiles. Currently, 35 countries are members of the MTCR, **including India** (**2016**).

Nuclear Suppliers Group (**NSG**): The NSG is a group of forty-eight nuclear supplier countries that **seeks to ensure that nuclear trade for peaceful purposes does not contribute to the proliferation of nuclear weapons or other nuclear explosive devices**. **India is not a member of the NSG**, the main reason being its refusal to sign the **Nuclear Non-Proliferation Treaty.**

Comprehensive Test Ban Treaty: It **bans all nuclear explosions**, whether for military or peaceful purposes. The 1996 treaty has so far been signed by 183 states and ratified by 162 states, **yet not in force**. The treaty **awaits signature and ratification** from **India**, **Pakistan**, and **North Korea** and, in addition, requires the **United States**, **China**, **Israel**, **Iran** and **Egypt** (which have already signed) to formally ratify it.

Treaty on the Non-Proliferation of Nuclear Weapons (NPT): It is a landmark international treaty whose objective is to **prevent the spread of nuclear weapons and weapons technology**, to **promote cooperation in the peaceful uses of nuclear energy** and to **further the goal of achieving nuclear disarmament and general and complete disarmament**. **India** has **not signed the NPT**.

The Treaty on the Prohibition of Nuclear Weapons (TPNW): Opened for signature in 2017, **it prohibits States Parties from developing, testing, producing, manufacturing, acquiring, possessing, or stockpiling nuclear weapons or other nuclear explosive devices**. The treaty entered into force on 22 January 2021, and **India has neither signed nor ratified it**.

8 Universe and Space Technology

ORIGIN OF UNIVERSE: BIG BANG THEORY

It is believed that the universe was born about 13.8 billion years ago in an event called the Big Bang. It is the most prevailing cosmological model for the birth of the universe.

Big Bang Theory

- It states that at some moment, all of space was contained in a single point of very high-density and high-temperature state from which the universe has been expanding in all directions ever since.
- After the initial expansion, the universe cooled sufficiently to allow the formation of subatomic particles and, later simple atoms.
- The majority of atoms produced by the Big Bang were hydrogen and helium along with trace amounts of lithium and beryllium.
- Giant clouds of these primordial elements (hydrogen and helium) later coalesced through gravity to form stars and galaxies.

Dark Energy: It is an unknown form of energy which is hypothesized to permeate (spread throughout) all of space, tending to accelerate the expansion of the universe.

Dark matter: It is a hypothetical form of matter that is thought to account for approximately 85% of the matter in the universe. Dark energy plus dark matter constitutes 95% of the total content of the universe.It is believed that dark matter is considered as the factor for unexplained motion of stars in galaxies.

UNIVERSE THROUGH TELESCOPES

- Space: It is a **three dimensional** region that begins where the earth's atmosphere ends.
- A telescope is an optical tool that observes distant objects using lenses, curved mirrors, or a combination of the two.

Hubble Telescope

- Since its launch, the observatory has produced important discoveries in the area of astronomy. It is the first big optical telescope to be mounted in space.
- It takes photographs of deep space and aids scientists with their understanding of the cosmos by seeing the furthest stars, galaxies, and planets.

James Webb Telescope

- NASA's primary infrared observatory is the James Webb Space Telescope (JWST).
- NASA, the European Space Agency (ESA), and the Canadian Space Agency (CSA) are working together on this project.
- It will Look for the first galaxies or bright objects that appeared after the Big Bang.
- Determine the evolution of galaxies.
- Observe the evolution of stars from their earliest beginnings through the development of planetary systems.
- Measure the physical and chemical features of planetary systems, including our own Solar System, and look into the possibility of life elsewhere.

Event Horizon Telescope (EHT) project

- EHT is a group of 8 radio telescopes used to detect radio waves from space.
- In 2019, Scientists from the EHT project released the first- ever optical image (or shadow image) of a Black hole located in the center of galaxy Messier 87 in the constellation Virgo.
- Sagittarius A* is the 2nd black hole to get photographed.

Chandrasekhar Limit

- Chandrasekhar Limit of 1.4 solar masses, is the theoretical maximum mass a white dwarf star can have and still remain a white dwarf. Above this mass, electron degeneracy pressure is not enough to prevent gravity from collapsing the star further into a neutron star or black hole.
- The limit is named after Nobel laureate Subrahmanyam Chandrasekhar, who first proposed the idea in 1931.

SUN CYCLE

The Sun is a massive, electrically charged ball of heated gas. When this charged gas travels, it creates a strong magnetic field. The magnetic field of the Sun passes through a cycle known as the solar cycle.

- The Sun's magnetic field totally turns every 11 years. The north and south poles of the Sun will transfer

locations as a result of this. After that, it takes another 11 years for the Sun's north and south poles to revert.

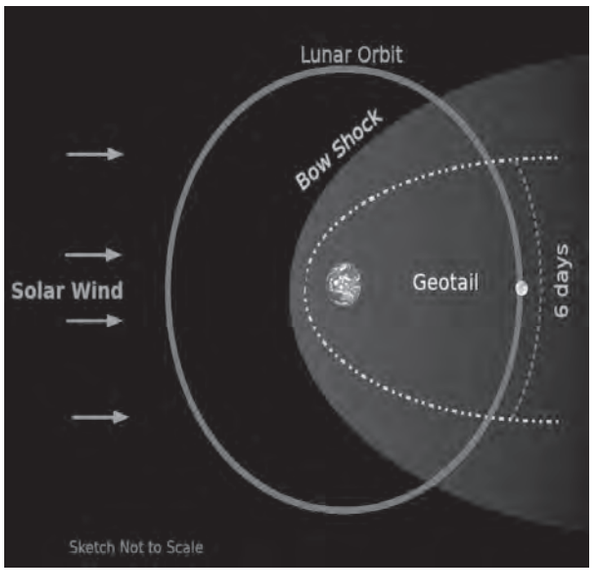
- As the magnetic fields change, so does the amount of activity on the Sun's surface.
- One way to track the solar cycle is by counting the number of sunspots. The beginning of a solar cycle is a solar minimum, or when the Sun has the least sunspots. Over time, solar activity—and the number of sunspots—increases.
- The middle of the solar cycle is the solar maximum, or when the Sun has the most sunspots.As the cycle ends, it fades back to the solar minimum and then a new cycle begins.
- Sunspots are the areas with the strongest magnetic fields, and therefore a good indicator of solar activity.
- The appearance of dark sunspots lowers the total luminosity of the Sun only by about 0.15% at sunspot maximum, and thus the variation of the sunlight has a negligible effect on the Earth's climate. This activity can have effects on Earth. For example, eruptions can cause lights in the sky, called aurora, or impact radio communications. Extreme eruptions can even affect electricity grids on Earth.

GEOTAIL

A location in space where the finest observations may be made. The zone exists as a result of the Sun's and Earth's interactions.

Formation of Geotail

- The solar wind is a continuous stream of charged particles emitted by the Sun.



- These particles are encased in the Sun's extended magnetic field.
- The magnetic field of the Earth obstructs the solar wind plasma.
- A magnetic envelope forms around Earth as a result of this interaction.
- The envelope is squeezed on the Earth's side facing the Sun into a zone about three to four times the Earth's radius.
- On the other side, the envelope is extended into a long tail, known as the Geotail, that reaches beyond the Moon's orbit.
- The Moon travels through the Geotail for around six days every 29 days.

Pulsars [UPSC 2023]

- A pulsar is a celestial phenomenon that generates thousands of pulses per second of radio waves and other electromagnetic radiation.
- Pulsars are compact, fast spinning neutron stars that are left over when a big star bursts.

SOLAR ECLIPSE

When the moon passes between the sun and the earth, a solar eclipse occurs. The moon stops the sun's light from reaching the earth when this happens. The planet is then bathed in the moon's shadow.

- **There are three types of solar eclipses**: annular solar eclipse, total solar eclipses, partial solar eclipses.
- When the sun, moon, and earth are not perfectly aligned, a **partial solar eclipse occurs.**
- A **total solar eclipse** occurs when the sun, moon, and earth are all aligned in a straight line.
- **Annular eclipse**: It is a form of complete solar eclipse known as an annular eclipse.
  - It occurs when the sun, moon, and earth are all on the same plane and not just in a straight line.
  - The moon must also be farther away from the earth in order for it to not entirely obscure the sun's disc, resulting in a narrow band of light around the dark colour of the moon that reveals the ring of fire. As a result, it's also known as the **eclipse of the ring of fire.**

GRAVITY

Gravity is the force by which a planet or other body draws objects toward its center. The force of gravity keeps all of the planets in orbit around the sun.

- Objects with more mass have more gravity. Gravity also gets weaker with distance. So, the closer objects are to each other, the stronger their gravitational pull is.

Relation between Gravity, Mass and weight

- Earth's gravity comes from all its mass. All its mass makes a combined gravitational pull on all the mass in your body. That's what gives you weight.
- And if you were on a planet with less mass than Earth, you would weigh less than you do here.
- Gravity isn't the same everywhere on Earth. Gravity is slightly stronger over places with more mass underground than over places with less mass.
- NASA uses two spacecraft to measure these variations in Earth's gravity. These spacecraft are part of the Gravity Recovery and Climate Experiment (GRACE) mission.

Gravity and Black Hole

- A black hole is an object in space that is formed after the death of a star (core runs out of fuel) and is so dense and has strong gravity that no matter or light can escape its gravity pull.
- Because no light can escape, it is black and invisible.
- Black holes pack so much mass into such a small volume that their gravity is strong enough to keep anything,even light, from escaping.
- The point where all that mass is trapped is called a singularity. It may be infinitely small, but its influence is enormous. **[UPSC 2017]**

Black holes are divided into three types: Stellar black holes (also known as unicorns), Supermassive black holes, and Intermediate-mass black holes.

Gravitational Waves [UPSC 2019]

- Gravitational waves were first proposed by Albert Einstein, 100 years ago as part of the Theory of Relativity.
- In 2016, scientists at Laser Interferometer Gravitational- wave Observatory (LIGO) first detected the gravitational waves.
- GWs are ripples in space-time that move at the speed of light and are created by some of the Universe's most furious and intense processes.
- They hold information about their cataclysmic origins, as well as crucial insights regarding gravity's nature.
- They form when
  - Things move at extremely high speeds,
  - When a star explodes asymmetrically (known as a supernova),
  - When two large stars orbit one other, and
  - When two black holes orbit each other and join.

Gravitational Lensing

- One of the most remarkable predictions of Einstein's theory of general relativity is that gravity bends light.
- That effect was first demonstrated during a total solar eclipse in 1919, when the positions of stars near the Sun were observed to be slightly shifted from their usual positions.
- Gravitational lensing occurs when two objects are nearly perfectly aligned along the line of sight.
- The gravitational field of the nearer object bends the light of the background object and produces several effects, including multiple imaging and magnification of the brightness.
- Gravitational lensing can provide information on the expansion rate and geometry of the Universe and about the distribution of mass in the Universe, particularly dark matter.

LIGO- India – InDIGO

- LIGO-India project is an Indian Initiative in Gravitational wave observations, expected to be completed by 2025.
- It aims to move one advanced LIGO detector from Hanford to Maharashtra (Hingoli district), India.
- The project is piloted by the Dept. of Atomic Energy (DAE) and Dept. of Science and Tech (DST).

PLANET

The most recent definition of a planet was adopted by the International Astronomical Union in 2006. It says a planet must do three things:

- It must orbit a star (in our cosmic neighborhood, the Sun).
- It must be big enough to have enough gravity to force it into a spherical shape.
- It must be big enough that its gravity cleared away any other objects of a similar size near its orbit around the Sun.

Dwarf Planet

- As per the International Astronomical Union (IAU):
- A dwarf planet is a celestial body that circles the sun, has enough mass to assume a roughly round shape, has not cleared the neighborhood surrounding its orbit, and is not a moon.
- Ceres, Pluto, Eris, Makemake, and Haumea are the first five dwarf planets discovered.

KEY TERMS

- **Kuiper Belt**
  - The Kuiper Belt is a ring of icy rocks & dust bodies just outside of Neptune's orbit, known as Kuiper belt objects or trans-neptunians.

- Pluto is the largest known Kuiper Belt Object instead of the 9th planet of our Solar system. There are bits of rock and ice, comets, and dwarf planets.

- **Asteroid Belt**
  - Asteroids are remnants of planetary formation mainly composed of refractory rocky and metallic minerals and some ice, that circle the sun in a zone lying between Mars and Jupiter.
  - The circular chain of asteroids is called the asteroid belt or main asteroid belt.
- **Ploonets**
  - A celestial object, which are orphaned moons that have escaped the bonds of their planetary parents.
  - The researchers explain that the angular momentum between the planet and its moon results in the moon escaping the gravitational pull of its parent planet.
- **Goldilocks Zone**
  - The 'Goldilocks Zone,' or habitable zone – 'the region around the star where a planet could sustain liquid water on its surface'. **[UPSC 2014]**
  - Our Earth is in the Sun's Goldilocks zone.
  - If Earth were where the dwarf planet Pluto is, all its water would freeze; on the other hand, if Earth were where Mercury is, all its water would boil off.
- **Kessler Syndrome:** The Kessler syndrome is a theory proposed by NASA scientist Donald J. Kessler in 1978, used to describe a self- sustaining cascading collision of space debris in LEO.
- **Asteroids**
  - Big chunks of rocks float through space and orbit the sun, mostly found in the main asteroid belt i.e. between Mars and Jupiter.
  - The biggest one is Ceres (940 km wide), twice as big as the Grand Canyon.
- **Meteor**
  - When a meteoroid enters the earth's atmosphere, it begins to burn up and falls to the ground.
  - This burning trail is known as meteor or falling stars.
- **Meteoroid**
  - Smaller rock pieces that break off from an asteroid, float through interplanetary space.
  - Can be as small as grain of sand or as large as a meter across.
- **Meteorite:** If a meteoroid rock doesn't completely burn up as it falls to Earth- the rock left behind is called a meteorite.
- **Comets**
  - Comets are frozen leftovers from the formation of the solar system composed of dust, rock and ices, ranging from few miles to tens of miles wide.
  - Orbits closer to the sun, they heat up and spew gases and dust into a glowing head visible in the atmosphere.
  - Comets have highly elliptical orbits, unlike planets which have near-circular orbits.
- **Van Allen Radiation Belts**
  - It is a zone of energetic charged particles, most of which originate from the solar wind.
  - The particles are captured by and held around a planet by that planet's magnetic field.
  - These are intense over the Equator and are absent over the poles.

ORBITS

An orbit is the curved path that an object in space (such as a star, planet, moon, asteroid or spacecraft) takes around another object due to gravity.

- Objects of similar mass orbit each other with neither object at the center, whilst small objects orbit around larger objects.
- In our Solar System, the Moon orbits Earth, and Earth orbits the Sun, but that does not mean the larger object remains completely still.
- Because of gravity, Earth is pulled slightly from its centre by the Moon (which is why tides form in our oceans) and our Sun is pulled slightly from its centre by Earth and other planets.
- The height of the orbit, or distance between the satellite and Earth's surface, determines how quickly the satellite moves around the Earth. An Earth-orbiting satellite's motion is mostly controlled by Earth's gravity.
- The orbits can be categorized as High Earth orbit, Medium Earth orbit, or Low Earth orbit based on the height of satellites from the earth.

Low Earth Orbit

- An orbit that is relatively close to Earth's surface. It is normally at an altitude of less than 1000 km but could be as low as 160 km above Earth.
- LEO is commonly used for communication and remote sensing satellite systems, as well as the International Space Station (ISS) and Hubble Space Telescope.
- Satellites placed in LEO orbit generally circle the Earth once in 90 minutes.

Middle Earth Orbit

- Medium Earth orbit comprises a wide range of orbits anywhere between LEO and GEO.
- It is similar to LEO in that it also does not need to take specific paths around Earth, and it is used by a variety of satellites with many different applications.
- The range of this orbit is between 2000 km - 35,780km.

- Generally, it takes 12 hours for the satellite to complete one rotation around the Earth.
- MEO is commonly used for navigation systems, including the U.S. Global Positioning System (GPS).

High Earth Orbit

- When a satellite reaches 42,164 kilometers from the Earth's center (about 36,000 kilometers from the surface), it is said to be in high Earth orbit.
- Because satellites in this orbit provide a steady view of the same surface, geostationary orbit is particularly useful for weather monitoring and communication (phones, television, radio).
- At this height, the orbital height of the satellite becomes equal to the Earth's rotational speed. So, this orbit at this height is called a geosynchronous or Geostationary Orbit.

Geostationary Orbit

- A geostationary orbit, also referred to as a geosynchronous equatorial orbit (GEO).
- A geosynchronous orbit is a high Earth orbit that allows satellites to match Earth's rotation. Located at 22,236 miles (35,786 kilometers) above Earth's equator.
- Because the satellite orbits at the same speed that the Earth is turning, the satellite seems to stay in place over a single longitude.

Polar orbit and Sun Synchronous orbit (SSO)

- Satellites in polar orbits usually travel past Earth from north to south rather than from west to east,passing roughly over Earth's poles.
- Polar orbits are a type of low Earth orbit, as they are at low altitudes between 200 to 1000 km.
- Satellites in SSO, traveling over the polar regions, are synchronous with the Sun. This means they are synchronized to always be in the same 'fixed' position relative to the Sun. This means that the satellite always visits the same spot at the same local time.
- This means that the satellite will always observe a point on the Earth as if constantly at the same time of the day.
- It serves a number of applications; for example, it means that scientists and those who use the satellite images can compare how something changes over time.

Transfer orbits and Geostationary Transfer Orbit

- Transfer orbits are used to get from one orbit to another.
- When satellites are launched from Earth and carried to space with launch vehicles, the satellites are not always placed directly on their final orbit.
- Often, the satellites are instead placed on a transfer orbit: an orbit where, by using relatively little energy from built- in motors, the satellite or spacecraft can move from one orbit to another.
- This allows a satellite to reach, for example, a high-altitude orbit like GEO without actually needing the launch vehicle to go all the way to this altitude, which would require more effort.

Lagrange point

- Lagrange Points are positions in space where the gravitational forces of a two body system like the Sun and the Earth produce enhanced regions of attraction and repulsion.
- These can be used by spacecraft to reduce fuel consumption needed to remain in position.
- Lagrange points are named in honor of Italian-French mathematician Joseph-Louis Lagrange.
- There are five special points where a small mass can orbit in a constant pattern with two larger masses.

Halo Orbit: It is an orbit around the Lagrange points.

Types of Satellites: Satellites can be classified by their function since they are launched into space to do a specific job.

- There are nine different types of satellites i.e. Communications Satellite; Remote Sensing Satellite; Navigation Satellite; Geocentric Orbit type satellites - LEO, MEO, HEO; Global Positioning System (GPS); Geostationary Satellites (GEOs); Ground Satellite; Polar Satellite; Nano Satellites, CubeSats and SmallSats.

SPACE TECHNOLOGY IN INDIA

- **Indian Space Research Organisation (ISRO)**
  - Nodal space research agency of Government of India
  - Founded on 15th August, 1969.
  - Headquarter: Bengaluru, Karnataka
  - Managed by the Department of Space (DOS), which reports directly to the PM.
- **Indian National Space Promotion and Authorization Centre (In-Space)**
  - The Indian National Space Promotion and Authorization Centre (IN-SPACe) was established by the Indian government to encourage private sector participation in a wide range of space activities.

- It will regulate and encourage Indian industry and startups to construct routine satellites, rockets, and commercial launch services
- It will have its own technical, legal, safety and security, monitoring, and activity promotion directorates.
- It will serve as a liaison between ISRO and private parties, assessing how India's space resources might be best utilized and space-based activities expanded.

- **New Space India Limited (NSIL)**
  - It is ISRO's commercial arm, with the primary goal of enabling Indian businesses to participate in high-tech space activities.
  - It is completely owned by the Government of India, which reports to the Department of Space (DOS).
  - NSIL will collaborate with IN-SPACe to enable industry consortiums to take on some of ISRO's responsibilities.
- **Antrix:** It was founded in 1992 as a government-owned private limited corporation with the mission of promoting and commercializing space products, providing technical consulting services, and transferring ISRO-developed technologies.

TYPES OF LAUNCH VEHICLES BY ISRO

Launchers or Launch Vehicles are used to carry spacecraft to space. India has two operational launchers: **Polar Satellite Launch Vehicle (PSLV)** and **Geosynchronous Satellite Launch Vehicle (GSLV). [UPSC 2018]**

- In India there are 4 generations of launch vehicles:
  - 1st Generation: Satellite launch vehicles.
  - 2nd generation: Augmented satellite launch vehicle
  - 3rd generation: Polar satellite launch vehicle(PSLV)
  - 4th Generation: Geosynchronous satellite launch vehicle(GSLV)
- PSLV can deliver payloads of up to:
  - 3,250kg to LEO (Low Earth Orbit)
  - 1600 kg to SSO (Sun Synchronous orbit)
  - 1400 kg to GTO (Geosynchronous Transfer Orbit)
  - Most famous launches by the PSLV: Chandrayaan-1 in 2008 and Mangalyaan/Mars Orbiter Mission in 2013.
  - PSLV-C37 launched 104 satellites on February 15, 2017, the highest number of satellites launched in a single flight so far.

Launch Services Vehicles

- **Geosynchronous Satellite Launch Vehicle (GSLV)**
  - GSLV is a 3-stage Launch vehicle with solid fuel in the 1st stage, liquid in the 2nd stage and cryogenic in the 3rd stage.
  - It was developed primarily to launch communication satellites (INSAT Series) of 2.5-tonne class in Geostationary Transfer Orbit and about 4.5 tons class in Low Earth Orbit.
- **GSLV Mk II**
  - This is the largest launch vehicle developed by India, which is currently in operation.
  - This fourth-generation launch vehicle is a three-stage vehicle with four liquid strap-ons.
  - The indigenously developed Cryogenic Upper Stage (CUS) forms the third stage of GSLV Mk II.
  - Liftoff mass: 4.14 tones.
- **GSLV Mk III**
  - This is a 3-stage heavy-lift rocket with an indigenous cryogenic engine in the 3rd stage.
  - GSLV Mk III (ISRO's Fat boy) is designed to carry 4-ton class of satellites into Geosynchronous Transfer Orbit (GTO) or about 10 tons to Low Earth Orbit (LEO), which is about twice the capability of the GSLV Mk II.
  - Most famous launches: injected Chandrayaan-2, India's second Lunar Mission, into Earth Parking Orbit on July 22, 2019, from Satish Dhawan Space Centre, Sriharikota.
  - Further, India's first human space flight Gaganyaan to be launched using GSLV Mk III in 2022.
- **Small Satellite Launch Vehicle (SSLV)**
  - Designed by ISRO's Vikram Sarabhai Space Centre, to launch payload capacity of 500 kg to Low Earth orbit & 300 kg to Sun-synchronous orbit for launching small satellites.
  - Objective: to commercially launch small satellites at a lower price and higher launch rate as compared to PSLV.
  - Unlike the PSLV and GSLV, the SSLV can be assembled both vertically and horizontally.
  - The first three stages of the vehicle will use a solid propellant, with a fourth stage being a velocity-trimming module.
- **SOUNDING ROCKETS**
  - Sounding rockets are one or two stage solid propellant rockets used for probing the upper atmospheric regions and for space research.
  - They also serve as easily affordable platforms to test or prove prototypes of new components or subsystems intended for use in launch vehicles and satellites.
  - The launch of the first sounding rocket from Thumba near Thiruvananthapuram, Kerala on 21 November 1963, marked the beginning of the Indian Space Programme.

- Sounding rockets made it possible to probe the atmosphere in situ using rocket-borne instrumentation.

- **ROCKET FUEL**
  - The Indian Space Research Organisation (ISRO) is using the very poisonous and corrosive fuel UDMH (Unsymmetrical Di-Methyl Hydrazine), combined with the oxidiser nitrogen Tetroxide. This is referred to as a "dirty combo."
  - Other space programmes throughout the world have switched to a cleaner and greener fuel, liquid methane or kerosene.
  - Changing to liquid methane would need the usage of a cryogenic engine, as any gas must be stored at extremely low temperatures to remain liquefied.
- **Propellant Used in Rocket**
  - The propellant is a chemical mixture that comprises a fuel and an oxidizer that is burned to provide thrust in rockets.
  - For propulsion, fuel is a substance that burns when mixed with an oxidizer.
    - The oxidizer is a substance that releases oxygen in order to be combined with a fuel. The mixture ratio is the proportion of oxidizer to fuel.
    - The condition of a propellant is classified as liquid, solid, or hybrid.
  - Liquid Propellant: The fuel and oxidizer are stored separately in a liquid propellant rocket and delivered to a combustion chamber by a system of pipes, valves, and turbopumps, where they are mixed and burned to produce thrust.
  - Cryogenic propellants are liquefied gases kept at extremely low temperatures, with the most common fuel being liquid hydrogen (LH2) and the oxidizer being liquid oxygen (LO2 or LOX).
  - At temperatures of -253 C (-423 F), hydrogen remains liquid, while oxygen remains liquid at temperatures of -183 C. (-297 F).
  - Solid propellant rockets are the most basic of rocket designs. They are made of a steel casing loaded with a mixture of solid compounds (fuel and oxidizer) that burn rapidly and produce thrust by ejecting hot gases from a nozzle.
  - Hybrid propellant engines are a type of engine that falls somewhere between solid and liquid propellant engines. One of the components is solid, which is generally the fuel, and the other is liquid,which is usually the oxidizer.
- **Cryogenic Engine**
  - A cryogenic rocket engine uses a cryogenic fuel or oxidizer, which means the fuel or oxidizer (or both) are gases that have been liquefied and kept at extremely low temperatures.
  - In comparison to solid and earth-storable liquid propellant rocket stages, cryogenic rocket stages are more efficient and produce greater thrust per kilogramme of propellant burned.
- **Air Breathing Engines**
  - In the burning of fuel, air-breathing engines utilise oxygen from the environment. The turbojet,turboprop, ramjet, and pulse-jet are among them.
  - Other methods in use are heavier, less efficient, and less cost-effective than this one.
  - Types of Air Breathing Engines:
    - **Ramjet**: A ramjet is a type of air-breathing jet engine that compresses incoming air for combustion without the use of a revolving compressor. At supersonic speeds, ramjets are most efficient, but at hypersonic speeds, they are ineffective.
    - **Scramjet:** A scramjet engine is superior than a ramjet engine because it can run at hypersonic speeds while still allowing supersonic combustion.
    - **Dual Mode Ramje**t (DMRJ) is a kind of jet engine that converts from a ramjet to a scramjet over the Mach 4-8 range, allowing it to function efficiently in both subsonic and supersonic combustion modes.

International Space Station

- The International Space Station (ISS) is a low-Earth-orbiting, habitable artificial satellite.
- NASA (United States), Roscosmos (Russia), JAXA (Japan), ESA (Europe), and CSA (Canada) are among the five space agencies involved in the project.
- The station serves as a microgravity and space environment research laboratory, where astrobiology, astronomy, meteorology, physics, and other fields are studied. On board the ISS, the atmosphere is identical to that of Earth.

Recent Developments

- India is seeking to launch its own space station by 2030, joining the league of US, Russia, and China to an elite space club.
- China has launched an unmanned module of its permanent space station, which it intends to finish by the end of 2022.
- The module, called Tianhe or Harmony of the Heavens was launched on China's heaviest carrier rocket, the Long March 5B.

MISSIONS TO SPACE

Exploration of the Sun

- The Parker Solar Probe is the first spacecraft to reach the solar corona's lower layers. The structure and dynamics of the Sun's coronal plasma and magnetic field will be studied.
- Parker measured particles and magnetic fields in the Sun's upper atmosphere, known as the corona,according to NASA.
  - Aditya L-1 Mission: The Indian Space Research Organisation (ISRO) is gearing up for Aditya-L1, the country's first scientific mission to study the Sun.
  - It would be positioned in the L1 Lagrange point, which is a location in space.
  - Aditya L1 will be launched with seven payloads (instruments) aboard the Polar Satellite Launch Vehicle (PSLV) XL.
  - It will conduct round-the-clock imaging of the Sun and investigate the corona, photosphere,chromosphere, solar emissions, solar winds and flares, and Coronal Mass Ejections.

Missions to Moon

- Numerous space missions have been launched to explore Earth's natural satellite as part of human exploration of the Moon.
- The Soviet Union's Luna 2 was the first spacecraft to reach the Moon's surface safely.
- Luna 9 was the first spacecraft to make a controlled soft landing, while Luna 10 was the first mission to enter orbit, both in 1966.
- Crewed missions to the Moon were carried out by the United States as part of the Apollo programme between 1968 and 1972. Apollo 8 was the first crewed mission to enter orbit in 1968.
- Neil Armstrong became the first person to walk on the Moon during Apollo 11 in July 1969.
- So far, 24 humans have visited this massive landmass, 12 have walked on it.
- **Recent Developments:** With Artemis missions, NASA will land the first woman and first person of color on the Moon, using innovative technologies to explore more of the lunar surface than ever before.

India' s Missions to Moon

- **Chandrayaan 1**
  - India's first mission to the Moon, was launched in 2008.
  - Chandrayaan 1 reached the lunar orbit 21 days after its launch and after making 3400 orbits around the Moon and transmitting data.
  - In late November 2008, Chandrayaan 1 began experiencing abnormally high temperatures.
  - The last contact with Chandrayaan 1 was on August 28, 2009. It still circles around the Moon.
- **Chandrayaan 2**
  - The failure of Chandrayaan-2, India's second mission to the Moon, to make a soft-landing on the lunar surface had led to much disappointment.
  - The lander and rover malfunctioned in the final moments and crash-landed, getting destroyed in the process
  - But that did not mean the entire mission had been wasted. The Orbiter part of the mission has been functioning normally.
- **Chandrayaan 3**
  - The Chandrayaan-3 mission consists of a lander module, a propulsion module, and a rover.
  - The Chandrayaan-3 Lander has solar panels on four sides, instead of only two in Chandrayaan-2.
  - Chandrayaan-3 is a follow-on mission to Chandrayaan-2 to demonstrate end-to-end capability in safe landing and roving on the lunar surface.
  - The spacecraft departed from the Satish Dhawan Space Centre in Sriharikota on July 14, 2023, and smoothly entered lunar orbit by August 5, 2023.
  - The lander achieved a flawless touchdown near the lunar south pole on August 23, 2023.
  - The total weight of Chandrayaan-3 is 3,900 kg, with the propulsion module weighing 2,148 kg and the lander and the rover both weighing 1,752 kg.

Missions to Mars

- The Soviets sent a series of probes to Mars beginning in 1960.
- Mariner 9 became the first space probe to circle another planet when it entered orbit around Mars on November 14, 1971.
- In 1997, NASA's Mars Global Surveyor was launched into orbit around Mars. The primary mapping mission was completed in early 2001, and the mission was a perfect success.
- In 1997, NASA's Mars Pathfinder landed in the Ares Vallis on Mars, carrying the robotic exploration spacecraft Sojourner.
- In 2001, NASA's Mars Odyssey orbiter was sent into orbit around Mars.

India' s Missions on Mars- Mangalyaan: ISRO launched the Mars Orbiter Mission, commonly known as Mangalyaan, on November 5, 2013. (ISRO). On September 24, 2014, it was successfully placed into Martian orbit.

Voyager Mission

- The twin spacecraft Voyager 1 and Voyager 2 were launched by NASA in separate months in the summer of 1977 from Cape Canaveral, Florida.
- As originally designed, the Voyagers were to conduct closeup studies of Jupiter and Saturn, Saturn's rings, and the larger moons of the two planets.
- During planetary flybys, Voyager 2 is the only probe that has ever studied Neptune and Uranus.It is the world's second man-made object to orbit the sun.
- Voyager 2 is the only spacecraft to have visited all four gas giant planets — Jupiter, Saturn, Uranus, and Neptune — and found 16 moons, as well as phenomena such as Neptune's seemingly ephemeral Great Dark Spot, Europa's ice shell fissures, and ring structures on each planet.

Gaganyaan Mission

- Gaganyaan is an Indian Space Research Organisation mission (ISRO).
- Three Gaganyaan flights will be sent into orbit, according to the Gaganyaan programme.
- Two unmanned missions and one human spaceflight are planned.
- Three Indian astronauts, including a woman, will be aboard the Gaganyaan system module, dubbed the Orbital Module.
- For 5-7 days, it will orbit Earth in a low-earth-orbit at a distance of 300-400 kilometres.
- The three-stage heavy lift launch vehicle GSLV Mk III, also known as the LVM-3 (Launch Vehicle Mark-3), will be utilised to launch Gaganyaan because it has the appropriate payload capabilities.
- Gaganyaan's important missions, including as the test vehicle flight to validate the crew escape system's performance and Gaganyaan's first uncrewed mission (G1), are planned for the second half of next year (2022).
- The second uncrewed trip, which will contain Vyommitra, a spacefaring human robot, will launch at the end of 2022.

SPACE DEBRIS

Space debris encompasses both natural meteoroid and artificial (human-made) orbital debris.

- Meteoroids are in orbit about the sun, while most artificial debris is in orbit about the Earth (hence, the term "orbital" debris).
- Orbital debris is any human-made object in orbit about the Earth that no longer serves a useful function.
- Such debris includes non-functional spacecraft, abandoned launch vehicle stages, mission-related debris, and fragmentation debris.
- There are approximately 23,000 pieces of debris larger than a softball orbiting the Earth.
- They travel at speeds up to 17,500 mph, fast enough for a relatively small piece of orbital debris to damage a satellite or a spacecraft.

Cause of concern for Space debris

- With the increasing amount of space debris and the advent of mega-constellations of thousands of satellites, there are fears that collisions such as that between Iridium 33 and Cosmos 2251 could set off a chain reaction.
- This chain reaction is called the Kessler syndrome, in which the resulting space debris would destroy other satellites and so on, with low Earth orbit eventually becoming unusable.

Instances of Misfortune

- In 1996, a French satellite was hit and damaged by debris from a French rocket that had exploded a decade earlier.
- On Feb. 10, 2009, a defunct Russian spacecraft collided with and destroyed a functioning U.S. Iridium commercial spacecraft.
- The collision added more than 2,300 pieces of large, trackable debris and many more smaller debris to the inventory of space junk.
- China's 2007 anti-satellite test, which used a missile to destroy an old weather satellite, added more than 3,500 pieces of large, trackable debris and many more smaller debris to the debris problem.

IRNSS-Navic [Upsc 2018]

- The Navigation with Indian Constellation (NavIC) satellite system is an autonomous regional navigation satellite system that provides location data in the Indian area and 1500 kilometers surrounding the Indian landmass.
- IRNSS would offer two types of services Standard Positioning Services, which would be available to all users, and Restricted Services, which would only be available to permitted users.
- There are seven satellites in all. Three will be geostationary above the Indian Ocean and four will be geosynchronous.
- This setup assures that at any one moment, at least one of fourteen ground stations is tracking each satellite, with a good likelihood that most of them will be visible from anywhere in India.

Space Technology and Disaster Management

- Gagan Enabled Mariner's Instrument for Navigation and Information (GEMINI) device.

- GEMINI is a portable satellite receiver connected to ISRO spacecraft. Because the gadget can send signals up to 300 nautical miles, fishermen beyond the signal range of their phone providers (i.e. 10-12 km) may also obtain warnings and alarms.
- It will make satellite-based communication easier, which will be especially important in the event of storms, strong seas, or tsunamis.
- The Indian Space Research Organization (ISRO) and the Airports Authority of India collaborated on GAGAN.
- It is India's first satellite-based global positioning system, relying on the GSAT satellites of ISRO.
- The disadvantage of this technology is that it only permits one-way communication, which means that fishermen cannot use it to make calls.

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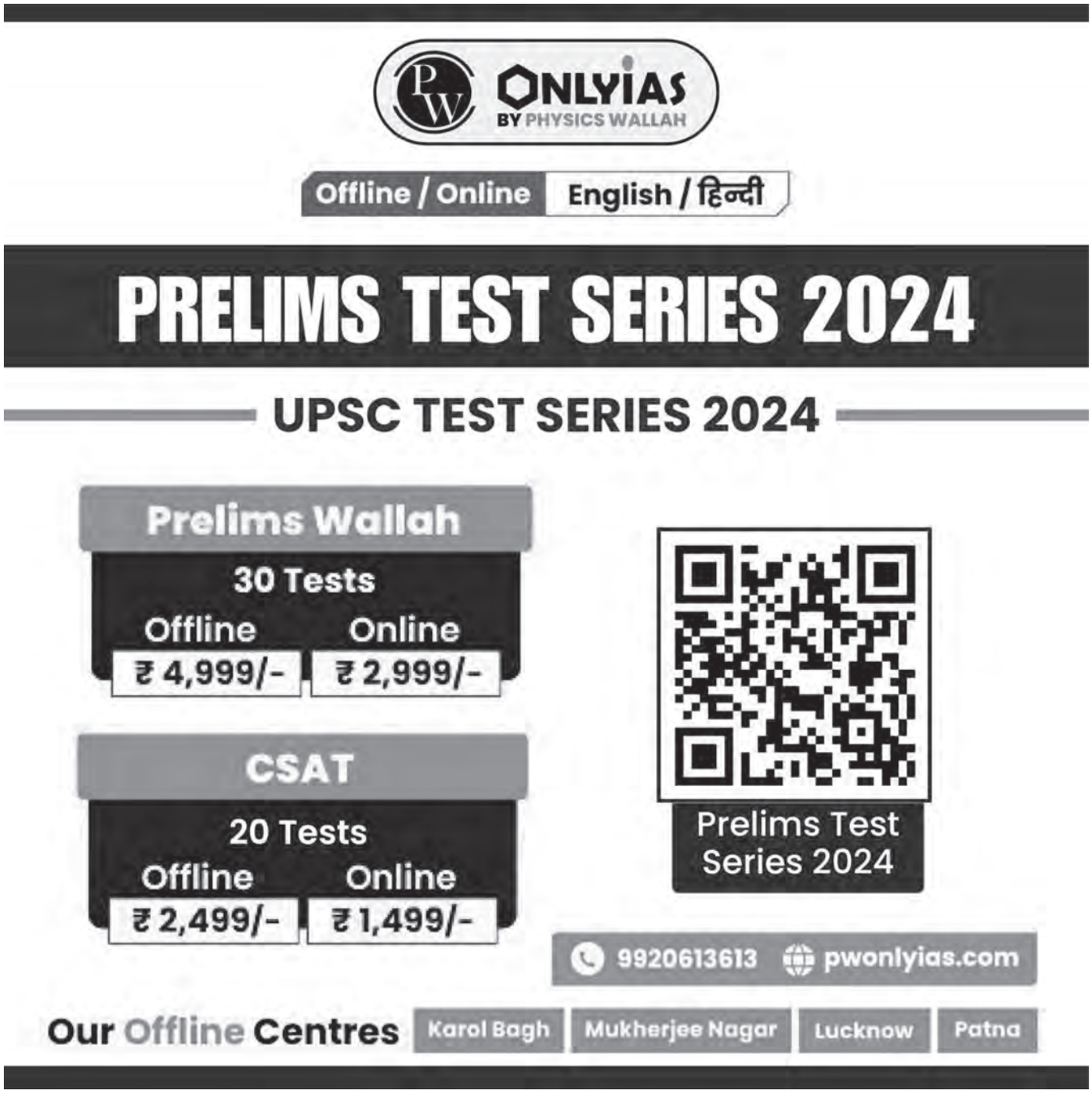

9 IPR Regime and Contribution of Indian Scientists

INTELLECTUAL PROPERTY RIGHTS

Intellectual property rights (IPRs) include mental works such as **inventions, literary and creative compositions, designs, symbols, names, and pictures** used in trade. For a limited amount of time, owners of intellectual property rights are granted exclusive use of the goods or property. For example copyright is alloted for 60 years from date of publication. Thus, providing property rights through patents, copyrights, and trademarks is known as intellectual property rights.

Categories of Intellectual Property Rights

- **Copyrights:** It protects original literary, artistic, and musical works. In India, the Copyright Act grants exclusive rights to creators, including authors, musicians, and artists.
- **Trademarks:** It distinguishes goods or services and can include symbols, names, and logos. The Trademarks Act governs trademark registration in India.
  - **The Trademarks Act of 1999** is a significant legislation in India that **governs the registration and protection of trademarks**. Enacted to bring the country's trademark laws in line with international standards, the act provides a comprehensive framework for the establishment and enforcement of trademark rights.
- **Patents:** It protects inventions, granting exclusive rights for a specified period. India's Patents Act outlines patentable subject matter and procedures for grant.
  - A patent is an exclusive right granted by a government to an inventor for a **limited period, typically 20 years**, in exchange for disclosing the invention to the public. This disclosure allows others to learn from the invention and build upon it, while also incentivizing the inventor to invest time and resources in developing the innovation.
  - India's patent policy has undergone changes, including the 2015 Patent Policy. Patents in India are governed by **"The patent Act 1970**" which was amended in 2005 to make it compliant with **Trade-Related Aspects of Intellectual Property Rights(TRIPS).**

Rights of Patent Owners

- Exclusive right to make, use, sell, import, or export the invention.
- Right to sue infringers who use their invention without permission.
- Right to license the invention to others for royalties.

Patent Criteria in India: An invention must be:

- **Novel:** Not already disclosed to the public anywhere in the world.
- **Inventive step:** Not obvious to a person skilled in the relevant field.
- **Industrially applicable:** Capable of being made or used in an industry.

- **Evergreening of patents:** The evergreening of patents is a practice of tweaking drugs in order to extend their patent term and thus their profitability.
- The **Indian Patents Act 1970** introduced many provisions to prevent the mischievous practice of "evergreening" of patents.

- **Industrial Design:** It refers to the application of creative and aesthetic principles to the design of mass-produced objects. It protects the ornamental aspects of functional items. The Designs Act governs registration in India.
- **Trade Secrets**: It encompasses confidential business information. India does not have a specific statute but recognizes trade secret protection under common law.
  - Protecting trade secrets is crucial in sectors like technology and manufacturing. India's legal framework is evolving to address the growing importance of trade secrets.

- **Geographical Indications (GI TAG):** It is a sign that **identifies a product originating from a specific geographical location** whose quality and reputation are essentially due to that origin. Obtaining GI protection for your product offers numerous advantages for producers and consumers alike.
  - **Registration of Geographical Indications:**An application for the registration of a GI is to be made to the **Registrar of Geographical Indications** in the form prescribed under the Geographical Indications of Goods (Registration and Protection) Act, 1999.
  - **Validity of GI Registration:**The initial term of GI registration in India is **10 years, and it can be renewed for further periods of 10 years each.**

Geographical Indications at the International Level

- **The TRIPS agreement** specifies additional protection for wines and spirits in addition to minimum requirements for GI protection.
- India enacted the Geographical Indications of Goods (Registration and Protection) Act, 1999, and the Geographical Indications of Goods (Registration and Protection) Rules, 2002 in order to comply with its obligation under TRIPS. **[UPSC 2018]**
- **TRIPS Agreement**
  - The Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) was established as part of the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) in 1994.
  - WTO administers the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), which establishes minimum standards for GI protection among its member states, including India.
- **Lisbon Agreement**
  - The Lisbon Agreement, **established in 1958** and administered by the World Intellectual Property Organization (WIPO), facilitates the international registration and protection of appellations of origin for products.
  - India is **not yet a member of the Lisbon Agreement**, but it can still be used to protect GIs from other countries in the EU and other regions.

- **Plant Varieties: Plant Breeder's Rights (PBR)** are a form of intellectual property (IP) that recognizes the contributions of plant breeders in developing new and improved varieties of plants.
  - Breeder's Rights are intellectual property protections for plant breeders, granting exclusive control over the commercial use of new plant varieties.

The Legal Framework: India established a legal framework for PBR with the **Protection of Plant Varieties and Farmers' Rights Act (PPV&FR Act) enacted in 2001[UPSC 2019].** This Act aims to:

- Recognize and protect the rights of plant breeders to their creations.
- Balance the rights of breeders with the rights of farmers to save, exchange, and use their own seeds.
- Promote the development of new plant varieties suitable for Indian conditions.

Key Provisions of the PPV&FR Act:

- **Eligible Plant Varieties:** The Act protects distinct, uniform, and stable varieties of all plant genera and species.
- **Rights Granted to Breeders:** Breeders of protected varieties have exclusive rights to produce, sell, distribute, import, and export the protected variety.
- **Farmers' Rights:** The Act recognizes the traditional rights of farmers to save, use, exchange, and sell seeds of protected varieties for their own consumption and non-commercial purposes.
- **Registration and Grant of PBR:** Breeders need to apply to the Plant Variety Protection and Farmers' Rights Authority (PPVFRA) for registration of their variety. The PPVFRA then grants PBR for a period of 15 years (20 years for trees and vines).

- **TRIPS Agreement**
  - Adopted by the World Trade Organization (WTO) in 1994, TRIPS establishes minimum standards for IP protection for member countries, including patents, copyrights, and trademarks.
  - It aims to promote innovation and international trade by providing exclusive rights to inventors and creators.
- **Compulsory Licensing**
  - A provision within TRIPS allows governments to **grant licenses to produce patented products without the consent of the patent holder** under certain circumstances.
  - This is primarily intended to address public health emergencies or ensure affordable access to essential medicines, particularly in developing countries.
- **TRIPS and Compulsory Licensing: Key Points:**
  - **General Rule vs. Exception:** While TRIPS promotes strong IP protection, it recognizes the need for flexibility in specific situations through compulsory licensing.
  - **Conditions for Compulsory Licensing:** Countries can grant compulsory licenses under limited circumstances, like national emergencies, public

non-commercial use, or to remedy anti-competitive practices.

- **Compulsory license in india**
  - Compulsory license in India is authorized by the **controller general** to third parties in line with patent act 1970.
  - The application for compulsory license is made to the controller general on the expiry of 3 years upon fulfillment of any of three conditions mentioned in section 83 of Indian patent act 1970.
  - Compulsory license can be issued by controller general **suo moto** after the notification of central government, **if there is either a national emergency or extreme urgency or in case of public non commercial use.**
  - India's **first compulsory license was granted to Natco Pharma, allowing them to produce a generic version** of Bayer's patented cancer drug, Nexavar. This aimed to enhance affordability and access to critical medication.

Objectives of IPR Policy

There are seven important objectives of the IPR policy **[UPSC 2017]**

- IPR Awareness: Outreach and Promotion – awareness about the economic, social, and cultural importance of IPRs in society.
- Establish an atmosphere of invention and innovation – stimulating the creation of IPRs.
- Replace the prevailing outdated laws – to create strong and effective IPR laws that balance the interests of rights owners with the larger public interest.
- Human Capital Development for teaching, research, and skill-building in Intellectual Property Rights – enhance and expand human resources, establishments, and capacities.
- Administration and management of innovation – update and reinforce service-oriented IPR administration.
- Commercialization of IPRs – Get value for IPRs via commercialization.
- To fight IPR violations by strengthening the execution and adjudicatory mechanisms.
- The policy put in place a legal framework that will spur the IPR regime and lessen the time the government takes to sanction a trademark to a month. At present, the procedure takes more than a year.

IMPORTANT INTERNATIONAL CONVENTIONS FOR INTELLECTUAL PROPERTY RIGHTS

- **TRIPS Agreement (Trade-Related Aspects of Intellectual Property Rights):** Part of the World Trade Organization (WTO) agreements, TRIPS establishes minimum standards for intellectual property protection globally. It covers patents, trademarks, copyrights, and trade secrets, aiming to harmonise regulations and promote innovation while facilitating international trade.
- **Berne Convention for the Protection of Literary and Artistic Works:** An international copyright agreement, the Berne Convention ensures the recognition and protection of copyright works across member countries. It establishes the principle of automatic copyright protection without the need for formalities, promoting the free flow of creative works globally.
- **Paris Convention for the Protection of Industrial Property:** Focused on industrial property rights, the Paris Convention provides a framework for the protection of inventions, trademarks, and industrial designs across member countries. It encourages mutual recognition and facilitates the application process for inventors and businesses.
- **WIPO Copyright Treaty (WCT):** Administered by the World Intellectual Property Organisation (WIPO), the WCT extends copyright protection to the digital environment. It addresses challenges posed by the digital age, ensuring that creators are protected in the online realm.
- **Patent Cooperation Treaty (PCT):** The PCT simplifies the international patent filing process. It allows inventors to file a single international patent application, which is then recognised in multiple member countries. This streamlines the procedure and provides a more cost-effective approach to seeking patent protection globally.

World Intellectual Property Organisation (WIPO): It is a **specialised agency of the United Nations** dedicated to promoting intellectual property (IP) rights as a tool for innovation and economic growth. With 193 member states, WIPO plays a vital role in shaping the global IP landscape.

NOBEL PRIZES

The Nobel Prize in Physics 2022

- **Nobel laureates: Alain Aspect, John F.** Clauser, and **Anton Zeilinger**
- "for experiments with entangled photons, establishing the violation of Bell inequalities and pioneering quantum information science"

The Nobel Prize in Chemistry 2022

- **Nobel laureates: Carolyn R. Bertozzi, Morten** Meldal, and **K. Barry Sharpless**
- "for the development of click chemistry and bioorthogonal chemistry"

The Nobel Prize in Physiology or Medicine 2022

- **Nobel laureates: Svante Pääbo**
- "for his discoveries concerning the genomes of extinct hominins and human evolution"

The Nobel Prize in Physics 2023

- **Nobel laureates: Pierre Agostini, Ferenc Krausz**, and **Anne L'Huillier**
- "for experimental methods that generate attosecond pulses of light for the study of electron dynamics in matter"

The Nobel Prize in Chemistry 2023

- **Nobel laureates: Moungi G. Bawendi,Louis E.** Brus, and **Aleksey Yekimov**
- "for the discovery and synthesis of quantum dots"

The Nobel Prize in Physiology or Medicine 2023

- **Nobel laureates: Katalin Karikó, Drew Weissman**
- "for their discoveries concerning nucleoside base modifications that enabled the development of effective mRNA vaccines against COVID-19"

THE CONTRIBUTIONS OF INDIAN SCIENTISTS

Indian scientists have made remarkable contributions across various fields, significantly advancing **global knowledge and innovation.** Their pioneering work, ranging from mathematics and physics to biology and space technology, has not only enhanced **scientific understanding** but also played a crucial role in **societal development and technological progress,** both within India and internationally.

Srinivasa Ramanujan Aiyangar (1887–1920)

- **Field:** Mathematics
- **Contributions:**
  - Ramanujan is celebrated for his pioneering contributions in the fields of **mathematical analysis, number theory, and infinite series.**
  - Despite lacking formal training, his intuition and originality led him to derive over 3,000 mathematical results, including properties of highly composite numbers, the **Ramanujan prime, the Ramanujan theta function, and partition formulae.**
  - In 1911, he published in the same journal a brilliant research paper on **Bernoulli** numbers. This got him recognition, and he became well known as a mathematical genius.

Chandrasekhara Venkata Raman (1888–1971)

- **Field:** Physics
- **Contributions:** He is best known for his work on the **scattering of light** and the discovery of the **Raman effect,** which demonstrated that **light quanta have particle-like properties** in addition to **wave-like properties.** His discovery was instrumental in the development of quantum physics.

Jagdish Chandra Bose (1858–1937)

- **Field:** Physics, Biophysics, and Botany
- **Contributions:**
  - In recognition of his work on **"The Electromagnetic Radiation and Polarisation of Electric Rays,"** he was knighted in 1917 and became a Fellow of the Royal Society of London in 1920. This distinguished him as the initial Indian physicist to achieve this honour in the field of physics.
  - Bose is credited with making significant contributions to the field of **radio and microwave optics.** He pioneered the investigation of **radio and microwave optics,** and he significantly contributed to plant science by experimenting with plant stimuli.

Homi Jahangir Bhabha (1909–1966)

- **Field:** Nuclear Physics
- **Contributions:** Bhabha is known as the **father of the Indian nuclear programme.** He was the founding director of the **Tata Institute of Fundamental Research and the Trombay Atomic Energy Establishment (now Bhabha Atomic Research Centre).**

Vikram Ambalal Sarabhai (1919–1971)

- **Field:** Space Science
- **Contributions:**
  - Dr. Vikram Ambalal Sarabhai, a prominent figure in modern India, was the founder of the Indian

Space Research Organisation (ISRO), and he also spearheaded the launch of India's inaugural satellite, Aryabhatta.

- Under the mentorship of Dr. C.V. Raman, he delved into the study of **cosmic rays,** culminating in a Ph.D. from Cambridge University. His research on cosmic rays revealed their origin as energetic particles from outer space, undergoing alterations influenced by the sun, the Earth's atmosphere, and magnetic forces during their journey to Earth.

Verghese Kurien (1921–2012)

- **Field:** Dairy Farming, White Revolution.
- **Contributions:**
  - Known as the **'Father of the White Revolution'** in India, Dr. Kurien was instrumental in transforming India's dairy industry.
  - He pioneered the **Anand model** of dairy cooperatives and played a key role in setting up the **National Dairy Development Board (NDDB)** and the **Gujarat Cooperative Milk Marketing Federation (GCMMF),** which manages the **Amul brand.**

Satyendra Nath Bose (1894–1974)

- **Field:** Physics.
- **Contributions:**
  - He was a renowned **Indian physicist** known for his work in **quantum mechanics** in the early 1920s. His most significant contribution was the development of **Bose-Einstein statistics** and the theory of the **Bose-Einstein condensate,** a state of matter for a **dilute gas of bosons** cooled to temperatures very close to **absolute zero.**
  - This work laid the foundation for the discovery of the Bose-Einstein condensate phenomenon, a pivotal concept in **quantum physics.** Bose's collaboration with Albert Einstein led to the development of Bose-Einstein statistics, which describe the statistical distribution of identical particles with integer spin, known as bosons, named in his honour.

Subrahmanyan Chandrasekhar (1910–1995)

- **Field:** Astrophysics
- **Contributions:** Subrahmanyan Chandrasekhar was a distinguished astrophysicist whose contributions significantly advanced the understanding of **stellar evolution.** He is best known for his theoretical work on the physical processes important to the structure and evolution of stars, including his formulation of the **Chandrasekhar limit.** This limit describes the maximum mass of a stable white dwarf star, beyond which it would collapse, leading to significant insights into the later evolutionary stages of massive stars. For his profound contributions to the field of astrophysics, **Chandrasekhar was awarded the Nobel Prize in Physics in 1983,** sharing it with William A. Fowler.

Har Gobind Khorana (1922–2011)

- **Field:** Biochemistry
- **Contributions:**
  - Har Gobind Khorana was a **Nobel Prize-winning biochemist** of Indian origin, celebrated for his groundbreaking research in **genetics.**
  - His most notable contribution was elucidating the role of **nucleotides** in protein synthesis, which was pivotal in understanding how genetic information is translated into proteins. Khorana's work on the synthesis of **oligonucleotides,** compounds that form the structure of DNA, was instrumental in the development of biotechnology.
  - For his significant contributions to the field of molecular biology, he was awarded the **Nobel Prize in Physiology or Medicine in 1968,** alongside Robert W. Holley and Marshall W. Nirenberg.

M. Visvesvaraya (1861–1962)

- **Field:** Civil Engineering
- **Contributions:**
  - M. Visvesvaraya was an eminent Indian engineer and statesman, widely regarded for his contributions in the fields of **civil engineering** and public works.
  - His most notable work includes the **design and construction of the Krishna Raja Sagara Dam in Mysore,** which played a pivotal role in transforming the region's irrigation system and agriculture.

Tessy Thomas (1963)

- **Field:** Missile Technology
- **Contributions:**
  - She is often referred to as the **"Missile Woman of India"** and has made significant contributions to India's defence research and development.
  - She is the first woman scientist to head a missile project in India, notably the **Agni-IV** missile project, a **long-range nuclear-capable missile.**

Shanti Swaroop Bhatnagar (1894–1955)

- **Field:** Chemistry
- **Contributions:**
  - Shanti Swaroop Bhatnagar was a renowned Indian scientist and a pioneer in the field of **chemical research in India.**

- He is best known for his significant contributions to **industrial chemistry and for establishing the Council of Scientific and Industrial Research (CSIR)** in India, serving as its first Director-General. Bhatnagar's work in the realm of chemical sciences led to the discovery of the **Bhatnagar-Mathur Magnetic Interference Balance,** a key instrument in scientific research.

Salim Ali (1896–1987)

- **Field:** Ornithology
- **Contributions:** Salim Ali, popularly known as the **"Birdman of India,"** was a pioneering Indian **ornithologist and naturalist.** He is best known for his systematic survey of the birds of India and several bird books, including the highly influential **"The Book of Indian Birds."**

M. S. Swaminathan (1925-2023)

- **Field:** Agriculture
- **Contributions:**
  - He is a renowned **Indian geneticist** and **international administrator,** celebrated for his leading role in **India's Green Revolution,** a movement that transformed agriculture in India and helped alleviate hunger and poverty in the 1960s and 1970s.
  - His development and promotion of **high-yielding varieties** of wheat and rice significantly increased food production in India, making the country self-sufficient in cereals and preventing widespread famine.

Meghnad Saha (1893–1956)

- **Field:** Physics, Astrophysics
- **Contributions:**
  - Meghnad Saha was an eminent **Indian astrophysicist** best known for his development of the **Saha Equation,** a fundamental formula in astrophysics that describes the **physical and chemical conditions** of stars.
  - This equation, crucial in the study of stellar atmospheres, helps in determining the temperature and ionization state of various elements in stars.

Prasanta Chandra Mahalanobis (1893–1972)

- **Field:** Statistics
- **Contributions:**
  - He was a renowned **Indian statistician and scientist,** best known for his pioneering work in statistics. He is credited with the development of the **Mahalanobis distance,** a statistical measure used to analyze the divergence between different data sets.
  - Mahalanobis also played a key role in the formulation of **India's second five-year plan,** which focused on industrialization and economic development.

Dr. Dilip Mahalanabis(1934-2022)

- **Field**: Medication
- **Contributions:** He invented the Oral Rehydration Solution (ORS) while working in refugee camps during the 1971 Bangladesh Liberation war. The Lancet called ORS "the most important medical discovery of the 20th century".

Upendranath Brahmachari(1873-1946)

- **Field**:physiology or medicine
- **Contributions:** He synthesized urea-stibamine in 1922 and determined that it was an effective treatment for kala-azar

Narinder Singh Kapany(1926-2020)

- **Field**:Physics
- **Contributions**: He was an Indian-American physicist best known for his work on fiber optics. Kapany is a pioneer in the field of fiber optics, and known for coining and popularizing the term.

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End Date- 12 Sept (2024)

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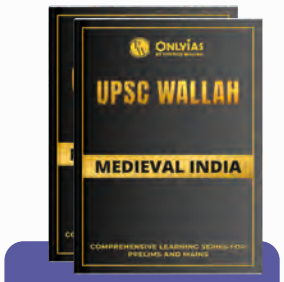

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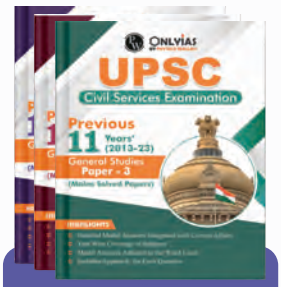

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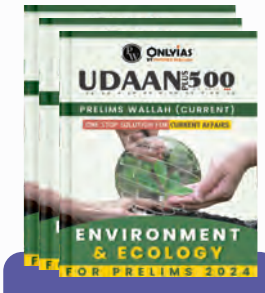

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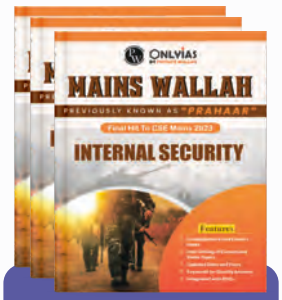

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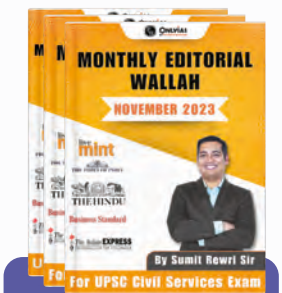

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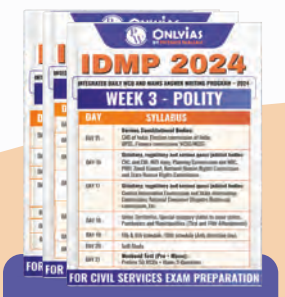

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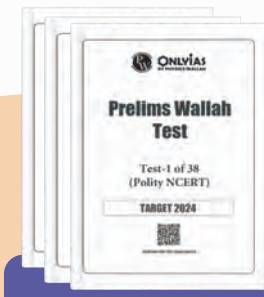

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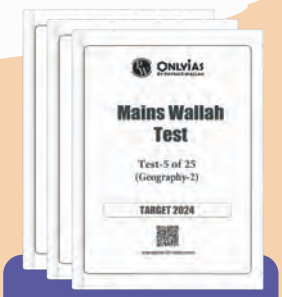

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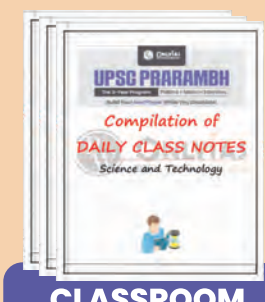

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