

- Water also obeys the law of diffusion: **Osmosis** - the movement of water molecules through such selectively permeable membrane. It is basically movement of water from a region of high water concentration through a semi-permeable membrane to a region of low water concentration.
- **What happens when we put an animal cell or a plant cell into a solution of sugar or salt in water?**
  - **Hypotonic Solution:** If the medium has higher water concentration than the cell, meaning, outside cell is very dilute, the cell will gain water.
  - **Isotonic Solution:** Same concentration, no movement.
  - **Hypertonic Solution:** The medium has a lower concentration of water than the cell, meaning that it is a very concentrated solution, the cell will lose water by osmosis. Such solution is called a hypertonic solution.
- **Thus, osmosis is a special case of diffusion through a selectively permeable membrane.**
  - Unicellular freshwater organisms and most cells tend to gain water through osmosis. Absorption of water by plant roots is also an example of osmosis.
  - Only living cells, and not dead cells, are able to absorb water by osmosis.
- The flexibility of cell membrane also enables the cell to engulf in food and other material from its external environment. Such process is known as **Endocytosis**. Amoeba acquires its food through such processes.
- **Cell Wall**
  - Plant cells in addition to plasma membrane, have another rigid outer covering called the cell wall. The cell wall lies outside plasma membrane. The plant cell wall is mainly composed of cellulose. Cellulose is a complex substance and provides structural strength to plants.
  - **Plasmolysis:** When a living plant cell loses water through osmosis there is a shrinkage or contraction of the contents of the cell away from the cell wall. The phenomenon is known as plasmolysis.
  - **Plant cells can withstand much greater changes in the surrounding medium than animal cells. Why?**
  - **Animal cells never have a cell wall.**

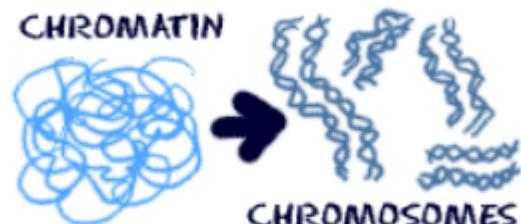
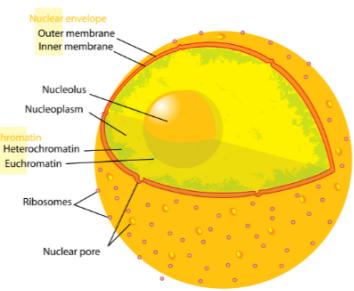
## B) NUCLEUS

- Nucleus acts as **brain/control centre** of the cell. It stores DNA, the genetic information that tells a cell how to live its life. It controls basic activities like eating, movement, reproduction, basic characteristics etc.
- Sometimes there are more than one nucleus in certain cells. These are called **multi-nucleated cells**.
- Almost all human cells have one nucleus with identical DNA. Some human cells have no nuclei at all e.g. the Red Blood Cells. Some cells like liver cells and some muscle cells, are multinucleated, meaning they have multiple nuclei.

- **M multinucleated** cells are more efficient as they have two control centres. For instance – Liver cells – Hepatocytes do a lot of jobs. They make protein for digestion, help remove harmful stuff from your blood, produce enzymes to digest fats and carbohydrates and store carbohydrate energy for the body. Having two nuclei is like having two sets of blueprints, so the cells can build two proteins at the same time.
- **Nucleoid:** In some organisms like bacteria, the nuclear region of the cell may be poorly defined due to the absence of nuclear membrane. Such an undefined nuclear region containing only nucleic acids is called nucleoid.

▫ **Structure**

- Nucleus has a double layered covering called the **nuclear membrane**.
  - The nuclear membrane has pores which allow the transfer of material (such as RNA and protein) from inside the nucleus to its outside, i.e. to the cytoplasm.
- **The nucleus contains**
- **Chromosomes**
    - Chromosomes are composed of DNA and proteins.
    - It contains information for inheritance of features from parents to next generation in the form of DNA (Deoxyribonucleic Acid) molecules.
    - **DNA** molecules contain the information necessary for constructing and organizing cells.
    - Functional segments of DNA are called **genes**.
  - **Chromatin Material**
    - i. When the cell is in a resting state (not dividing) there is something called chromatin in the nucleus. It is made up of DNA, RNA, and nuclear protein.
    - ii. Chromatin material is visible as entangled mass of thread like structures.
    - iii. Whenever the cell is about to divide the chromatin material gets organized into chromosome (the rod shape structure)



▫ **Nucleolus**

- It looks like nucleus inside a nucleus. It is made up of RNA and protein.
- It is the structure where ribosomes are made.
- After ribosomes leave the nucleus, they will have the important job of synthesizing proteins.

### C) CYTOPLASM

- The cytoplasm is the fluid content inside the plasma membrane. It also contains many specialized cell organelles. Each of these cell organelles perform a specified function for the cell.

A. **Cell organelles** are enclosed by membranes to keep its own content separate from external environment.

B. In **Prokaryotes**, besides the absence of a defined nuclear region, the membrane-bound cell organelles are also absent. On the other hand, the **eukaryotic cells** have nuclear membrane as well as membrane-enclosed organelles.

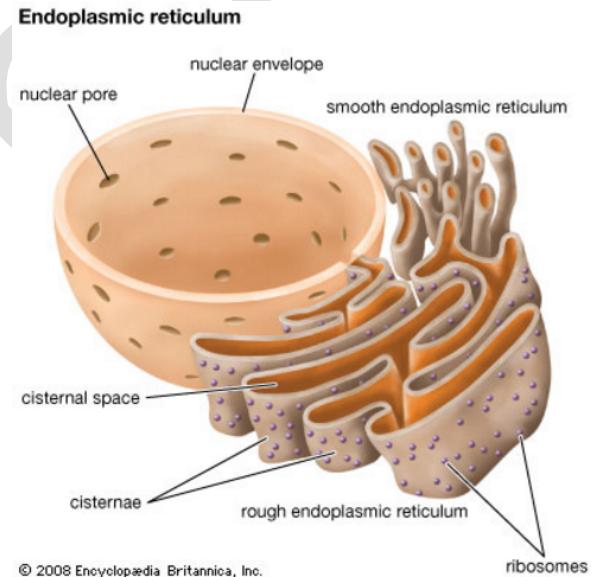
### C. Significance of membranes

- i. Significance of membranes can be illustrated with the example of viruses.
- ii. Viruses lack any membranes and hence don't show characteristics of life until they enter a living body and use its machinery to multiply.

### - Important Cell Organelles

#### A. Endoplasmic Reticulum (ER)

- ER functions both as a passageway for intercellular transport and as a manufacturing surface.
- It is a large network of membrane bound tubes and sheets to transport material. It looks like long tubules or round and oblong bags (vesicles). The ER membrane is similar in structure to plasma membrane.
- Some cells like Prokaryotes or RBCs **don't have** ER of any kind.
- Cells that synthesize and release a lot of proteins would need a large amount of ER. Cells from Pancreas or liver will have large number of ER structures.
- **Two types of ER**
  - **Rough Endoplasmic Reticulum (RER)**
    - RER looks rough under a microscope because it has particles called ribosomes attached to its surface. Ribosomes which are present in all active cells, are the sites of protein manufacture.
    - RER looks like sheets or disks of bumpy membranes while smooth ER looks more like tubes.
    - The manufactured proteins are then sent to various places in the cell depending on need, using the ER.
    - The RER are also attached to nuclear envelope that surrounds the nucleus. This attachment allows for movement of molecules through membranes.



© 2008 Encyclopædia Britannica, Inc.

#### ▪ Smooth Endoplasmic Reticulum (SER)

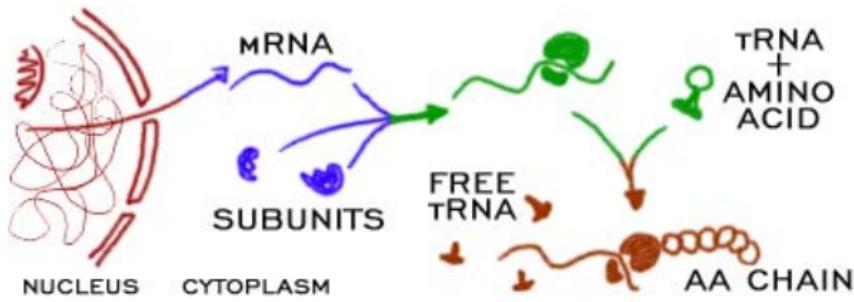
- SER help in manufacturing of fat molecules, or lipids, important for cell function.
  - They are mostly shaped like tubes.
  - Some of these lipids help in building of cell membrane. This process of known as membrane **biogenesis**.
  - Some other proteins and lipids function as enzymes and hormones.
- 
- Although the ER varies greatly in appearance in different cells, it always forms a **network system**. Thus, one function of ER is to serve as **channels for the transport of materials** (especially proteins) between various regions of the cytoplasm or between the cytoplasm and the nucleus.
  - The ER also functions as a cytoplasmic framework providing a **surface for some of the biochemical activities of the cell**.
    - e.g.: In liver cells of vertebrates, SER plays a crucial role in detoxifying poisons and drugs

#### B. Ribosomes (not organelles)

- **Note:** Ribosomes are not organelles. They are not membrane-enclosed, instead they are macro-molecules made of both RNA and proteins.
- They are the protein factories of the cell. Composed of two subunits, they can be found floating freely in cell's cytoplasm or embedded within the endoplasmic reticulum.
- **Every cell needs Ribosomes**, so they are found in both prokaryotes and Eukaryotes.
- Using the templates and instructions provided by two different types of RNA, ribosomes synthesize a variety of proteins that are essential to the survival of the cell.
- There are two sub-units to every ribosome.
- **The Process of protein synthesis**
  - Protein synthesis starts when mRNA moves from nucleus to a ribosome on the surface of RER.
  - The two sub-units of ribosomes come together and combine with mRNA. They lock onto the mRNA and start the protein synthesis.
  - Ribosome builds the amino acid chain. The process is simple. First, you need an amino acid. Another nucleic acid that lives in the cell is **transfer RNA**. It is bonded to amino acids floating around the cell. With mRNA offering instructions, the ribosome connects to a tRNA and pulls off one amino acid. The tRNA is then released back into the cell and attached to another amino acid.
  - When the protein is complete RER pinches off a vesicle. That vesicle, a small membrane bubble, can move to the cell membrane or the Golgi apparatus. Some of the protein will

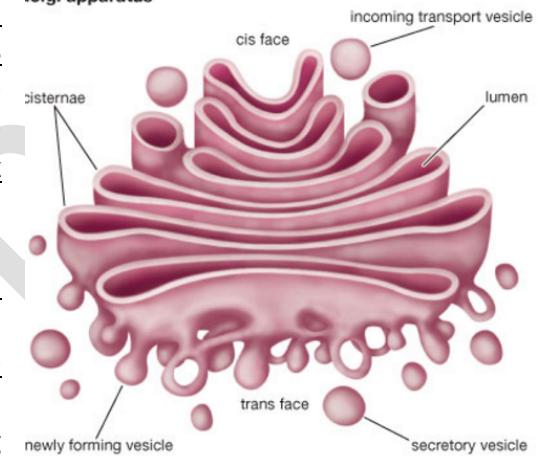
be used in the cell and some will be sent out into intercellular-space.

## Mixing and Matching Amino Acids



### C. Golgi Apparatus (pronounced 'GOL-JI')

- **Structure:** The Golgi apparatus, first described by Camillo Golgi, consists of system of membrane-bound vesicles arranged approximately parallel to each other in stacks called cisterns. These membranes often have connection to membrane of ER and therefore constitute another portion of a complex cellular membrane system.
- **Functions** of GA include storage, modification and packaging of products in vesicles.
  - Complex sugar can be made out of simple sugar
  - Turning protein into usable form by folding them into different shapes or adding other materials to protein such as lipids or Carbohydrates.
  - It is also involved in formation of lysosomes.
- After making these big molecules, Golgi apparatus packages them into vesicles, and either stores them for later use or sends them out of the cell.



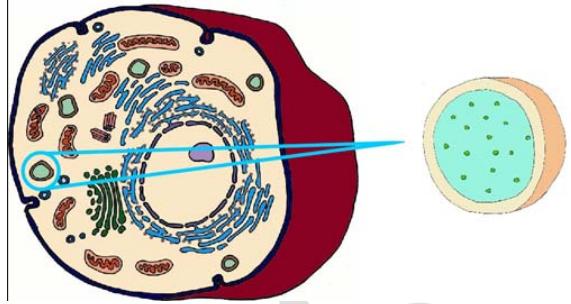
### D. Lysosomes

- **Structure:** Lysosomes are membrane bound sacs filled with powerful digestive enzymes capable of breaking down organic material. These enzymes are made at RER. The membrane ensures that the internal enzymes don't digest the cell itself.
- **Functions**
  - It is a kind of waste disposal system of the cell. Lysosome help to keep the cell clean by digesting any foreign material as well as worn-out cell organelles.

## Lysosome

### - Suicide bags of cell

- During the disturbance in cellular metabolism, for example, when the cell gets damaged, lysosomes may burst, and enzymes digest their own cell. Therefore, lysosomes are also known as suicide bags of a cell.



- They are not commonly found in plant cells.  
The tough cell walls keep out the foreign substance.

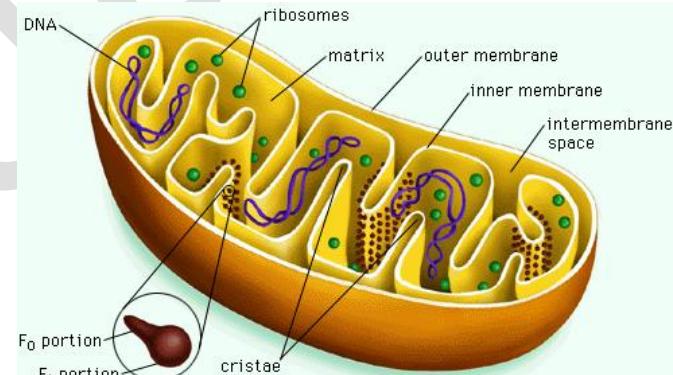
## E. Mitochondria

### - Structure:

- Mitochondria has two membranes covering instead of one.
- The outer membrane is very porous while the inner membrane is deeply folded. These folds create large surface areas for ATP generating chemical reactions.
- Mitochondria are **strange organelles** in the sense that they have their own DNA and ribosomes. Therefore, mitochondria are able to make some of their proteins.

### - Functions

- Mitochondria are known as **powerhouse of the cell**.
- The energy required for various chemical activities needed for life is released by mitochondria in the form of **ATP (Adenosine Triphosphate)** molecules during a process called cellular respiration.
- ATP is known as the energy currency of the cell. It provides energy for all the cellular activities.
- Cells which need more energy have more mitochondria. (For e.g. muscle cells)
- The body uses energy stored in ATP for making new chemical compounds and for mechanical work.
- Mitochondria are also involved in controlling the concentration of Calcium ( $\text{Ca}^{2+}$ ) ions within cell.



## F. PLASTIDS (not found in animal cells)

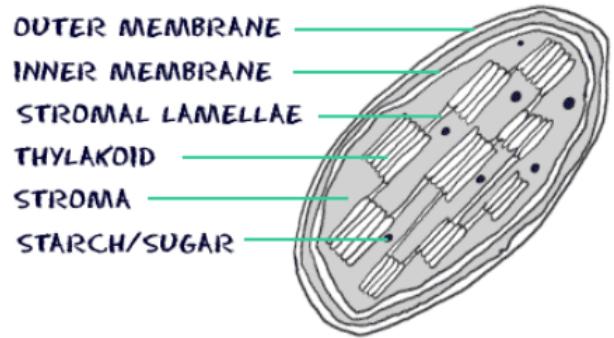
### - Structures:

- The internal structure of plastids consists of numerous membrane layers embedded in a material called the Stroma.
- Plastids are similar to mitochondria in external structure.
- Like mitochondria, plastids also have their own DNA and ribosomes.

### - Two types of plastids

- **Chromoplasts** (coloured plastids)

- **Leucoplasts** (white or colourless)-> these are organelles in which material such as starch, oil and protein granules are stored. Thus, primary purpose of leucoplast is **storage**.

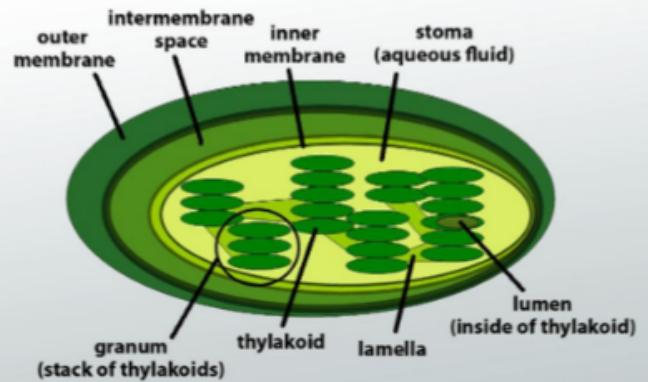


- **Chloroplasts:** Plastids containing the green pigment chlorophyll are known as **chloroplasts**.

- Chloroplasts are important for photosynthesis in plants and thus are food producers of the cell. They convert light energy of sun into sugars that can be used by cells. The entire process is called photosynthesis and it all depends on little green chlorophyll molecule in each chloroplast. In the process of photosynthesis, plants create sugar and release oxygen.

- Two membranes (named outer and inner membrane) surrounds the stroma and the grana (stacks of thylakoid).

One thylakoid stack is called grana. The stacks of thylakoid sacs are connected by **stroma lamella**. The **lamella** act like **skeleton of the chloroplast**, keeping all the sacs a safe distance from each other and maximizing the efficiency of the organelle.



- **Chlorophyll molecules sit on surface of each thylakoid** and capture light energy from sun. As energy-rich molecules are created by the light-dependent reactions, they move to the stroma where carbon (C) can be fixed and sugars can be synthesized. They also contain various yellow and orange pigments in addition to chlorophyll.

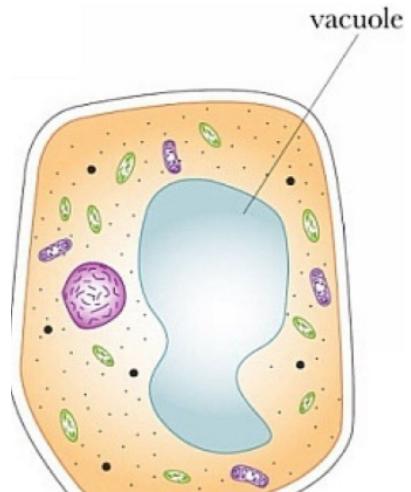
## G. Vacuoles

- **Structure:**

- Vacuoles are of small size in animal cells while plant cells have very large vacuoles.
- The central vacuole of some plant cells may occupy 50-90% of the cell volume.

- **Functions**

- Vacuoles are storage sacs for solid and liquid contents. Many substances of importance in life of the plant cell are stored in vacuoles. These include amino acids,



sugars, various organic acids, some proteins and waste products.

- In plant cells vacuoles are full of cell sap and provide turgidity and rigidity to the cell.
- In single celled organisms like Amoeba, the food vacuole contains the food items that the amoeba has consumed.
- In some other unicellular organisms, specialized vacuoles also play important roles in expelling excess water and some wastes from the cell

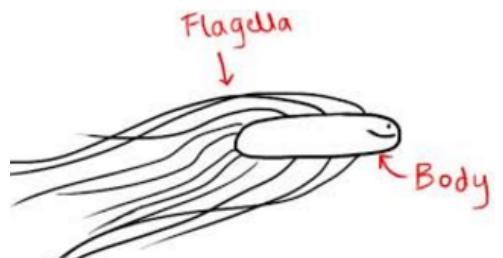
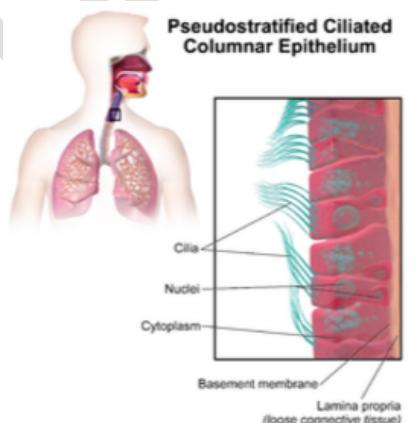
#### H. **Cytoskeleton** (Not organelles)

- It is the microscopic network of protein and tubules in the cytoplasm of many living cells, giving them **shape and coherence**.
- It is complex network of interlinking filament and tubules that extend throughout cytoplasm, from the nucleus to plasma membrane.



#### I. **Some unique structures which only some cells have**

- i. **Cilia:** In humans, the respiratory tract is lined with cells that have cilia. These are microscopic hair like projections that can move in waves. This feature help in trapping inhaled particles in the air and expels when you cough.
- ii. **Flagella:** Some bacteria have flagella. A Flagellum is like a little tail that can help a cell move or propel itself. The only human cell that have a flagellum is sperm cell.



### 5) SOME THINGS TO NOTE:

- Even every multi-cellular organism come from a single cell
- While observing a cell under micro-scope, we use iodine solution, safranin solution or methylene blue solution to stain the cells, so that different organelles are clearly visible.
- All cells have a cell membrane, cytoplasm, and genetic material.

### 6) IMPORTANT SCIENTISTS

- **Discovery of Cell (1665)**

- **Robert Hooke** (father of cytology - the branch of science which studies cell) while examining a thin slice of cork saw that the cork resembled the structure of a honey comb (hexagonal compartments). He in 1665 made the chance observation through a self-designed microscope. He called these boxes **cells**.
  - This was the very first time that someone had observed that living things appear to consist of separate units.
- **Discovery of a living cell (1674)**
  - Anton Von Leeuwenhock (father of bacteriology). He studied bacterial, protozoan cells etc.
- **Discovery of nucleus (1831)**
  - Robert Brown
- Term **Protoplasm** was coined by Purkinje in 1839 for the fluid substance of the cell.

## 2. TISSUES

### 1) INTRODUCTION

- In a unicellular organism, a cell performs all basic functions. For example, in Amoeba, a single cell carries out movement, intake of food and respiratory gases, respiration and excretion.
- But in multicellular organism there are millions of cells. Most of these cells are specialized to carry out a few functions. Each specialized function is taken up by a different group of cells. A group of cells that are similar in structure and/or work together to achieve a particular function forms a tissue.
- Tissues are the fabric of your body. (Infact, the term tissue literally means woven)
- When two or more tissues combine, they form organs. Kidneys, lungs, liver etc are all organs which are made of different kind of tissues.
  - Function of an organ depend on the kinds of tissues it is made of.
- **Histology:** The study of tissues.

### 2) FOUR PRIMARY TYPES OF ANIMAL TISSUES

#### A) NERVOUS TISSUES

- All cells possess the ability to respond to a stimulus. However, cells of a nervous tissue are highly specialized for being stimulated and then transmitting stimulus very rapidly from one place to another within the body.
- **Two big functions of nervous tissues**
  - Sensing stimuli
  - Sending electrical impulse through the body often in response to stimuli.
- The brain, spinal cord and nerves are all composed of the nervous tissue.
- **Nervous tissue is made of two different types of cells**
  - Neurons
  - Glial cells
- **A neuron** consists of a cell body with a cytoplasm and nucleus, from which long thin hair-like parts arise.

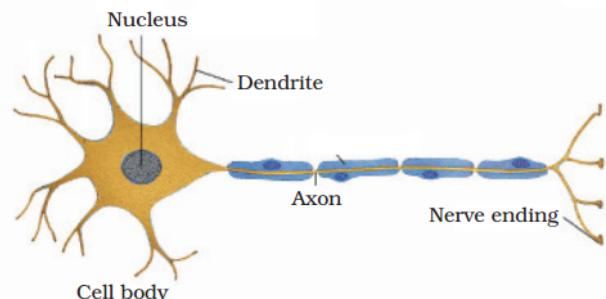
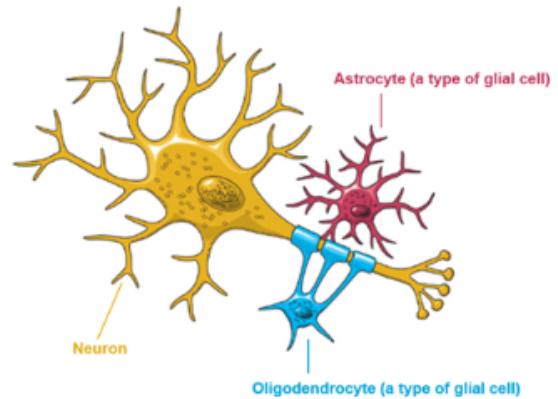


Figure 2.1: A neuron unit of nervous tissue

- Usually each neuron has a single long part, called the **axon** and many short, branched parts called dendrites.
- An individual nerve cell may be upto a meter long.
- **Cell body (soma)** is the neurons life support. It contains all the necessary things like nucleus, mitochondria etc.
- **Dendrites:** They collect signals from other cells to send back to soma. Thus, they are the listening end.
- **Axon** works like a transmission cable and carries messages to another neurons, muscles and glands.
- Neurons are present all over the body.
- **Glial Cells:** These are other types of nervous cells which provide support insulation, and protection and tethering them to blood vessels.

**Simplified View of a Neuron and Glial Cells**



## B) MUSCLE TISSUES/ MUSCULAR TISSUES

- Muscular tissues consist of elongated cells, also called muscle fibres. This tissue is responsible for movement in our body.
- Muscles contain special protein called contractile protein, which can contract and relax to cause movement.
- Unlike your nervous tissues, your muscle tissues can contract and move.
- It is well vascularized meaning it has a lot of blood coming and going.
- **Two types of Muscle tissues**
  - 1. Voluntary Muscles/Skeletal Muscles**
    - Can be moved by conscious will.
      - e.g. Muscle in our limbs
    - Also called skeletal muscles as they are mostly attached to bones and help in body movement.
    - Under microscope, these muscles show alternate light and dark bands or striations when stained appropriately. As a result, they are also called striated muscles.
    - The cells of this tissue are long, cylindrical, unbranched and multinucleate (having many nuclei).

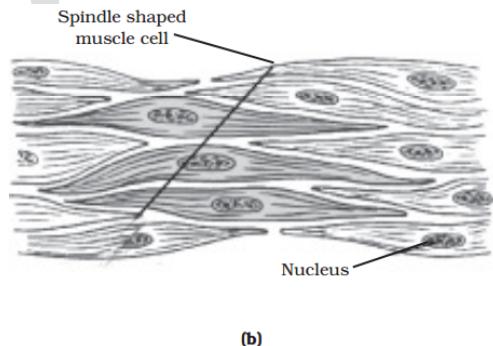
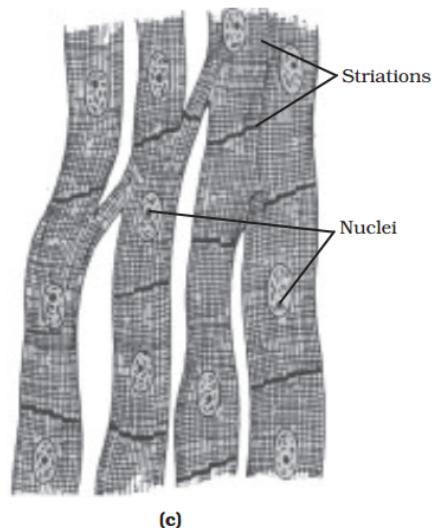


Figure 2.3: Striations



## 2. Involuntary Muscles

- It is not in our control. Movement is involuntary. We cannot really start them and stop them simply by wanting to do so.
- The movement of food in the alimentary canal or the contraction and relaxation of blood vessels are the examples of involuntary movement.
- **Smooth muscles** (a type of involuntary muscles) control such movements.
- They are also found in iris of the eye and in the bronchi of the lungs.
- The cells are long with pointed ends (spindle shaped) and uninucleate (having a single nucleus). They are also called unstriated muscles.
- The muscles of heart show rhythmic contraction and relaxation throughout life. These muscles are called cardiac muscles (another type of involuntary muscles). Heart muscles cells are cylindrical, branched, striated and uninucleate.
  - Cardiac muscle is only found in heart.

## C) EPITHELIAL TISSUES

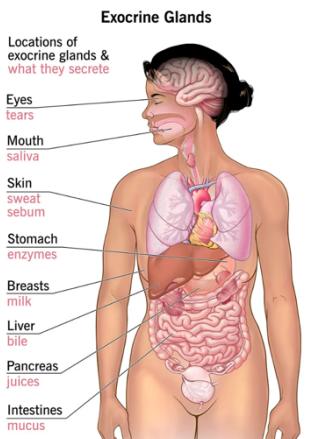
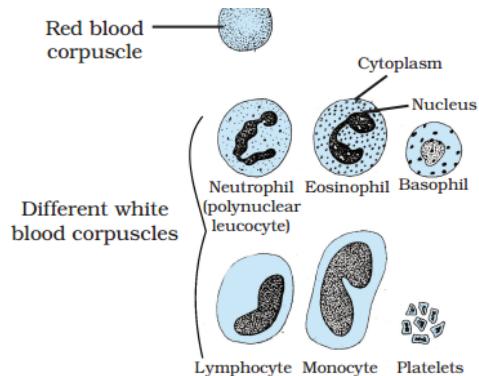
- The covering or protective tissues in animal body are epithelial tissues.
  - It covers most organs or cavities within the body.
    - **This protects** our deeper layers of tissues from injury or infection
    - E.g.: Lining of stomach with epithelial cells that produce mucus -> we don't digest our stomach along with our food.
  - It also forms barrier to keep different body systems separate.
  - Permeability of cells of epithelia play an important role in regulating the exchange of materials between the body and the external environment and also between different body parts.
    - Tissues lining small intestine allows you to absorb nutrients through diffusion and active transport.
    - Urinary waste gets filtered through different epithelia lining the kidneys
- E.g.
  - **The skin**, the lining of mouth, the lining of blood vessels, lung alveoli and kidney tubules are all made of epithelial tissues.
- They are tightly packed and form a continuous sheet. They have a very small amount of cementing material between them and almost no intercellular spaces.
- All epithelium is usually separated from the underlying tissues by an extracellular fibrous basement membrane.
- **Avascular:** All of our epithelial tissues are avascular - meaning they don't have blood supply.
  - Instead, they rely on the blood supply in the supporting connective tissues around them for the material they need.
- **Polar:** All of our epithelial tissues are polar - meaning that they have distinct sides.
  - **Apical Side** or the upper side is exposed to outside of the body of whatever internal cavity it is lining.
  - **Basal Side** or inner side is tightly attached to the basement membrane.
- **Epithelium can also be divided into following groups**

## 1. Proper Epithelium

- **Discussed above**
- **Covers most organs and cavities and separates various organs**

## 2. Glandular Epithelium

- Epithelial cells often acquire additional specialization as gland cells, which can secrete substances at the epithelial surface. Sometimes a portion of the epithelial tissues folds inward, and a multicellular gland is formed. This is **glandular epithelium**.
- **Glandular epithelium forms two different kinds of glands**
  - **Endocrine Glands**
    - Secrete hormones right into your blood stream or to nearby cells
    - e.g.1: Hormone thyroxine is secreted by endocrine gland: **Thyroid**
      - It needs to be distributed throughout the body so that it can stimulate the metabolism in all of our cells
    - E.g.2: Pancreas is an endocrine gland which releases Glucagon (raised blood sugar) and Insulin (lowers blood sugar; stimulates metabolism of glucose, protein, fat).
    - E.g.3: Testes is an endocrine gland which releases testosterone (it develops and maintains male sexual characteristics and maturation)
  - **Exocrine Glands**
    - Secrete their juices into tubes or ducts that lead to the outside of the body or inside of the tube, rather than right into the blood.
    - E.g.
      - Sweat, Saliva, Mucus, stomach acids, milk (if you are lactating)
    - **Note:** The Pancreas is a unique dual gland that has both exocrine and endocrine function. It consists of 95% of exocrine and less than 5% of endocrine functions.



## D) CONNECTIVE TISSUES

- Connective tissue is almost everywhere in the body. How much of it is there depends on organ to organ.
  - e.g. Skin is mostly connective tissue while the brain has very little of this since it is almost all nervous tissues
- Cells of connective tissues are loosely spaced and embedded in an intercellular matrix.

- The matrix can be jelly like, fluid, dense or rigid.
  - The nature of matrix differs in accordance with the function of the particular connective tissues.
- **Blood** has a fluid (liquid) matrix called plasma, in which RBCs, WBCs and platelets are suspended.
  - The plasma contains proteins, hormones and salts.
  - Blood flows and transport gases, digested food, hormones and waste materials to different parts of the body.
- **Bones**
  - Another example of connective tissue. It forms the framework that supports the body. It also anchors muscles and support the main organs of the body.
  - It is also strong and inflexible tissue.
  - Bone cells are embedded in a hard matrix that is composed of calcium and phosphorus compounds.
- **Ligament**
  - Two bones can be connected to each other by another type of connective tissue called ligament. The tissue is very elastic.
  - Ligament contains very little matrix.
- **Tendons**
  - They connect muscles to bones and are another type of connective tissue.
  - Tendons are fibrous tissues with great strength but limited flexibility.
- **Cartilage**
  - Another type of connective tissue cartilage, has widely space cells. The solid matrix is composed of proteins and sugars.
  - Cartilage smoothens bone surface at joints and is also present in the nose, ear, trachea and larynx.
- **Areolar Connective tissue** is found between the skin and muscles, around blood vessels and nerves and in the bone marrow.
  - It fills the space inside the organs, supports internal organs and helps repair of tissues.
- **Adipose tissue**
  - Fat storing adipose tissues is found below the skin and between internal organs.
  - The cells of this tissue are filled with fat globules. Storage of fat also lets it act as an insulator.
- **Four Major Classes of Connective Tissues**
  - Proper Connective Tissues
  - Cartilage Connective Tissues
  - Bone Connective tissues
  - Blood Connective tissues
- **How connective tissues contribute**

- Binding and supporting
  - Protecting
  - Insulating
  - Storing reserve fluid and energy
  - Transporting substances within the body
  - Movement
- **E.g.**
- **Fat** which is a type of proper connective tissue provides insulation and fuel storage. It also serves structural purposes like holding your kidney in place etc.
  - **Bones, Tendons, and Cartilage** bind, support, and protect your organs and give you a skeleton so you can move with purpose.
  - **Blood** transports hormones, nutrients and other materials all over the body. It is a type of connective tissue.
- **All connective tissues have three factors in common** that sets them apart from other tissue types
- **Common Origin**
    - They all develop from **MESENCHYME** a loose and fluid kind of embryonic tissue.
  - **Degree of vascularity**
    - Connective tissues have a different degree of vascularity or blood flow
    - E.g. most cartilages are avascular meaning no blood vessels, while other types of connective tissues like dense irregular tissue in our skin is brimming with blood vessels.
  - **Mostly composed of non-living material**
    - All connective tissues are mostly composed on non-living material called the extracellular matrix.
    - While other tissue types are mainly made of living cells.
    - Extracellular matrix is mostly made of two components
      - i. **Ground Substance**
        - Watery, rubbery, unstructured material that fills in spaces between the cells and protects the cells from their surroundings
        - It is made of starch and protein molecules mixed with water.
      - ii. **Fibers**
        - It provides support and structure to otherwise shapeless ground substances
          - E.g. Collagen fibre

### 3) PLANT TISSUES

- Plants and animals are not made of same kind of tissues.
  - i) Different structure
    - Most tissues are supportive, which provide them with structural strength
    - Most of these tissues are dead
      - Since dead cells can provide mechanical strength as easily as live ones, and need less maintenance.

ii) Different functions

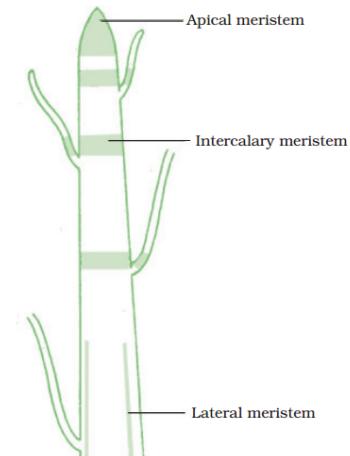
- Plants are stationary, whereas animals are mobile
- The growth of plant is limited to certain regions, while this is not so with animals
- There are some tissues in plants that divide throughout their life. These tissues are localized in certain regions
  - Meristematic tissues -> always growing
  - Permanent tissues
- Animal tissues -> no such demarcation in dividing and non-dividing tissues
- Structural organization of organs simple in plants and far more complex in animals

iii) **Because of above differences it is clear that plant tissues must be very different than animal tissues**

- **Types of Plant Tissues**

**1) MERISTEMATIC TISSUES**

- Growth of plants occur only in certain specific regions. This is because the dividing tissue, also known as meristematic tissues, is located in this point.
- Depending on the region where they are present, meristematic tissues can be classified as
  - **Apical**
    - Present at the growing tips of stems and roots and increase the length of the stem and the root.
  - **Lateral**
    - The girth of the stem or root increases due to lateral meristem (cambium).
  - **Intercalary meristem**
    - It is the meristem at the base of the leaves or internodes (on either side of the nodes) on twigs.
- As the cells of the tissue are very active, they have dense cytoplasm, thin cellulose walls and prominent nuclei. They lack vacuoles.
- New cells produced by meristem are initially like those of meristem itself, but as they grow and mature, their characteristics slowly change and they become differentiated as components of other tissues.



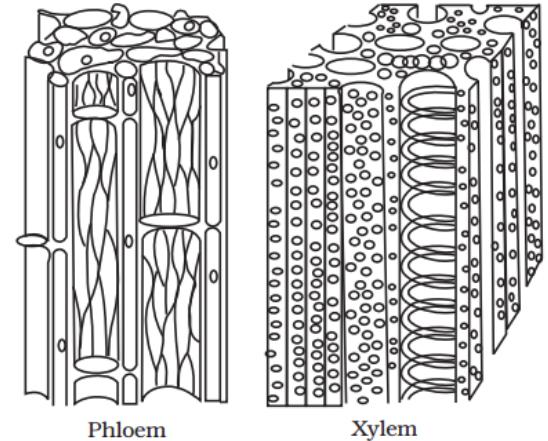
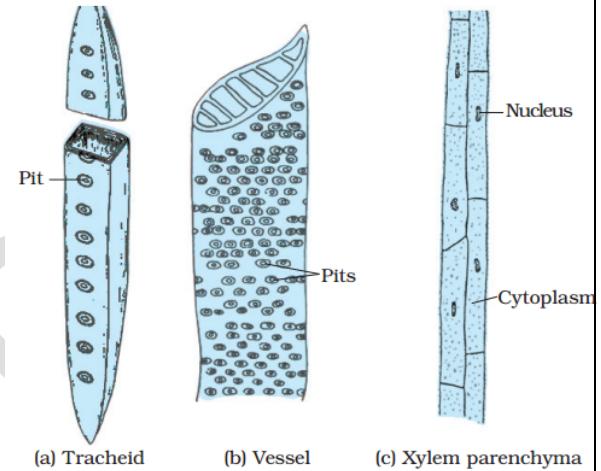
**Fig. 6.2:** Location of meristematic tissue in plant body

**2) PERMANENT TISSUES**

- After cells are formed by meristematic tissue, they take up a specific role and lose the ability to divide. As a result, they form permanent tissues.
- This process of taking up a permanent shape, size, and a function is called the differentiation to form different types of permanent tissues.
- **Types of Permanent Tissues**
  - (i) **Simple Permanent Tissues**
    - They are made of one type of cells. A few layers of cells form the basic packaging tissue.

## (ii) Complex Permanent Tissues

- Complex permanent tissues are made of more than one type of the cells. All these cells coordinate to perform a common function.
- **Xylem and Phloem** are examples of such complex tissues.
  - They are both conducting tissues and constitute a vascular bundle.
  - Vascular or conductive tissues are distinctive feature of complex plants, one that has made possible their survival in the terrestrial environment.
- **Xylem**
  - It consists of tracheid's, vessels, xylem parenchyma and xylem fibres.
  - Tracheid and vessels are tubular structures. This allows them to transport water and minerals vertically.
  - The parenchyma stores food and helps in the sideways conduction of water.
  - Fibres are mainly supportive in function
- **Phloem** is made up of four types of elements:
  - Sieve tubes
    - Tubular cells with perforated walls.
  - Companion cells
  - Phloem fibres
  - Phloem parenchyma
- **Phloem is unlike xylem in that material can move in both directions in it.**
  - Phloem transfers food in leaves to other parts of the plant.
  - Except for phloem fibres, phloem cells are living cells.



### 3. BLOOD TYPE AND RELATED ISSUES

#### - Introduction

- Blood consists of red blood cells (and other cells not relevant here) floating in fluid called Plasma. The RBCs carry on their surface a set of markers with which plasma interacts. The compatibility and cross talk between the RBC and the plasma is what makes each blood type special.
- The markers on the cell are determined by a master type called H, out of which are generated types A, B, AB and O.
- In addition to A and B antigen, there is a third antigen called Rh factor, which can either be (+) or (-)
  - Rh- patient can only be given Rh- blood
  - Rh+ patient can get either Rh- or Rh+ blood
- **A blood type** (also called a blood group) is defined as the classification of blood based on the presence or absence of inherited antigenic substances on the surface of red blood cells (RBCs).
- A series of related blood types constitutes a **blood group system**, such as the Rh or ABO system. The frequencies of the ABO and Rh blood types vary from population to population

#### - ABO System

Blood Group	Antigen
A	Has only A antigen on red cells (and B antibody in the plasma)
B	Has only B antigen on red cells (and A antibody in the plasma)
AB	Has both A and B antigens on red cells (but neither A nor B antibody in the plasma)
O	Has neither A nor B antigens on red cells (but both A and B antibody are in the plasma)

- The universal red cell donor has Type O negative blood type
- The universal plasma cell donor has Type AB positive blood type.

#### - Donating blood by compatibility type

- In a blood transfusion, a patient must receive a blood type compatible with his or her own blood type. If the blood types are not compatible, red blood cells will clump together, making clots that can block blood vessels and cause death.

Blood Type	Donate Blood To	Receive Blood From
A+	A+ AB+	A+ A- O+ O-
O+	O+ A+ B+ AB+	O+ O-
B+	B+ AB+	B+ B- O+ O-
AB+	AB+	Everyone
A-	A+ A- AB+ AB-	A- O-
O-	Everyone	O-
B-	B+ B- AB+ AB-	B- O-
AB-	AB+ AB-	AB- A- B- O-

- **Blood types are inherited just like the eye colour.** The chart below shows possible blood type of a child according to their parents blood group

<b>Parent 1</b>	AB	AB	AB	AB	B	A	A	O	O	O
<b>Parent 2</b>	AB	B	A	O	B	B	A	B	A	O
O					●	●	●	●	●	●
A	●	●	●	●	●	●	●	●	●	●
B	●	●	●	●	●	●	●	●	●	●
AB	●	●	●		●					

- **RH Factor Inheritance**

- We inherit one Rh factor from each parent, either Rh+ or Rh-. Everyone has 2 Rh "factors" in their blood cells. They can be either positive (+) or negative (-). The only way to be Rh negative is for both parents to have at least 1 negative (-) factor and for you to receive it from both of them.
- If you receive one Rh+ factor you are Rh+. **Only those people with two Rh negative "factors" are considered Rh- blood type.**
- **Possible Rh Factor combinations are**
  - a. ++ = Rh positive
  - b. +- = Rh positive
  - c. -- = Rh Negative
- **Examples**
  - a. If both parents are ++, then the child must be ++
  - b. If both parents are --, then child must be --
  - c. If one parent is ++ and the other parent is +-, there is 50/50 chance of the child being either ++ or +-.

**A child who is (--) cannot come from a parent who is (++) , because the child must inherit at least one of those (+'s).** Both parents must have at least 1 Negative (-) "setting" to have a Rh-Negative Child.

- **Bombay Blood**

- It is a blood type called (hh)- , a rare one (1 in 10,000 Indians) first discovered in 1952).

▪ **Biology behind Blood types**

- The markers on the cell are determined by a master type called H, out of which are generated types A, B, AB and O.
- The Bombay doctors found that the **hh type (Bombay type people)** can accept only from other hh type, and also can receive only from the hh types. This makes the Bombay Blood types a very special and rare category of people.
- **How did this happen and why are these people so rare?** It is largely because of extensive inbreeding within the same lineage or close-community marriages, often consanguineous, such that the 'blood type' or the gene pool is greatly restricted. Such intra-community marriages have happened in small isolated communities such as the gypsies, Russian Jewish or Parsi communities. It is thus likely that the Bombay Blood types have common ancestral origins.

The advertisement features the LevelUp IAS logo at the top, followed by two main course offerings:

**ACE CSAT**  
CSAT FOUNDATION COURSE  
FOR CSE 2024

**LET'S DEVELOP CRITICAL THINKING**

**STARTS: 8<sup>TH</sup> JAN 2024**

*By Abhishek Inamdar*  
M.Sc. Mathematics, BITS Pilani

**PRELIMS MASTER PROGRAM** **BATCH 2.0**  
FOR CSE PRELIMS 2024

A group photo of nine students is shown below the program title.

**STARTS: 8<sup>TH</sup> JAN 2024**

Office Complex No. 6, 3<sup>rd</sup> Floor Old  
Rajinder Nagar, New Delhi-110060 | ☎ 08045248491  
7041021151

# TARGET PRELIMS 2024

## BOOKLET-9; S&T-9

### BIOTECHNOLOGY

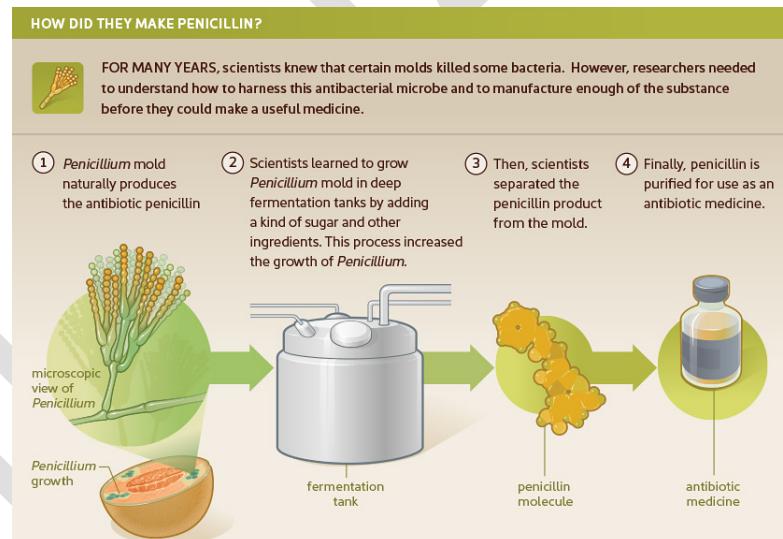
#### TABLE OF CONTENTS

<b>1. Introduction .....</b>	<b>2</b>
<b>2. Basis of Biotechnology .....</b>	<b>2</b>
1) Basics understanding of Genetic Material .....	3
A) Gene.....	3
B) DNA (Deoxyribonucleic Acid).....	3
C) Chromosomes .....	6
D) RNA .....	6
<b>3. Two core techniques that enabled birth of modern biotechnology are: .....</b>	<b>8</b>
1) Genetic Engineering .....	8
2) Maintenance of Sterile (microbial contamination-free) ambience in chemical engineering process	8
<b>4. Tools of Recombinant DNA Technology.....</b>	<b>8</b>
1) Restriction Enzymes .....	8
2) Cloning Vector.....	9
3) DNA Ligase .....	9
4) Host Organisms .....	9
<b>5. CRISPR-CAS9 .....</b>	<b>9</b>
4) how Gene Therapy Using CRISPR can cure Cancer (Dec 2022: Source the Hindu) .....	11
A) Understanding T-Cells in more details .....	12
<b>6. Dark DNA – class discussion .....</b>	<b>13</b>
<b>7. Somatic Cell Nuclear Transfer.....</b>	<b>13</b>
<b>8. Applications of Biotechnology.....</b>	<b>13</b>
2) GM Crops .....	13
A) BT Cotton .....	14

B)	BT Brinjal .....	14
C)	GM Mustard.....	15
D)	GM Rubber – developed by Kerala based - Rubber Research Institute of India.....	16
E)	Increasing the nutrient content – Golden Rice .....	17
F)	Issue of illegal cultivation of GM Crops: .....	18
G)	Scientists are engineering plants to produce insect ‘sex perfume’ to replace pesticides (April 2023).....	18
<b>3)</b>	<b>Reduced Height Genes (Rht): Advantages and Limitations.....</b>	<b>19</b>
<b>3)</b>	<b>Biotechnological Application in Medicines .....</b>	<b>20</b>
A)	Vaccines (covered separately with health section).....	20
B)	Mass Production of Effective Therapeutics .....	20
C)	Genetically Engineered Insulin.....	21
D)	Gene Therapy.....	21
E)	Molecular Diagnosis.....	27
F)	Disease control through Genetically modified organisms .....	27
G)	Personal Genomics .....	28
<b>4)</b>	<b>Transgenic Animals .....</b>	<b>28</b>
<b>5)</b>	<b>Biotechnology and Environment .....</b>	<b>29</b>
H)	GM algae, crops etc. can provide more biomass for biofuel. ....	29
B)	Biodiversity Conservation .....	29
C)	To detect invasive species: .....	30
<b>5)</b>	<b>GM INsects.....</b>	<b>30</b>
A)	Guidelines for Genetically Engineered (GE) Insects: Released by DBT in April 2023 .....	31
<b>9.</b>	<b><i>Other topics (Only class discussion)</i> .....</b>	<b>32</b>
<b>1)</b>	<b>Gene Mapping / Gene Sequencing .....</b>	<b>32</b>
<b>2)</b>	<b>Earth Bio Genome Project .....</b>	<b>32</b>
<b>3)</b>	<b>DArk DNA.....</b>	<b>32</b>
<b>4)</b>	<b>Stem Cell Research.....</b>	<b>32</b>
<b>5)</b>	<b>Chim Studies in India .....</b>	<b>32</b>
<b>6)</b>	<b>Synthetic Biology .....</b>	<b>32</b>
<b>10.</b>	<b>Relevant PYQs .....</b>	<b>32</b>

## 1. INTRODUCTION

- **Definitions**
  - Biotechnology is the use of biological processes, organisms, or systems to manufacture products intended to improve the quality of human life.
    - E.g., Curd, Alcohol, GM crops, test-tube baby, developing a DNA vaccine or correcting a defective gene, are all part of Biotechnology.
  - Depending on the tools and applications, it often overlaps with the (related) fields of bioengineering, biomedical engineering, bio manufacturing, molecular engineering etc.
- **Two Sections of Biotechnology:** The entire field of Biotechnology can be divided into two sections
  - **Classical/traditional/Old Biotechnology**
    - E.g.
      - Curd being prepared with the help of microbes
      - Brewing alcohol
      - Cheese, bread and vinegar
      - Penicillin
    - In all the above product only natural capabilities of the microorganisms and cells were exploited.



### ▫ Modern Biotechnology

- Modern biotechnology refers to manipulation of genome or innate capabilities of organisms for making it more desirable or to synthesis a valuable product.
- E.g.
  - Genetic Engineering
- Tissue/Cell Culture (it refers to growth of tissue or cells in an artificial medium separate from the organisms)

## 2. BASIS OF BIOTECHNOLOGY

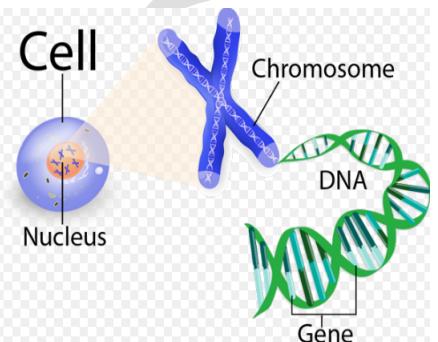
- Most living organisms have DNA as genetic material, DNA (Deoxyribonucleic Acid).
  - Some viruses have RNA as genetic material (e.g. Tobacco Mosaic viruses, QB bacteriophage, etc.)

- Now since all living organisms have DNA, it is possible to make changes, mix and match and this gives rise to possibility of the use of biotechnology.

## 1) BASICS UNDERSTANDING OF GENETIC MATERIAL

### A) GENE

- It is basic physical and functional unit of heredity. It contains the code for a molecule that has a function. They act as instructions to make molecules called proteins
- Genes are located on DNA. It is a short section of DNA. DNA can be cut and separated, forming a sort of 'bar code' that is different from one person to the next.
- In humans, genes vary in size from a few hundred DNA bases to more than 2 million bases.
- The Human Genome Project has estimated that humans have between 20,000 and 25,000 genes.

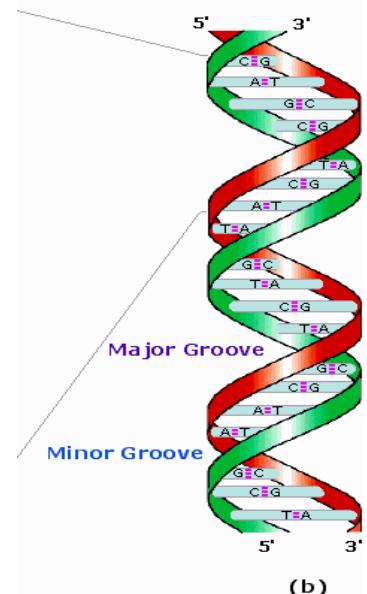


#### Gene Mapping

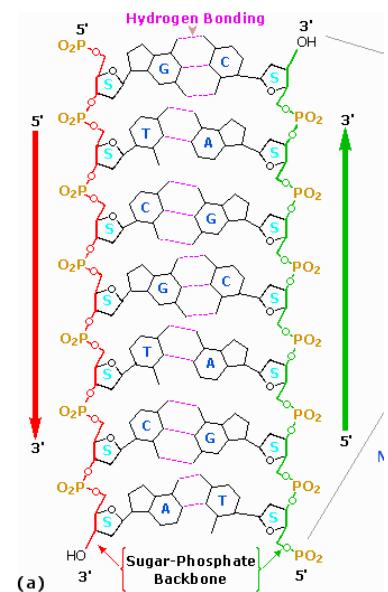
- Determining the gene's functionality and position of the gene in the chromosome is called gene mapping.

### B) DNA (DEOXYRIBONUCLEIC ACID)

- DNA is the hereditary material in humans and almost all other organisms. Nearly every cell in a person's body has the same DNA. Most DNA is located in the cell nucleus (where it is called nuclear DNA), but a small amount of DNA can also be found in the mitochondria (where it is called **mitochondrial DNA or mtDNA**)
- DNA is long polymer of deoxyribonucleotides. I.e. a deoxyribonucleotide is the monomer, or single unit, of DNA, or deoxyribonucleic acid.
- The length of the DNA is usually defined as number of nucleotides (or a pair of nucleotides referred to as base pairs) present in it.
- Human DNA is  **$3.3 \times 10^9$  base pairs**.
- Structure of Polynucleotide Chain**



- A nucleotide has three components - a nitrogenous base, a pentose sugar, (deoxyribose in case of DNA), and a phosphate group.
- There are two types of nitrogenous base.
  - Purines** (Adenine and Guanine)
  - Pyrimidines** (Cytosine, Uracil and Thymine)
- Note: Thymine is only found in DNA and Uracil only in RNA
- DNA bases pair up with each other, A with T and C with G, to form units called base pairs.
- The bases in two strands are paired through hydrogen bond (H-bonds) forming base pairs (bp). Adenine forms two hydrogen bonds with Thymine from opposite strand and vice-versa. Similarly, Guanine is bonded with Cytosine with three H-bonds.
- The structure of double helix is somewhat like a ladder, with the base pairs forming the ladder's rungs and sugar and phosphate molecules forming the vertical sidepieces of the ladder.
- The two chains are coiled in right-handed fashion.



### a) WHAT IS DNA FINGERPRINTING?

- DNA fingerprinting, also called DNA typing, DNA profiling, genetic fingerprinting, genotyping, or identity testing is a method of isolating and identifying variable elements in the base pair sequence of DNA.
- This technique was developed in 1984 by British geneticist **Alec Jeffreys**, after he noticed that certain sequences of highly variable DNA (known as **minisatellites**), which don't contribute to the function of genes, are repeated within genes.
- It was also noticed that each individual has a unique pattern of minisatellites (the only exceptions being multiple individuals from a single zygote, such as identical twins).
- DNA fingerprinting is a technique** that simultaneously detects lots of mini satellites in the genome to produce a pattern unique to an individual. This is a **DNA Fingerprint**.
- How is DNA fingerprint created?**
  - Obtaining a sample of cells:** such as skin, hair, or blood cells which contain DNA.
  - Extract** and purify DNA from these cells.
  - PCR** is used to amplify the desired fragments of DNA many times over creating thousands of copies of the fragments.
  - Once an adequate amount of DNA has been produced using PCR, the exact sequence of nucleotide pairs in a segment of DNA can be determined by using one of several **biomolecular sequencing methods**.

- **Application of DNA Fingerprinting:**
  - **Identification:** It is a forensic technique used to identify individuals/ dead bodies by characteristics of their DNA.
  - **Solving legal disputes:**
    - **Physically connect a piece of evidence to a person** or rule out someone as a suspect.
    - To determine **paternity and other relationships**
  - **Medical applications:**
    - Match tissue of organ donors with those of people who need transplant
    - Identify diseases that are passed down through your family
    - Help find cure for those diseases, called hereditary diseases.
- **Problems:**
  - **Sources of errors:** Sample contamination, faulty preparation procedures, and mistakes in interpretation of results are major sources of error.

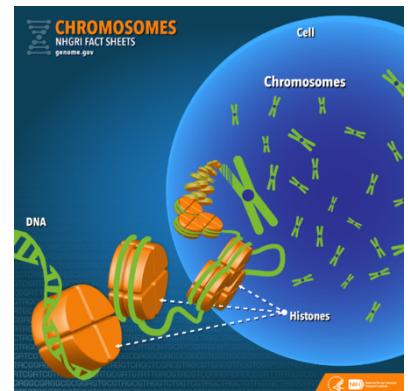
## b) DNA BARCODING

- **DNA Barcoding** is a tool for **rapid species identification** based on DNA sequence. It uses as short section of DNA from a specific gene or genes.
  - The way barcodes on a product, uniquely identifies a commercial product, in the same way, short gene segments – known as **DNA barcodes** – are unique for each species.
  - DNA barcoding has emerged as a global standard for fast and reliable genetic species identification of animals, plants and fungi.
- **Different gene regions are used to identify the different organismal groups using barcoding:**
  - For e.g., for animals (birds, butterflies, fish) and some protists – a short DNA sequence of COI gene found in mitochondrial DNA is used.
  - Similarly, Species identification of land plants is enabled by the combination of two different chloroplast gene regions – matK and rbcL.
  - Fungi species can be determined by the ITS region.
- **The ultimate goal of DNA barcoding is to build a publicly accessible reference database with species-specific DNA barcode sequences.**
- **Various methods of DNA Barcoding:** Barcoding can be done from tissue from a target specimen, from a mixture of organisms (bulk samples), or DNA present in environmental samples (e.g. water or soil). The methods barcoding will differ in each of these cases:

- **Tissue Samples**
- **Bulk Samples:** This sample contains several organisms from the taxonomic group under study.
  - E.g. – Aquatic macroinvertebrate samples collected by kick-net, or insect samples collected with a Malaise trap.
- **eDNA samples:** The environmental DNA (eDNA) method is a non-invasive approach to detect and identify species from cellular debris or extracellular DNA present in environmental samples (e.g., water or soil).
  - The main difference between bulk samples and environmental samples is that the bulk sample usually provides a large quantity of good-quality DNA.
- **Applications of DNA Barcoding:**
  - Identifying plant leaves (even when flowers and fruits are not available)
  - Identifying pollen collected on the bodies of pollinating animals
  - Identifying insect larvae which may have fewer diagnostic characteristics than adults
  - Investigating the diet of an animal based on its stomach content

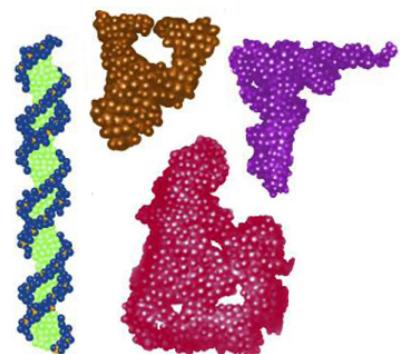
### C) CHROMOSOMES

- In the nucleus of each cell, the DNA molecule is packaged into thread-like structure called chromosomes.
- Each chromosome is made up of DNA tightly coiled many times around protein called histones that support the structure.
- The adjacent figure shows the relation between chromosome and DNA molecule



### D) RNA

- RNA stands for ribonucleic acid. It is a molecule with long chain of nucleotides. A nucleotide contains a nitrogenous base, a ribose sugar, and a phosphate.
- Like DNA, RNA is also vital for living cells.
- **Shape and structure**
  - It comes in a variety of different shapes.
  - Unlike double-stranded DNA, RNA is a single-stranded molecule in many of its biological roles and has a much shorter chain of nucleotides.

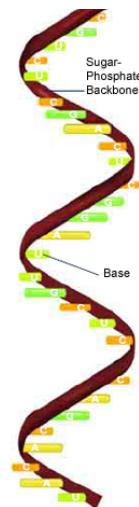


*RNA comes in a variety of different shapes.  
Double-stranded DNA is a staircase-like molecule.  
Image Credit: National Institute of General Medical Sciences*

- However, RNA can, by complementary base pairing, form intra-strand (i.e., single-strand) double helixes, as in tRNA

- **Functions of RNA**

- Carrying **genetic material** in some viruses
- The main job of RNA is to **transfer the genetic code needed for the creation of proteins from the nucleus to the ribosome**. The process prevents DNA from having to leave the nucleus. This keeps the DNA and genetic code protected from damage. Without RNA, proteins could never be made.
- Some RNAs act as enzymes. Such RNA enzymes are called ribozymes and they exhibit many of the features of a classical enzyme.



*Ribonucleic acid (RNA) has the bases adenine (A), cytosine (C), guanine (G), and uracil (U). Image Credit: National*

- **mRNA, rRNA, and tRNA**

- RNA is central to protein synthesis.
  - First a type of RNA called messenger RNA (mRNA) carries information from DNA to structure called ribosomes.
  - These ribosomes are made from proteins and ribosomal RNA (rRNAs).
  - These all come together and form a complex that can read messenger RNAs and translate the information they carry into proteins. This requires the help of transfer RNA or tRNA.
- RNA is formed from DNA by a process called transcription. This uses enzymes like RNA polymerase.
- **Transcriptome** is the set of all messenger RNA molecules in one cell or a population of cells.
  - Because transcriptome includes all mRNA transcripts in the cell, the transcriptome reflects the genes that are being actively expressed at any given time.

**Biotechnology makes it possible to move gene which is responsible for some particular feature from one organism to another.**

### a) RNA INTERFERENCE TECHNOLOGY

- » RNA Interference Technology (RNAi) is a biological process in which RNA molecules inhibit gene expression or translation, by neutralizing targeted mRNA molecules.
- » It is also known as **co-suppression, post-transcriptional gene silencing (PTGS), and quelling**.
- » Here mechanisms are developed to degrade mRNA molecules. This decreases their activity by preventing translation, via gene silencing.
- » **Functions/Applications**
  - » RNA interference is a vital part of the immune response to viruses and other foreign genetic material, especially in plants where it may prevent the self-propagation of transposons.

- » RNA interference has an **important role** in defending cells against parasitic nucleotide sequences – virus etc.
- » It can be useful to **study the function of a gene** in experimental biology in cell culture.

### 3. TWO CORE TECHNIQUES THAT ENABLED BIRTH OF MODERN BIOTECHNOLOGY ARE:

#### 1) GENETIC ENGINEERING

- » Technique to alter the chemistry of genetic material (DNA and RNA), to bring about desired modifications into host organisms and thus change the phenotype of the host organisms.  
Jelly fish glow at night. If we want other living organism to glow at night, we can extract the gene which is responsible for this glow and put it in the new host organism.
- » **Advantage of genetic engineering over traditional hybridization process**
  - » Traditional hybridization processes -> can lead to inclusion and multiplication of undesirable genes along with desired genes.
  - » Genetic engineering solves the above problem by isolating and introducing only one or a set of desirable genes without introducing undesirable genes.

#### 2) MAINTENANCE OF STERILE (MICROBIAL CONTAMINATION-FREE) AMBIENCE IN CHEMICAL ENGINEERING PROCESS

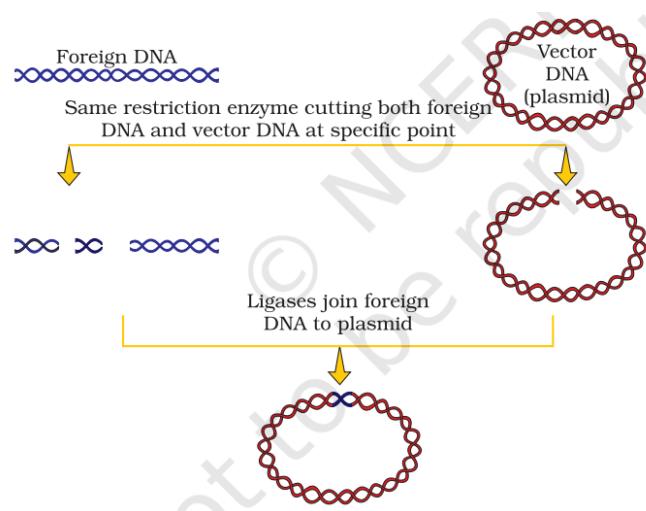
- » To enable growth of only the desired microbe / eukaryotic cell in large quantities for the manufacture of biotechnological products like antibiotics, vaccines, enzymes etc

### 4. TOOLS OF RECOMBINANT DNA TECHNOLOGY

Genetic engineering or recombinant DNA technology can be accomplished only if we have key tools, i.e., **restriction enzymes, polymerase enzymes, ligases, vector and the host organisms.**

#### 1) RESTRICTION ENZYMES

- A restriction enzyme or restriction endonuclease is an enzyme that cuts DNA at a near specific recognition nucleotide sequence known as restriction sites.
  - To cut DNA, all restriction enzymes make two incisions, once through each sugar-phosphate backbone (i.e. each strand) of the DNA double helix.



- **Restriction endonuclease** are used in genetic engineering to form 'recombinant' molecule of DNA, which are composed of DNA from different sources/genomes.
- When cut by same restriction enzyme, the resultant DNA fragments have the same kind of 'sticky-ends' and, these can be joined together (end-to-end) using **DNA ligases**.

## 2) CLONING VECTOR

- They are used to transfer the foreign DNA to host DNA.
- Vectors used at present are engineered in such a way that they help easy linking of foreign DNA.

## 3) DNA LIGASE

- » It is a specific type of enzyme, a ligase that facilitates the joining of DNA together by catalyzing the formation of a phosphodiester bond.

## 4) HOST ORGANISMS

- The organism where the gene would be inserted.
- Techniques such as micro-injection are used. Here recombinant DNA is directly injected into nucleus of an animal cell.
- In other methods suitable for plants, the cells are bombarded with high velocity microparticles of gold or tungsten coated with DNA in a method known as **biolistic or gene gun**.
- Another method is using 'disarmed pathogen' vectors, which when allowed to infect the cell, transfer the recombinant DNA into the host.

## 5. CRISPR-CAS9

- What is **(CRISPR/CAS9)**?
  - CRISPR-CAS9 is a new genome editing tool, which is simpler, faster, cheaper, more versatile and more accurate than the previous techniques of editing DNA and has wide range of potential applications.
  - **Background: The inspiration for CRISPR:**
    - The inspiration of developing CRISPR CAS9 came from the **CRISPR system used by several bacteria** to fight against bacteriophages.
    - CRISPR (Clustered Regularly Interspaced Short Palindromic Sequence) are short DNA sequences found in the genome of Prokaryotic organisms such as bacteria, which are reminders of various bacteriophage (virus) attacks that the bacteria successfully defended against. Cas9 enzyme (part of the bacteria's defence mechanism) uses these

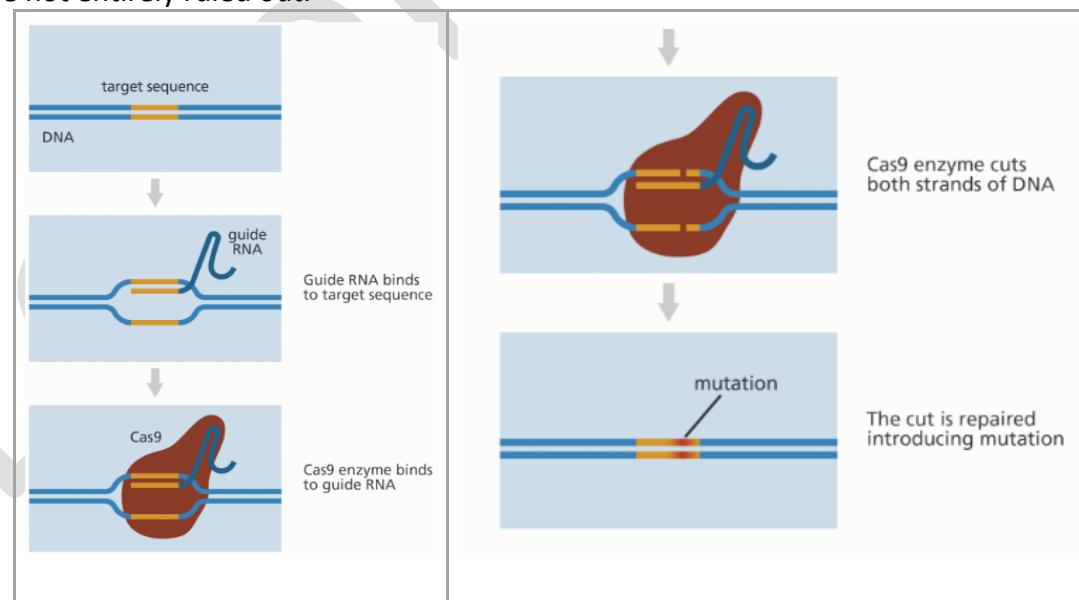
flags to precisely target and cut any foreign DNA, thus protecting the bacteria from future attacks by similar bacteriophages.

- Emmanuelle Charpentier of France and Jennifer Doudna of the US won the Nobel Chemistry Prize in 2020 for developing CRISPR-Cas9. This was the first time a Nobel Science prize has gone to a women-only team.

**NOTE:** Prof. Charpentier, 51, and Prof. Doudna, 56, were just **the sixth and seventh women to receive the Nobel Prize in Chemistry.**

- **How does CRISPR-CAS9 work? (Clustered Regularly interspaced short palindromic repeats)**

- [https://www.youtube.com/watch?v=UKbrwPL3wXE&ab\\_channel=MayoClinic](https://www.youtube.com/watch?v=UKbrwPL3wXE&ab_channel=MayoClinic)
- The first task is to identify the particular sequence of genes that is cause of problem and thus have to be deleted.
- Once this is done, an RNA molecule (called guideRNA) is programmed to locate this sequence of DNA stand, just like the 'find' or 'search' function of a computer.
- After this, a special protein called Cas9 (CRISPR associated Protein 9), which is often described as 'genetic scissors / molecular scissors', is used to break the DNA strand at specific points so that bits of DNA can then be added or removed.
  - A DNA strand, when broken, has a natural tendency to re-attach and heal itself. But if the auto-repair mechanism is allowed to continue, the bad sequence can regrow. So, scientists intervene during the auto-repair process by supplying the correct sequence of genetic codes, which attaches to the broken DNA strand.
- The entire process is programmable, and has remarkable efficiency, though chances of error are not entirely ruled out.



- **Applications of CRISPR-CAS9**

- The technology has had a **revolutionary impact** on life science.

- Its applications include:
  - **Curing diseases genetic in nature** – i.e., the diseases are caused by unwanted changes or mutations in genes. These include common blood disorders like sickle cell Anaemia, eye diseases including color blindness etc.
  - **Deformities arising out of abnormalities in gene sequences** – like stunted or slow growth, speech disorders, or inability to stand or walk can also be treated by CRISPR.
  - **Developing GM crops and animals.**
    - For e.g., Japan has already approved the commercial cultivation of a tomato variety that has been improved using CRISPR-based intervention.
    - In India, several research groups are working on CRISPR-based enhancements for various crops including rice and banana.

- **Limitation**

- **Potential of misuse:** (bioterrorism; designer babies)
- **Collateral Damage (Knock-on Effect):**
- **Ethics of CRISPR** – Should humans be allowed to modify how the nature works?

#### 4) HOW GENE THERAPY USING CRISPR CAN CURE CANCER (DEC 2022: SOURCE THE HINDU)

- **What is T-cell acute lymphoblastic leukaemia (T-ALL)**
  - It is a type of cancer where the T-cells, which are a class of white blood cells, equipped to hunt and neutralize threats to the body, turn against the body and end up destroying healthy cells that normally help with immunity. The disease is rapid and progressive and is usually treated by chemotherapy and radiation therapy.
- **How gene therapy treated this?**
  - Alyssia, a teenage girl, had tried several of the standard treatments including chemotherapy and radiation. But the treatment wasn't successful.
  - Then she enrolled in an experimental trial conducted by doctors and scientists at the University College, London and Great Ormond Street Hospital. She was the **first patient to receive experimental gene therapy that relied on a new technique called 'base-editing'**.
  - **What is base editing?**
    - When a misarrangement in the sequence of nitrogen bases (ATCG) is edited to arrange it properly, it is called base editing. David Liu, of the Broad Institute, Massachusetts has improvised on the CRISPR-cas9 to be able to directly change certain bases: thus, a C can be changed into G and T into an A. While still a nascent technology, **base editing is reportedly more effective at treating blood disorders**

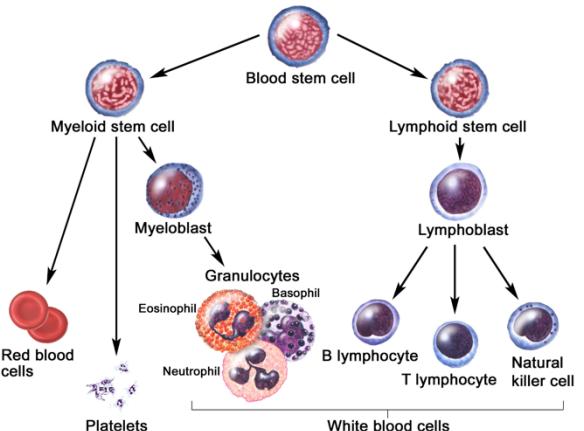
which were caused by so-called single point mutations, or when a change in a single base pair can cause terminal disease.

- Alyssia's case:

- In Alyssia's case, her T-cells – perhaps because of a misarrangement in the sequence of bases – had become cancerous. The objective of the gene therapy in the case of T-cell leukemia was to fix her immune system in a way that it stops making cancerous T-cells.
- First, healthy T-cells were extracted from a donor and put through a series of edits.
  - The first base edit blocked the T-cells targeting mechanism so it would cease attacking Alyssia's body.
  - The second removed a chemical marking, called CD7, which is on all T-cells.
  - Third prevented the T-cells from being killed by a chemotherapy drug.
  - Finally, the T-cells were programmed to destroy all cells – cancerous or protective – with CD7 marked on it.
  - After spending a month in remission, she was given a second donor transplant to regrow her immune system that would contain healthy T-cells.
- How effective was the treatment?
  - Her cancer doesn't seem to have re-surfaced.
- More verification needed:
  - It has been 1.5 years since she was first diagnosed with the disease and whether the treatment has reliably and entirely fixed her immune system, remains to be established.

#### A) UNDERSTANDING T-CELLS IN MORE DETAILS

- T cells are a type of white blood cells. They are part of immune system and develop from **hematopoietic stem cells** (blood stem cells) present in bone marrow. They help protect body from infection and may help fight cancer. They are also called T Lymphocyte and thymocyte.
- After getting born from blood stem cells, they migrate to thymus gland to develop. T-cells derive their name from the thymus. In thymus, the precursor cells mature into several distinct type of T cells. This differentiation continues after they have left the thymus.



- One of the important functions of T-cells is immune mediated cell death – it is carried out by two major subtypes – CD8+ “Killer” and CD4+ “helper” T cells. These are named for the presence of the cell surface proteins CD8 and CD4.
- T cells, also known as “Killer T-cells”, are cytotoxic – this means that they are able to directly kill virus-infected cells, as well as cancer cells.
- T-cells can be distinguished from other lymphocytes by the presence of a T-cell receptor (TCR) on their cell surface.

## 6. DARK DNA – CLASS DISCUSSION

## 7. SOMATIC CELL NUCLEAR TRANSFER

- In genetics and developmental biology, somatic cell nuclear transfer (SCNT) is a **laboratory technique for creating an ovum with a donor nucleus.**
  - In SCNT the nucleus, which contains the organism's DNA, of a somatic cell (a body cell other than a sperm or egg cell) is removed and the rest of the cell discarded.
  - At the same time, the nucleus of an egg cell is removed.
  - The nucleus of the somatic cell is then inserted into the unnucleated egg cell.
  - After being inserted into the egg, the somatic cell nucleus is reprogrammed by the host cell.
  - The egg, now containing the nucleus of a somatic cell, is stimulated with a shock and will begin to divide.
  - **After many mitotic divisions in culture**, this single cell forms a blastocyst (an early stage embryo with about 100 cells) with almost identical DNA to the original organism

It can be used in embryonic stem cell research, or in regenerative medicine where it is sometimes referred to as "therapeutic cloning." It can also be used as the first step in the process of reproductive cloning.

## 8. APPLICATIONS OF BIOTECHNOLOGY

### 2) GM CROPS

- **GM Crops, Advantages and Controversies**

- Crops whose DNA has been altered are known as GM crops. This genetic modification of crops can add or remove certain characteristics from the plant and thus can bring many advantages.
  - Make crops **more tolerant to anti-biotic stresses** (cold, drought, salt, heat) etc.
    - E.g., GM Rubber developed by Rubber Research Institute of India
  - Make plants **Pest Tolerant**.
    - Reduces reliance on chemical pesticides.
    - E.g. BT cotton, BT Brinjal (in Bangladesh)
  - Help to **reduce post-harvest losses**
  - Enhance the **nutritional value** of food, e.g., Golden Rice (Vitamin A enriched rice)
  - Tailor-made plants to supply **alternative resources** to industries, in the form of starches, fuels, and pharmaceuticals.

#### A) BT COTTON

- Specific BT Toxic gene (*cry1Ac*) were isolated from *Bacillus thuringiensis* and incorporated into several crop plants such as cotton. This produces proteins that kill certain insects such as lepidopterans (tobacco budworm, armyworm), beetles, etc.
- It has been grown in India since 2002 and over the years have given increase productivity and area under crop cultivation. It has also led to decrease in insecticide which fought bollworms by 97%.
- **Note:** **Bollgard® Bt Cotton** (single gene technology) is India's first biotech crop technology approved for commercialization in 2002, followed by Bollgard® II – double gene technology in mid-2006, by the GEAC.
  - **Bollgard® cotton** provides in-built protection for cotton against destructive American Bollworm *Heliothis Armigera* infestations, and contains an **insecticidal protein from a naturally occurring soil microorganism, Bacillus thuringiensis (Bt)**.
  - Bollgard® II technology contains a superior double-gene technology - Cry1Ac and Cry 2Ab which provides protection against bollworms and *Spodoptera caterpillar*, leading to better boll retention, maximum yield, lower pesticides costs, and protection against insect resistance.
  - Both, Bollgard® II and Bollgard® insect-protected cotton are widely planted around the world as an environmentally friendly way of controlling bollworms.
- But it has also raised concerns like increased water consumption, and emergence of pesticide resistant pests (e.g., pink bullworm), and increased use of insecticide for controlling pests like sucking pests.

#### B) BT BRINJAL

- Transgenic Brinjal created by inserting a **crystal protein gene (Cry1Ac)** from the soil bacterium Bacillus thuringiensis into the genome of various brinjal cultivar. It gives resistance against lepidopteron insects in particular the Brinjal fruit and shoot border (BFSB), the most common pest which affects 30-50% of the Brinjal crops.
- The crop also cleared the GEAC's biosafety test in 2009. But, government yielded to anti-GM activists and declared a moratorium in 2010 on the crop.
- But some cases of illegal BT Brinjal cultivation was observed in Haryana in 2019
  
- **Why are some groups are calling for allowing of BT Brinjal in India?**
  - It had cleared the GEAC's biosafety test in 2009.
  - **Increased benefit for farmer**
  - When GM Crops are not officially available, farmers turn to **unapproved knock offs** that may not conform to accepted biosafety standards.
  
- **Why is BT Brinjal not allowed in India? Why is it opposed by various activists?**
  - There are fears that it may **impact India's plant biodiversity**.
  - Further, **cross pollination** may lead to **herbicide resistant super weeds** that can further threaten environment and biodiversity.
  - **Health Impact** is something that needs to be studied more.
  - **Not so obvious benefits:** A recent study from surveys of farmers indicate that 2/3<sup>rd</sup> of the farmers who moved to BT Brinjal have had a 'bad' or 'very bad' experience.

### C) GM MUSTARD

- **What is GM Mustard?**
  - DMH-11 (Dhara Mustard Hybrid) is a genetically modified (GM) mustard Hybrid.
  - GM mustard is the country's first genetically modified food crop.
  - It was developed by a team of scientists led by former Vice Chancellor Deepak Pental, of DU at Center for Genetic Manipulation of Crop Plants (CGMCP), Delhi University by crossing Indian mustard cultivars with juncea lines of East European origin like 'Early Heera' and Donskaja.
  
- **Claim of higher yield:**
  - Claims around 30% more yield than the traditional varieties
  
- **What genetic modification was achieved and what are its benefit?**
  - **Barnase gene and Barster gene** from *Bacillus amyloliquefaciens*
    - Barnase impairs pollen production

- Barster blocks the function of Barnase
  - Hybridization becomes possible:
    - This method was used to developed DMH-11 by crossing a popular Indian mustard variety 'Varuna' (the barnese line) with an East European 'Early Heera-2' mutant (barstar).
- **Arguments for and against approval of GM mustard**
- » **For**
    - **Higher Production**
    - **Reducing Import Dependency**
    - **Saving Forex**
    - **Keeping India Scientifically relevant**
  - » **Against**
    - The main contention is that the GM mustard incorporates three alien genes - barnase, barstar, and bar - rendering it inherently unsafe for human and animal health.
      - But these genes have already been deployed in Canola, and we import it freely.
    - Mustard is a food crop unlike cotton, so both should not be compared
    - All health effects not properly known yet
    - Environmental damages should be studied properly first.
    - Yield claims have been challenged by many organizations
  - » **GEAC Approval (Oct 2022)**
    - In Oct 2022, GEAC approved commercial cultivation of genetically modified mustard yet again. The approval allowed environmental release of two varieties of genetically engineered mustard, so that it can be used for developing new parental lines and hybrids under the supervision of ICAR. The environmental release of DMH-11 will allow for its seed production and testing as per existing ICAR guidelines and other extant rules/ regulations prior to commercial release. The field demonstration studies on the effect of GE mustard on honeybees and other pollinators was also allowed to be conducted.

#### **D) GM RUBBER – DEVELOPED BY KERALA BASED - RUBBER RESEARCH INSTITUTE OF INDIA**

- Rubber Research Institute of India have developed a plant tailored for the climatic conditions in the Northeast.
- Rubber board research farm at Sarutari on the outskirts of Guwhati now sports world's first GM rubber plant, tailored for climatic condition in the north-east.

- **Genetic Modification:** The GM rubber has additional copies of the gene MnSOD, or manganese-containing superoxide dismutase, inserted in the plant, which is **expected to tide over the severe cold conditions during winter** – a major factor affecting the growth of young rubber plants in the region

## E) INCREASING THE NUTRIENT CONTENT – GOLDEN RICE

### ▫ Golden Rice

#### - What is Golden Rice?

- The IRRI and its national research partners have developed golden rice to complement existing interventions to address vitamin A deficiency (VAD). It is a serious public health problem affecting millions of children and pregnant women globally.
- Golden rice is variety of rice produced through genetic engineering to biosynthesize beta-carotene. Beta-carotene is a nutrient similar to what is found in orange colored fruits and vegetables and is converted into Vitamin-A as needed by the body.
- Thus, golden rice can help south and south-east Asian countries, where two-thirds or more of daily calorific intake is obtained from rice. Research has indicated that the golden rice can provide upto 50% of the daily requirement of an adult for vitamin A.



- Golden rice was one of the 7 winners of the 2015 Patents for Humanity Awards by the United States Patent and Trademark Office
- **Safety Evaluation by International Rice Research Institute**
  - The safety evaluation of Golden rice has shown that it is as safe and nutritious as conventional rice but comes with added benefit of beta-carotene.
- **About International Rice Research Institute:**
  - IRRI is the world's premiere research organization dedicated to reducing poverty and hunger through rice science; improving the health and welfare of rice farmers and consumers; and protecting the rice growing environment for future generation.
  - It is an independent, non-profit, research and educational institute, founded in 1960 by the Ford and Rockefeller foundations with support from the Phillipines government.
  - The institute is headquartered in Los Banos, Philippines and has offices in 17 rice-growing countries in Asia and Africa.
  - It works with in-country partners to develop advanced rice varieties that yield more grain and better withstand pests and disease as well as flooding, drought, and other harmful effects of climate change.

---

#### F) ISSUE OF ILLEGAL CULTIVATION OF GM CROPS:

- **BT Brinjal** Illegal cultivation in Haryana Rajasthan etc.
- **Sale of Illegal HTBt (Herbicide tolerant Bt) cotton seeds** has doubled this year(June 2021)
  - The HTBt cotton variant adds another layer of modification to BT cotton, making the plant resistant to the herbicide glyphosate, but has not been approved by regulators.
  - **Support for HTBt:** Groups like Shetkari Sangathan are demanding the legalization of HTBt cotton.
    - **Saves cost:** Weeding labour cost reduces, only one round of glyphosate spraying is needed to deal with the weed.
    - **Illegal sales** reduce accountability, hampers government revenue and farmers are at risk of getting wrong information.
  - **Concerns/Fears:**
    - Glyphosate have carcinogenic effect
    - Unchecked spread of herbicide resistance to nearby plants through pollination, creating a variety of superweeds etc.

---

#### G) SCIENTISTS ARE ENGINEERING PLANTS TO PRODUCE INSECT 'SEX PERFUME' TO REPLACE PESTICIDES (APRIL 2023)

- Researchers are engineering tobacco plants to produce moth pheromones that could potentially be used to create traps that can lure insects as a replacement for harmful pesticides.
- **Note:** Pheromones are chemicals that are produced and released by animals. When they are released by an individual of a species, they effect the behaviour of other individuals. Animals secrete these pheromones to trigger different kinds of behaviour. The pheromones that trigger sexual arousal can be thought of as a kind of 'sex perfume', attracting other individuals of the same species.
- The researchers engineered plants to produce chemicals that mimic these pheromones.
- **Note:**
  - Chemically produced insect pheromones are already used for pest control and have been for some decades. Some insect traps contain pheromones to attract the insect to them, for use in the house garden, and in food production systems.
  - **Disadvantages of these chemically produced pheromones:** It is not possible to make complex pheromones by this mechanism. Moreover, chemical manufacturing process produces a number of other pollutants.
- **GM Crop Route:**
  - Researchers used Nicotiana benthamiana, a species of tobacco.
  - Note: The same plant has been engineered to produce ebola antibodies and even coronavirus like particles for use in COVID vaccine.

- Here, scientists built a sequence of DNA in the lab that mimic moth's genes and also put in place a few molecular switches that can precisely regulate how the molecules are formed. The switches can turn the manufacturing process on and off.
- **Advantages of using pheromones:** They are highly species specific and unlike broad spectrum pesticides don't kill other species of pollinators.

### 3) REDUCED HEIGHT GENES (RHT): ADVANTAGES AND LIMITATIONS

#### Introduction

- Since the 1960s and the Green Revolution, **reduced height (Rht) genes have increased global yields** because the short-stemmed wheat they produce puts more investment into the grains rather than into the stems and has improved standing ability. It leads to reduced risk of lodging, increase in partitioning and assimilation of grains, more fertile florets per spriglet and higher harvest index (the proportion of plant weight in grains).
- The high yielding wheat variety developed by **Borlaug**, which required higher use of fertilizers and pesticides, produced bigger grains. However, the heavier grains caused the plants to become unstable and prone to lodging. Therefore, **Borlaug introduced dwarfing genes** into wheat giving plants a stronger, shorter stem that resisted lodging.
  - 21 reduced height genes** in wheat Rht1 – Rht21, have been described so far.
  - In India, the presently available semi-dwarf varieties, which were explored during the Green Revolution, carry conventional Rht1 dwarfing alleles (variant form of a given gene) and produce optimum yields under high-fertility irrigated conditions.
- **Limitations of Dwarf wheats:**
  - Dwarf wheats are not well adapted to deeper sowing conditions. This is due to shorter coleoptiles, and low early vigor often results into reduced seedling emergence. Further shorter coleoptiles lead to crop residue posing a problem for seedling emergence.
  - These wheats also don't work in drought conditions they can't be planted deep inside the soil to access moisture. They will fail to reach the surface of the soil.
- **Key Research to solve the issue:**
  - Scientists at Agharkar Research Institute (ARI), an autonomous institute of DST, have mapped to alternative dwarfing genes of Rht14 and Rht18. These genes are associated with better seedling vigor and longer coleoptiles (sheath protecting the young shoot tip).
  - **Advantages:**

- a) The new wheat variety will be suitable for sowing under rice stubble retained condition and in **dry environments**. It would thus reduce the need of water and also contribute to reduction in crop stubble burning.
  - b) It also diversifies the genetic base of dwarfing genes considering diverse wheat growing zones in India.
2. Recent research published in the *Proceedings of the National Academy of Sciences (PNAS)* journal on 23<sup>rd</sup> Nov 2022 says that Scientists at the John Innes Centre, in collaboration with an international team of researchers, have discovered **the new “reduced height” or semi dwarf gene called Rht13**. The varieties of wheat with Rht13 gene could be rapidly bred into wheat varieties to enable farmers to grow reduced-height wheat in **drier soil conditions**.
- Rht13** overcome this problem of seedling emergence because the **gene acts in tissues higher-up in the wheat stem**. So, the dwarfing mechanism only takes effects once the seedling has fully emerged. This gives farmers a significant advantage when planting deeper in dry conditions.

### 3) BIOTECHNOLOGICAL APPLICATION IN MEDICINES

The recombinant DNA technological processes have had a great impact in the area of health care by enabling mass production of safe and more effective therapeutic drugs.

- Further, the recombinant therapeutics do not induce unwanted immunological responses as is common in case of similar products isolated from non-human sources.
- At present, more than 30 recombinant therapeutics have been approved for human-use the world over.
  - In India, around 12 of these are presently being marketed.

---

#### A) VACCINES (COVERED SEPARATELY WITH HEALTH SECTION)

- For e.g., various vaccines for COVID-19 were developed with the help of biotechnology – mRNA vaccines, vaccines with attenuated virus

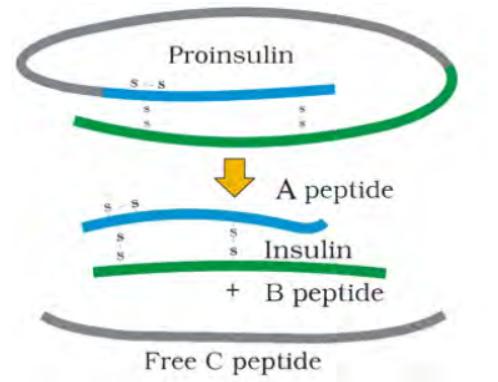
---

#### B) MASS PRODUCTION OF EFFECTIVE THERAPEUTICS

- The recombinant DNA technological processes have had a great impact in the area of health care by enabling mass production of safe and more effective therapeutic drugs.
- **Advantages of recombinant therapeutics:** Further, the recombinant therapeutics do not induce unwanted immunological responses as is common in case of similar products isolated from non-human sources.
- At present, more than 30 recombinant therapeutics have been approved for human-use the world over.
- In India, around 12 of these are presently being marketed

### C) GENETICALLY ENGINEERED INSULIN

- Earlier, Insulin used for diabetes was extracted from pancreas of slaughtered cattle and pigs.
  - » Caused patients to develop some kind of allergies or other kinds of reactions to the foreign protein.
- Structure of Insulin
  - » Insulin consists of two short polypeptide chains: Chain A and Chain B, that are linked together by disulphide bridges.
  - » In Mammals, including humans, insulin is synthesized as a pro-hormone (like a pro-enzyme, pro hormone also needs to be processed before it becomes a fully mature and functional hormone) which contains an extra stretch called C peptide.
  - » This C peptide is not present in the mature insulin and is removed during maturation into insulin.



- The main challenge for production of insulin using rDNA technique was getting insulin assembled into a mature form.
- How this was achieved through Biotechnology
  - 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 disulphide bonds to form human insulin.

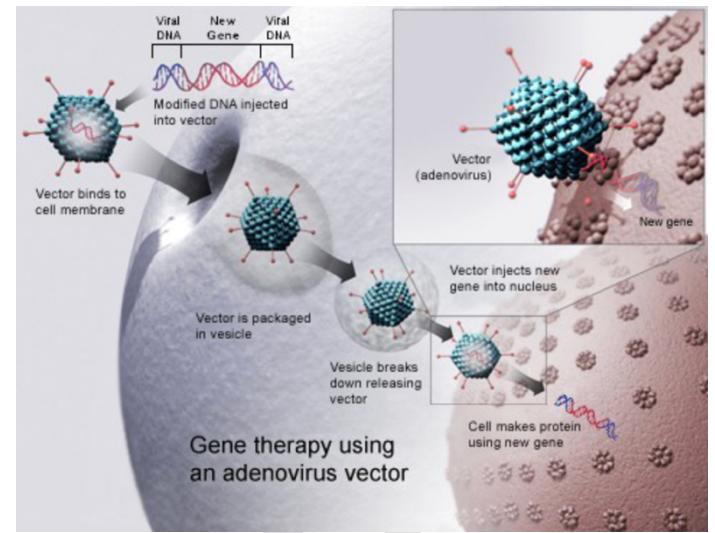
### D) GENE THERAPY

#### - Introduction

- » If a person is born with a hereditary disease, can a corrective therapy be taken for such disease? Gene therapy is an attempt to do this.
- » Gene therapy refers to the process of introduction, removal or change in the content of an individual's genetic material with the goal of treating the disease and a possibility of achieving long term cure.

» **Gene Therapy Products (GTPs)** include the mechanisms to deliver nucleic acid components by various means for therapeutic benefit to patients. They include entities that are used for things like gene augmentation, gene editing, gene silencing, synthetic or chimeric gene augmentation etc.

- **Note:** Not all medical procedures that introduce alterations to a patient's genetic makeup can be considered a gene therapy. For e.g.: Bone Marrow transplantation and organ transplants in general have been found to introduce foreign DNA into patients.



#### - Advantages of promoting gene therapy

- **Permanent result may be a possibility:**
- **High burden of rare genetic diseases in India:** Around 7 crore of India's population suffers from rare genetic diseases. Gene therapy can prove to be a turning point in treatment of such genetic diseases.
- **Worldwide market for the gene therapy products** is expected to go to \$250 billion by 2025.

#### - Concerns/Limitations

- Promotion of development of gene therapy also brings along with it unique technical risks and ethical challenges.
- **Technical Challenges**
  - The gene therapy may be associated with **unwanted immune system reactions**. For e.g., when vectors (viruses) are attacked by the immune system of the body.
  - Current gene therapy mechanisms can sometimes **target the wrong cells**.
  - **The delivery viruses may mutate** and become harmful.
- **Ethical Challenges**
  - For e.g. creation of GM babies using germline gene editing by a Chinese scientist attracted global criticism and fueled debate on ethical concerns regarding applications of gene therapy technologies.
  - **Playing god** debate.

#### - National Guidelines for Gene Therapy Product Development and Clinical Trials – Released by ICMR in Dec 2019: Key Highlights

- » The guidelines are **aimed** at ensuring that **gene therapies are introduced in India** and **clinical trials for gene therapy can be performed in an ethical, scientific and safe manner.**
- » They provide the **general principles for developing gene therapy products (GTPs)** for any **human ailment and provide a framework** for all areas of GTP production including **pre-clinical testing, clinical administration, human clinical trials, as well as long term follow up.** These must follow the established general principles of biomedical research.
- » They **apply to all stakeholders** involved in the field of gene therapy including **researchers, clinicians, oversight/regulatory committees, industry, patient support groups and any other involved in GTP development** or their application in humans and their derivatives.
- » The guidelines will serve as a **roadmap** for those in the field trying to develop gene and cell **therapies** and will thus **contribute to accelerating the development** of advanced therapeutic options
- ICMR has also proposed setting up of **task force to promote gene technology research in the country.**

#### a) CAR-T CELL THERAPY

- **Why in news?**
  - The CDSCO has granted **market authorization for NexCAR19**, India's first indigenously developed CAR-T cell therapy, to ImmunoACT (Nov 2023)
- **Background: How Cancer has been treated before CAR T-Cell Therapy:**
  - **Surgery** (removing the cancer)
  - **Radiotherapy** (delivering ionizing radiation to the tumour)
  - **Systematic Therapy** (administering medicines that act on tumour)
    - The **earliest form** of systematic therapy was **chemotherapy**. It **preferentially acts on cancer cells** because of the latter's rapid, unregulated growth and poor healing mechanisms. These drugs have **modest response rate** and **significant side effects** as they effect numerous cell types in the body.
    - 
    - The next stage in its evolution was **targeted agents** a.k.a. **immunotherapy**: The drugs bind to **specific target on the cancer or in the immune cells** that help the tumour grow or spread. This method often has **less side effects** as the impact on non-tumour cells is limited. However, it is **effective only against tumours that express these targets.**
- **CAR-T Cell Therapy** has emerged as a **new development in this front.**
  - It is a revolutionary therapy that **modifies immune cells**, specifically T-Cells, by **turning them into potent cancer fighters known as CAR-T Cells.**
  - **How it works?**
    - In CAR T-cell therapy, **the patient's blood is drawn to harvest T-cells** – immune cells that play a major role in **destroying tumour cells.**

- Researchers modify these cells in the laboratory so that they express specific proteins on their surface, known as **chimeric antigen receptors** (CAR): they have an affinity for proteins on the surface of tumour cells. This modification in the cellular structure allows CAR T-cells to effectively bind to the tumour and destroy it.
- These modified cells are then infused back into the patient's blood stream after conditioning them to multiply more effectively.
- The cells are even more specific than targeted agents and directly activate the patient's immune system against cancer, making the treatment more clinically effective. This is why they are called '**living drugs**'.
- **Advantages of CAR-T Cell therapy over other Cancer fighting methods:**
  - It is very accurate and only targets cancer cells.
  - It makes the treatment easier with onetime therapy (unlike several sessions of chemotherapy)
  - It can also fight non-responsive cancer patients.
  - It is designed to cure and provide lifelong benefits.

- **Where is it being used today?**

- CAR T-cell therapies are approved for **Leukaemias** (cancers arising from the cells that produce white blood cells) and **Lymphomas** (arising from the lymphatic system)
- It is also being used among patients with cancers that have returned after an initial successfully treatment or which haven't responded to previous combinations of chemotherapy or immunotherapy.

- **CAR T-Cell Therapy in India:**

- The first major clinical trial showing they were effective was published almost a decade ago. The first indigenously developed therapy in India was successfully performed only in 2021.
- **In Oct 2023, the Central Drugs Standard Control Organization (CDSCO) granted market authorization for **NexCAR19**, India's first indigenously developed CAR-T cell therapy, to **ImmunoAct**, a company incubated by IIT Bombay. This paves the way for commercial launch of this therapy in India.**
  - It is designed to target cancer cells that carry the CD19 protein. This protein acts like a flag on cancer cells, which allows CAR-T cells to recognize and attach themselves to the cancer cells and start process of elimination.
  - **Who can get the NexCAR19 therapy?**
    - The therapy is for people with B-Cell lymphomas who didn't respond to standard treatments like chemotherapy, leading to relapse or reoccurrence of the cancer.
    - **B-Cell leukaemia is most common among children. Are they also eligible?**
      - » For now, therapy's approval is only for patients aged 15 years and above.
      - » The pediatric trial phase is currently underway at the **Tata Memorial Hospital**, in collaboration with IIT-Bombay.

- **Significance:**
  - India is one of the first developing country to have its own Car-T therapy. Even some developed nations don't have their own CAR-T therapies and they import from USA or Europe.
  - This reduces the cost of treatment to about 1/10<sup>th</sup> of the cost abroad and has the potential of boosting medical tourism in India. It costs around Rs 3.3 crores abroad while in India it will cost somewhere between 30-40 lakh rupee.
  - Lab and animal studies have shown that **NexCAR19** lead to significantly lower drug-related toxicities. For e.g., it causes minimal damage to neurons and the central nervous system, a condition known as neurotoxicity. The therapy also leads to minimal Cytokine Storm Syndrome (CRS), which is characterized by inflammation and hyperinflammation in the body due to the death of a significant number of tumour cells, as CAR-T cells are designed to target and eliminate cancer cells.

---

#### b) WHAT IS B-CELL LYMPHOMA

- B-Cell Lymphoma is a form of cancer that starts in a white B-cell called a **Lymphocyte**. B-Cell Lymphocytes make antibodies, the proteins in the immune system that help fight infections. They are often found in lymph nodes or other lymphoid tissues such as the spleen.
- **In B-Cell Lymphoma**, some lymphocytes are no longer healthy and don't fight infections. Instead, they grow out of control, crowding out the normal cells and causing the Lymph nodes to get bigger.

---

#### c) GENE THERAPY TO TREAT SICKLE CELL ANAEMIA AND THALASSEMIA (NOV 2023) (WILL BE COVERED WITH HEALTH BOOKLET)

---

#### d) PFIZER'S HEMOPHILIA B GENE THERAPY SUCCEEDS IN LATE-STAGE STUDY (DEC 2022: SOURCE – THE HINDU)

- **About Haemophilia B:**
  - It is a hereditary bleeding disorder. It hampers body's ability to make a blood-clotting protein called factor IX.
  - **What happens when you bleed?**
    - At the time of bleeding, a series of reactions take place in the body that helps blood clots to form. This process is called coagulation. It needs various proteins called coagulation, or clotting factors. A person has higher chances of bleeding if one or more of these factors are missing and are not functioning like they should.
    - **Factor IX (nine)** is one such coagulation factor. **Haemophilia B** is the result of the body not making enough factor IX. It is caused by an inherited X-linked recessive trait, with the defective gene located on the X chromosome.
  - **Most people with haemophilia B are male.** (Reason – Class discussion)

- **Pfizer's haemophilia B gene therapy succeeds in late-stage study:**
  - The study showed that a single dose of the therapy was superior to the current standard of care in helping reduce the bleeding rate in patients with moderately severe to severe forms of haemophilia B.
  - Pfizer's therapy, fidanacogene elaparovec, is designed to help patients produce factor IX themselves after a one-time treatment, as opposed to current treatments, which focus on regular infusions of the protein.
- **Pfizer is also testing other experimental gene therapies in late-stage trials as potential treatments for the bleeding disorder haemophilia A and muscular disorder Duchenne muscular dystrophy.**

---

#### e) NOTE: HAEMOPHILIA A

- It is also called factor VIII(8) deficiency or classic haemophilia. It is a genetic disorder caused by missing or defective factor VIII (FVIII), a clotting protein.

---

#### f) DUCHENNE MUSCULAR DYSTROPHY

- **About muscular dystrophy:**
  - It is a group of diseases that cause progressive weakness and loss of muscle mass. In muscular dystrophy, abnormal genes (mutations) interfere with the production of proteins needed to form healthy muscle.
  - There are many kinds of muscular dystrophy. The Symptoms of most common variety begin in Childhood, mostly in boys. Other types don't surface until adulthood.
  - **Sign:** The main sign of muscular dystrophy is progressive muscle weakness. Specific signs and symptoms begin at different ages and in different muscle groups, depending on the type of muscular dystrophy.
- **About Duchenne muscular dystrophy:**
  - Most common type of muscular dystrophy.
  - Although girls can be carriers and mildly affected, it's much more common in boys.
  - **Signs and symptoms** which typically appear in Childhood are:
    - Frequent falls
    - Difficulty rising from a lying or sitting position
    - Trouble running and jumping
    - Walking on the toes
    - Large calf muscle
    - Delayed growth

- Learning disabilities.
- Other types of muscular dystrophy include: Becker Muscular Dystrophy

---

## E) MOLECULAR DIAGNOSIS

- For treatment of any disease, early diagnosis and understanding its pathophysiology is very important. Using **conventional methods** of diagnosis (**serum and urine analysis**, etc.) early detection is not possible.
- Recombinant DNA technology, Polymerase Chain Reaction (PCR) and Enzyme linked Immuno-Sorbent Assay (ELISA) are some of the techniques that serve the purpose of early detection.
  - PCR is a technique used in molecular biology to amplify a single copy or a few copies of a piece of DNA across orders of magnitude, generating thousands to millions of copies of a particular DNA sequence.
    - It is now routinely used to detect HIV in suspected AIDS patients. It is being used to detect mutations of genes in suspected cancer patients too.
  - ELISA is based on the principle of antigen-antibody interaction. Infection by pathogen can be detected by the presence of antigens (proteins, glycoproteins etc.) or by detecting the antibodies synthesized against the pathogens
- E.g. Tests During COVID-19
  - RT-PCR Test
    - The test detects the presence of viral RNA in human samples.
    - In this test first the viral RNA is converted into DNA (reverse transcription)
    - PCR is a process where a few copies of DNA are amplified to produce millions of copies.
    - This is done with the help of enzymes, primers, and probes.
  - Rapid Anti-Body Test
    - A rapid test is conducted to determine if there has been any kind of recent viral infection in a person's body. When a pathogen enters a human body, specific anti-bodies are released as a response to the virus. A rapid test can detect the presence of such anti-bodies in blood, serum or plasma samples question.
    - This is a simple test and can give results in 10-30 minutes.
    - It should be noted that it is not a confirmatory test for COVID-19. It is only a preliminary screening for diagnosis of coronavirus infection.
    - Further, a negative test doesn't rule out COVID-19 infection. A rapid test comes positive after 7-10 days of viral infection and remains positive for several weeks after that.

---

## F) DISEASE CONTROL THROUGH GENETICALLY MODIFIED ORGANISMS

- By introducing sterile mosquitoes (genetically formed). (concept - not done yet)
- Synthetic vector genome which is incapable of hosting the parasite and/or virus.

## G) PERSONAL GENOMICS

- It is the branch of genomics concerned with sequencing and analysis of the genome of an individual. The genotyping stage employs different techniques, including single-nucleotide polymorphism (SNP) analysis chips (typically 0.02% of the genome), or partial or full genome sequencing.
- **Uses**
- Once the genotypes are known, the individual's genotype can be compared with the published literature to determine likelihood of trait expression and disease risk.
- Personalized medicines
  - It is a medical method that targets treatment structures and medicinal decisions based on patient's predicted response or risk of disease.
  - Various subcategories of personalized medicines
    - Predictive Medicines
    - Precision Medicines
    - Stratified Medicines
- It predicts the right kind of treatment
  - Efficacy of toxicity of chemotherapy, or radiotherapy etc.

## 4) TRANSGENIC ANIMALS

- Animals that have their DNA manipulated to possess and express an extra (foreign) gene are known as transgenic animals.
  - Transgenic rats, rabbits, pigs, sheep, cows and fish have been produced, although over 95% of all existing transgenic animals are mice.
  - **Why so much medical research on mice, rat?**
    - **Genetic, biological and behaviour characteristics** closely resemble that of humans and many symptoms of human conditions can be replicated in mice and rats.
      - We share between 95% of the same genes, and our immune system are even more compatible.
      - Therefore, the result of mouse experiment often correlates to human biology
      - Further, mice can be genetically manipulated to mimic virtually any human disease or condition.
  - **Convenience**
    - Rodents are small, easily housed and maintained, and adapt well to the new surroundings.
  - **Reproduce quickly and short lifespan:** Reproduce quickly and have short life span of 2-3 years - so several generations of mice can be observed in sort span of time.

- **Relatively Inexpensive**
  - Can be brought in large quantities from commercial producers
- **Mild tempered and docile**
  - Rodents are also generally mild tempered and docile, making them easy for researchers to handle.
- **How transgenic animals are helpful?**
  - **Normal physiology and development**
    - Experimenting on how alteration of genes would affect humans.
  - **Study of disease**
    - Many transgenic animals are designed to increase our understanding of how genes contribute to the development of disease.
  - **Biological Products**
    - Some medicines might require some biological products which are often expensive to produce.
    - Transgenic animals that produce useful biological products can be created by the introduction of portion of DNA (or genes) which code for a particular product.
      - E.g. : Human protein ( $\alpha$ -1-antitrypsin) used to treat emphysema.
      - In 1997, the first transgenic cow - Rosie, produced human protein-enriched milk (2.4 grams per liter).
        - The milk contained the human alpha-lactalbumin and was nutritionally a more balanced product for human babies than natural cow milk.
    - **Vaccine Safety**
      - Transgenic mice are being developed for use in testing of safety of vaccines before they are used on humans.
      - Transgenic mice are being used to test the safety of the polio vaccine.
    - **Chemical safety testing**
      - This is known as toxicity safety testing.
      - The procedure is same as used for testing toxicity of drugs.

## 5) BIOTECHNOLOGY AND ENVIRONMENT

### H) GM ALGAE, CROPS ETC. CAN PROVIDE MORE BIOMASS FOR BIOFUEL.

### B) BIODIVERSITY CONSERVATION

- a. E.g. -> De-extinction of species; **Colossal** is a new bioscience and genetics company, with the idea of bringing many extinct species back to life. Scientists at Harvard University in the USA would insert

the Giant Woolly mammoth's (extinct 4,000 years ago) genes responsible for tiny ears, subcutaneous fat and hair length and color into living elephant skin cells. Once they are successful in bringing these hybrids back to life, Colossal will proceed with the ultimate goal of reviving the ancient extinct animals by producing more such hybrids.

**Criticism:** Immoral; revival of these species may threaten the existing ecosystem and disturb the food chain which has evolved over the years; Rather than focusing on revival of long extinct species, biotechnology should focus on protecting the existing ones.

### C) TO DETECT INVASIVE SPECIES:

- Environmental DNA based assay to detect invasive catfish in waterbodies (Nov 2022 – Source: DTE)
  - Conventional methods to detect invasive species like using nets, traps, and visual observations, are cumbersome, the researchers from CCMB now have developed Environmental DNA (e-DNA) based molecular methods to provide a time and cost-effective alternative.
  - eDNA is defined as “genetic material obtained directly from environmental samples (soil, sediments, water etc.) without any obvious signs of the biological source material. It is an efficient, non-invasive and easy-to-standardize sampling approach. It can be obtained from ancient as well as modern environment. With scientific advancements in DNA sequencing technologies, the technique is increasingly being used for biodiversity monitoring.
  - CSIR-CCMB has designed a molecular assay utilizing eDNA to specifically detect this invasive catfish in Indian ecosystem, which is affordable and quick, and will be very useful tool in conservation management. They use a reliable eDNA-based quantitative PCR assay to detect the African Sharptooth Catfish from water samples in the aquatic system.

### 5) GM INSECTS

- A genetically modified (GM) insect refers to insects whose DNA has been engineered through various genetic engineering tools like CRISPR CAS9.
- Various GE insects are available globally today. The development and application of GE insects offers applications in various fields:
  - **Improving Human Health:**
    - **Vector Management** in human and livestock health: GE mosquitoes for e.g. can be designed to carry genes that limit their ability to transmit diseases such as dengue, malaria etc.
    - **Reduction in use of chemicals** -> Maintenance and improvement of both human health and environmental health.
  - **Food Security:**
    - **Management of crop insect pests:** Insects can be genetically engineered to carry traits that reduce the population of agricultural pests.

- » For e.g. introducing sterile males can help control pest population.
  - **Increased food production:** Protein production for healthcare purposes; honey production etc.
    - » Engineering honeybees to make better-quality and/or quantities of honey can contribute to reduced imports and may facilitate exports.
  - **Improvement in beneficial insects** like pollinators, predators, parasitoids etc.
  
  - **Economic Application:**
    - Other than improved agri production, improvements in productive insects (e.g. silkworm, lac insect) etc can promote economic growth.
      - » E.g. GE silkworms can produce finer and/or cheaper silk, affecting prices and boosting sales.
  
  - **Fighting pollution and ensuring environmental sustainability:**
    - Reduction in use of chemical will contribute to reduced pollution and environmental sustainability. Similarly, improved pollinators can contribute to biodiversity production.
    - Some GE insects can be used as bio-indicators to monitor pollution or detect some specific substance in environment.
- **Some Concerns:**
- **Ecological Risk:** Once introduced in the environment, it's very difficult to contain these insects. And if some future problem emerges, it would be difficult to control.
  - **Unforeseen health implications** when these GM insects interact with humans.
  - **Bioweapons:** GE insects may be used to produce bioweapons.
  - **Regulatory challenges:** Government guidelines like Guidelines for Genetically Engineered insects; National Guidelines for Gene Therapy Product Development and Clinical Trials' have similar ambiguity.
  - **Ethical concerns:** GE insects raise a question – “If human being should act as God” and make changes in the living organisms around it.

#### **A) GUIDELINES FOR GENETICALLY ENGINEERED (GE) INSECTS: RELEASED BY DBT IN APRIL 2023**

- The guidelines provide procedural roadmaps for those interested in creating GE insects.
  - It intends to help Indian researchers navigate regulatory requirements.
  - The guidelines are harmonized to guidance from WHO on GE mosquitoes.
  
- But **experts have identified some issues with the guidelines:**
  - b) **Uncertainty of Purpose:** The guidelines don't specify the purpose for which GE insects may be approved in India. It only provides regulatory procedures for R&D on insects with some beneficial applications.

- c) **Uncertainty for Researchers:** The guidelines are applicable only to research and not to confined trials or deployment.
  - » Government authorities will also have to closely follow the deployment of these insects. Once deployed, the GE insects can't be recalled, and unlike GM foods, they are not amenable to individual consumer choice.
- d) **Uncertainty of Ambit:** The guidelines offer SOPs for GE mosquitoes, crop pests, and beneficial insects – but what 'beneficial' means, in the context is GE insect is not clear.

## 9. OTHER TOPICS (ONLY CLASS DISCUSSION)

### 1) GENE MAPPING / GENE SEQUENCING

### 2) EARTH BIO GENOME PROJECT

### 3) DARK DNA

### 4) STEM CELL RESEARCH

- Adult Stem Cells
  - Induced pluripotent stem cells
- Embryonic Stem Cells
  - 1) **Totipotent Stem Cells:** These can differentiate into all possible types of stem cells.
  - 2) **Pluripotent Stem Cells:** These are the cells from an early embryo and can differentiate into any cell type.
  - 3) **Multipotent Stem Cells:** These differentiate into a closely related cell type. E.g., the hematopoietic stem cells differentiate into red blood cells and white blood cells.
  - 4) **Oligopotent Stem Cells:** Adult lymphoid or myeloid cells are oligopotent. They can differentiate into a few different types of cells.
  - 5) **Unipotent Stem Cells:** They can produce cells only of their own type. Since they have the ability to renew themselves, they are known as unipotent stem cells. E.g., Muscle stem cells.

### 5) CHIM STUDIES IN INDIA

### 6) SYNTHETIC BIOLOGY

## 10. RELEVANT PYQS

1	<p>Which of the following professional(s) are more likely to run the risk of permanent change in their cell's DNA? [Prelims 1996]</p> <ol style="list-style-type: none"> <li>1. Researchers using Carbon 14 isotope</li> <li>2. X-Ray Technician</li> <li>3. Coal Miner</li> <li>4. Dyer and Painter</li> </ol> <p>Select the correct answer using the codes given below:</p> <ol style="list-style-type: none"> <li>A. 2 alone</li> <li>B. 1, 2 and 3</li> <li>C. 1, 2 and 4</li> <li>D. 1, 3 and 4</li> </ol>
2	<p>Which of the following techniques can be used to establish the paternity of a child? [Prelims 1997]</p> <ol style="list-style-type: none"> <li>(a) Protein analysis</li> <li>(b) Chromosome counting</li> <li>(c) Quantitative analysis of DNA</li> <li>(d) DNA fingerprinting</li> </ol>
3	<p>[Prelims 1999]</p> <p>Assertion(A): Insect resistant transgenic cotton has been produced by inserting BT gene  Reason(R): The Bt gene is derived from a bacterium</p> <ol style="list-style-type: none"> <li>(a) Both A and R are true and R is the correct explanation of A</li> <li>(b) Both A and R are true and R is not a correct explanation of A</li> <li>(c) A is true and R is false</li> <li>(d) A is false and R is true</li> </ol>
4	<p>[Prelims 1999]</p> <p>Assertion(A): Dolly was the first cloned Mammal  Reason(R): Dolly was produced by in vitro fertilization</p> <ol style="list-style-type: none"> <li>(a) Both A and R are true and R is the correct explanation of A</li> <li>(b) Both A and R are true and R is not a correct explanation of A</li> <li>(c) A is true and R is false</li> <li>(d) A is false and R is true</li> </ol>
5	<p>[2000]</p> <p>Assertion(A): DNA fingerprinting has become a powerful tool to establish paternity and identity of criminals in rape and assault cases  Reason(R): Trace evidences such as hairs, saliva and dried semen are adequate for DNA analysis</p>

	<p>(a) Both A and R are true and R is the correct explanation of A          (b) Both A and R are true and R is not a correct explanation of A          (c) A is true and R is false          (d) A is false and R is true</p>
6	<p>Insect Resistant Cotton plants have been genetically engineered by inserting a gene from a/an [2000]          (a) virus          (b) bacterium          (c) Antibiotics          (d) Alcohol</p>
7	<p>The American multinational company, Monsanto, has produced an insect resistant cotton variety that is undergoing field trials in India. A toxic gene from which one of the following bacteria has been transferred to this transgenic cotton? [2001]</p> <p>A. <i>Bacillus Subtilis</i>          B. <i>Bacillus thuringiensis</i>          C. <i>Bacillus amyloliquefaciens</i>          D. <i>Bacillus globlii</i></p>
8	<p>With reference to latest developments in stem cell research, consider the following statements:</p> <ol style="list-style-type: none"> <li>1. The only source of human stem cells are the embryos at blastocyst stage</li> <li>2. The stem cells can be derived without causing destruction to blastocyst</li> <li>3. The stem cells can regenerate themselves in vitro virtually forever</li> <li>4. Indian research centres also created a few cell lines which can be developed into many types of tissues</li> </ol> <p>Which of the statements are correct?</p> <p>A. 1, 2 and 4          B. 1, 2 and 3          C. 3 and 4 only          D. 1 and 3</p>
9	<p>Genetically modified 'golden rice' has been engineered to meet human nutritional requirements. Which of the following statements best qualifies golden rice? [2010]</p> <p>(a) the grain has been fortified with genes to provide three times higher grain yield per acre than other high yielding varieties          (b) Its grains contain pro-vitamin A which upon ingestion is converted to vitamin A in the human body          (c) Its modified genes cause the synthesis of all the nine essential amino acids          (d) Its modified genes cause the fortification of its grains with vitamic D</p>

10	<p><i>At present, scientists can determine the arrangement or relative positions of genes or DNA sequences on a chromosome. How does this knowledge benefit us? (2011 Pre)</i></p> <ol style="list-style-type: none"> <li>1. It is possible to know pedigree of livestock.</li> <li>2. It is possible to understand the causes of all human diseases.</li> <li>3. It is possible to develop disease-resistant animal breeds.</li> </ol> <p>Which of the statements given above are correct?</p> <ol style="list-style-type: none"> <li>a. 1 and 2 only</li> <li>b. 2 only</li> <li>c. 1 and 3 only</li> <li>d. 1, 2 and 3 only</li> </ol>
11	<p><i>A genetically engineered</i> from of Brinjal, known as the Bt-brinjal, has been developed. The objective of this is [prelims 2011]:</p> <ol style="list-style-type: none"> <li>(a) to make it pest-resistant</li> <li>(b) to improve its taste and nutritive qualities</li> <li>(c) to make it drought resistant</li> <li>(d) to make its shelf-life longer</li> </ol>
12	<p>With reference to 'stem cells', frequently in the news, which of the following statements is/are correct? [2012]</p> <ol style="list-style-type: none"> <li>1. Stem cells can be derived from mammals only</li> <li>2. Stem cells can be used for screening new drugs</li> <li>3. Stem cells can be used for medical therapies</li> </ol> <p>Select the correct answer using the codes given below:</p> <ol style="list-style-type: none"> <li>(a) 1 and 2 only</li> <li>(b) 2 and 3 only</li> <li>(c) 3 only</li> <li>(d) 1, 2 and 3</li> </ol>
13	<p><b>What are the reasons for the people's resistance to the introduction of Bt brinjal in India (2012)</b></p> <ol style="list-style-type: none"> <li>1. Bt Brinjal has been created by inserting a gene from a soil fungus into its genome</li> <li>2. The seeds of Bt brinjal are terminator seeds and therefore, the farmers have to buy the seeds before every season from the seed companies</li> <li>3. There is an apprehension that the consumption of Bt Brinjal may have adverse impact on health</li> <li>4. There is some concern that the introduction of Bt brinjal may have adverse effect on the biodiversity</li> </ol> <p>Select the correct answer using the codes given below:</p>

	<ul style="list-style-type: none"> <li>a. 1, 2 and 3 only</li> <li>b. 2 and 3 only</li> <li>c. 3 and 4 only</li> <li>d. 1, 2, 3 and 4</li> </ul>
14	<p><i>Other than resistance to pests, what are the prospects for which genetically engineered plants have been created? (Prelims 2012)</i></p> <ul style="list-style-type: none"> <li>1. To enable them to withstand drought</li> <li>2. To increase the nutritive value of the produce</li> <li>3. To enable them to grow and do photosynthesis in spaceships and space and space stations</li> <li>4. To increase their shelf life</li> </ul> <p>Choose the correct answer from the codes provided below:</p> <ul style="list-style-type: none"> <li>A. 1 and 2 only</li> <li>B. 3 and 4 only</li> <li>C. 1, 2 and 4 only</li> <li>D. 1, 2, 3 and 4</li> </ul>
15	<p>Recombinant DNA technology (Genetic Engineering) allows genes to be transferred (Pre 2013)</p> <ul style="list-style-type: none"> <li>1. Across different species</li> <li>2. From Animals to plants</li> <li>3. From microorganisms to higher organisms</li> </ul> <p>Select the correct answer using the codes given below:</p> <ul style="list-style-type: none"> <li>a. 1 only</li> <li>b. 2 and 3 only</li> <li>c. 1 and 3 only</li> <li>d. 1, 2 and 3</li> </ul>
16	<p>The Genetic Engineering Appraisal Committee is constituted under the: [Prelims 2015]</p> <ul style="list-style-type: none"> <li>(a) Food Safety and Standards Act, 2006</li> <li>(b) Geographical Indications of Goods (Registration and Protection) Act, 1999</li> <li>(c) Environment (Protection) Act, 1972</li> <li>(d) Wildlife (Protection) Act, 1972</li> </ul>
17	<p>In the context of the development in Bio-informatics, the term 'Transcriptome', sometimes seen in the news, refer to: (Pre 2016)</p> <ul style="list-style-type: none"> <li>a. A range of enzymes used in genome editing</li> <li>b. The full range of mRNA molecules expressed by an organism</li> </ul>

	<p>c. The description of the mechanism of gene expression d. A mechanism of genetic mutations taking place in cells</p>								
18	<p>What is the application of Somatic Cell CJ Nuclear Transfer Technology? (Pre 2017)</p> <p>a. Production of bio larvicides b. Manufacture of biodegradable plastics c. Reproductive cloning of animals d. Production of organisms free of diseases</p>								
19	<p><b>Consider the following pairs:</b> [Prelims 2018]</p> <table border="1"> <thead> <tr> <th>Terms sometimes seen in news</th><th>Context/Topic</th></tr> </thead> <tbody> <tr> <td>i. Belle II Experiment</td><td>Artificial intelligence</td></tr> <tr> <td>ii. Blockchain Technology</td><td>Digital/ Cryptocurrency</td></tr> <tr> <td>iii. CRISPR – Cas9</td><td>Particle Physics</td></tr> </tbody> </table> <p>Which of the pairs given above are correctly matched?</p> <p>A. 1 and 3 only B. 2 only C. 2 and 3 only D. 1, 2 and 3 only</p>	Terms sometimes seen in news	Context/Topic	i. Belle II Experiment	Artificial intelligence	ii. Blockchain Technology	Digital/ Cryptocurrency	iii. CRISPR – Cas9	Particle Physics
Terms sometimes seen in news	Context/Topic								
i. Belle II Experiment	Artificial intelligence								
ii. Blockchain Technology	Digital/ Cryptocurrency								
iii. CRISPR – Cas9	Particle Physics								
20	<p>With reference to the Genetically modified mustard (GM mustard) developed in India, consider the following statements (Prelims 2018)</p> <ol style="list-style-type: none"> <li>1. GM Mustard has the genes of a soil bacterium that give the plant the property of pest resistance to a wide variety of pests</li> <li>2. GM Mustard has the genes that allow the plant cross-pollination and hybridization</li> <li>3. GM Mustard has been developed jointly by IARI and Punjab Agricultural University</li> </ol> <p>Which of the statements given above is/are correct?</p> <p>a. 1 and 3 only b. 2 only c. 2 and 3 only d. 1, 2 and 3 only</p>								
21	<p><b>What is cas9 protein that is often mentioned in news ?</b> (Pre 2019)</p> <p>(a) A molecular scissors used in targeted gene editing (b) A biosensor used in the accurate detection of pathogens in patients.</p>								

	<p>(c) A gene that makes plants pest-resistant          (d) A herbicidal substance synthesized in generally modified crops</p>
22	<p>With reference to the recent developments in science which one of the following statements is not correct? (Pre 2019)</p> <p>(a) Functional chromosomes can be created by joining segments of DNA taken from cells of different species          (b) Pieces of artificial functional DNA can be created in laboratories.          (c) A piece of DNA taken out from an animal cell can be made to replicate outside a living cell in a laboratory.          (d) Cells taken out from plants and animals can be made to undergo cell division in laboratory petri dishes.</p>
23	<p>'RNA interference (RNAi)' technology has gained popularity in the last few years. why? (Pre 2019)</p> <p>1. It is used in developing gene silencing therapies.          2. It can be used in developing therapies for the treatment of cancer.          3. It can be used to develop hormone replacement therapies.          4. It can be used to produce crop plants that are resistant to virtual pathogens.</p> <p>Select the correct answer using the code given below.</p> <p>(a) 1, 2 and 4          (b) 2 and 3          (c) 1 and 3          (d) 1 and 4 only</p>
24	<p>Bollgard I and Bollgard II technologies are mentioned in the context of: [Prelims 2021]</p> <p>(a) Clonal Propagation of crop plants          (b) Developing GM crop plants          (c) Production of plant growth substance          (d) Production of biofertilizers</p>
25	<p>Consider the following statements: [Prelims 2022]</p> <p>DNA Barcoding can be a tool to:</p> <ol style="list-style-type: none"> <li>1. Assess the age of a plant or animal.</li> <li>2. Distinguish among species that look alike.</li> <li>3. Identify undesirable animal or plant materials in processed foods.</li> </ol> <p>Which of the statements given above is/are correct?</p>

	<p>A. 1 only</p> <p>B. 3 only</p> <p>C. 1 and 2 only</p> <p>D. 2 and 3 only</p>
26	<p>Microsatellite DNA is used in the case of which one of the following? [Prelims 2023]</p> <p>A. Studying the evolutionary relationship among various species of fauna</p> <p>B. Stimulating 'stem cells' to transform into diverse functional tissues</p> <p>C. Promoting Clonal Propagation of horticulture plants</p> <p>D. Assessing the efficacy of drugs by conducting a series of drug trials in a population</p>



# TARGET PRELIMS 2024

## BOOKLET-10; S&T-10

### HEALTH

#### 1. TABLE OF CONTENTS

1. <i>Table of Contents</i> .....	0
2. <i>National Family Health Survey – 5 (NFHS)</i> .....	4
3. <i>Reports</i> .....	4
1) ‘Healthy States, Progressive India’ – a report by NITI Aayog .....	5
4. <i>Schemes/Programs/initiatives</i> .....	5
1) Ayushman Bharat – Pradhan Mantri Jan Arogya Yojna (AB-PMJAY) .....	5
2) Ayushman Bharat – Digital Health Mission (AB-DHM) .....	6
A) E-Sanjeevani – National Telemedicine Service .....	7
3) Pm Ayushman Bharat Health Infrastructure Mission (PMAB-HIM).....	7
4) Decriminalization of Medical Negligence .....	8
5) Immunization Program in India/ Vaccination .....	8
6) BCG Vaccine – 100 years and Counting .....	10
5. <i>Maternal health – Schemes</i> .....	11
a) Understanding Maternal Mortality Rate .....	11
b) National Health Mission 2013.....	11
c) Janani Surakha Yojana (2005 Scheme).....	11
d) Janani Shishu Suraksha Karyakram .....	12
e) Maternity Benefit Scheme (MBS) / Pradhan Mantri Matritva Vandana Yojana (PMMVY).....	12
f) State governments running their effective Schemes (TN and Odisha) .....	13
6. <i>Nutrition</i> .....	13
1) Various Initiatives to fight malnutrition in the country .....	13
2) MICRONUTRIENTS vs Macro Nutrients .....	14
a) Micronutrients .....	14
b) Macro-nutrients .....	15
A) Trans fat vs Saturated Fat vs Mono-saturated Fat vs Poly-unsaturated Fat .....	15
3) Fortification of Food.....	17
a) Food Fortification.....	17

b)	Biofortification:.....	17
c)	Rice Fortification: Extrusion technology: .....	18
<b>4)</b>	<b>Diseases due to Nutritional Deficiencies.....</b>	<b>19</b>
<b>7.</b>	<b>Some Nutrition based updates .....</b>	<b>21</b>
<b>1)</b>	<b>Anaemia.....</b>	<b>21</b>
<b>8.</b>	<b>Viral Diseases vs Bacterial Diseases .....</b>	<b>21</b>
<b>9.</b>	<b>COVID-19 .....</b>	<b>22</b>
<b>1)</b>	<b>Corona Viruses .....</b>	<b>22</b>
<b>2)</b>	<b>SARS-COV-2: Naming, Structure and Physiology .....</b>	<b>23</b>
<b>3)</b>	<b>Structure of the Virus .....</b>	<b>23</b>
<b>4)</b>	<b>Naming of the Disease – Corona Virus Disease-19 (COVID-19) .....</b>	<b>24</b>
<b>5)</b>	<b>Covid-19 Disease caused by infection of SARS-COV-2 (2019 n-COV) .....</b>	<b>24</b>
<b>6)</b>	<b>Diagnosis .....</b>	<b>24</b>
<b>7)</b>	<b>CYTOKINE STORMS AND ITS IMPACT ON COVID-19 DEATHS .....</b>	<b>25</b>
<b>8)</b>	<b>Mucormycosis or Black Fungus.....</b>	<b>25</b>
<b>9)</b>	<b>Variants of Concern.....</b>	<b>25</b>
A)	Details of Delta Variant .....	25
B)	Details of Omicron Variant (variant B.1.1.529) .....	26
C)	Recent Mutations in News:.....	26
<b>10.</b>	<b>Various Types of Vaccines: .....</b>	<b>26</b>
<b>1)</b>	<b>2023 Nobel Prize in Physiology or Medicine .....</b>	<b>28</b>
<b>11.</b>	<b>Other Viral Diseases .....</b>	<b>30</b>
<b>1)</b>	<b>Measles.....</b>	<b>30</b>
<b>2)</b>	<b>Rubella .....</b>	<b>31</b>
<b>3)</b>	<b>Human Immunodeficiency Virus (HIV) and AIDS (aCQUIRED immunodeficiency syndrome).....</b>	<b>31</b>
A)	Stem Cell Therapy to treat HIV have shown success: .....	32
B)	Global Situation of HIV:.....	33
C)	Vaccination Efforts:.....	33
D)	HIV situation in India.....	33
<b>4)</b>	<b>Polio .....</b>	<b>34</b>
A)	Two types of Vaccines: OPV and IPV.....	35
B)	Issue of Vaccine Derived Polio Virus .....	35
<b>5)</b>	<b>Ebola Virus Disease (EVD).....</b>	<b>36</b>
<b>6)</b>	<b>Rabies .....</b>	<b>36</b>
<b>7)</b>	<b>Human Papilloma Virus (HPV) .....</b>	<b>37</b>
<b>8)</b>	<b>Cervical Cancer .....</b>	<b>38</b>
<b>9)</b>	<b>Dengue .....</b>	<b>38</b>

<b>10)</b>	<b>Zika Fever / Zika Disease .....</b>	<b>39</b>
<b>11)</b>	<b>Japanese Encephalitis .....</b>	<b>40</b>
<b>12)</b>	<b>Acute Encephalitis Syndrome (AES) .....</b>	<b>40</b>
<b>13)</b>	<b>West Nile Virus.....</b>	<b>41</b>
<b>14)</b>	<b>Chikungunya .....</b>	<b>41</b>
<b>15)</b>	<b>Mosquitoes are emerging as Big Issue .....</b>	<b>42</b>
<b>16)</b>	<b>World Mosquito Program (WMP) .....</b>	<b>43</b>
<b>17)</b>	<b>Kyasanur Forest Disease (KFD) / Monkey Fever .....</b>	<b>44</b>
<b>18)</b>	<b>Influenza .....</b>	<b>44</b>
A)	Influenza A Virus .....	44
B)	Swine Flu.....	45
C)	Avian Influenza: Bird FLU.....	46
D)	The European Union is Experiencing the largest Bird Flu outbreak in Europe: Report by European Food Safety Authority (EFSA) (2022 and 2023).....	46
E)	First Case of Avian Flu found in Antarctic Region (Oct 2023 ).....	46
<b>19)</b>	<b>NIPAH.....</b>	<b>47</b>
a)	NIPAH.....	47
b)	why zoonotic diseases are infecting humans more and more.....	48
<b>20)</b>	<b>Hepatitis.....</b>	<b>48</b>
<b>21)</b>	<b>NoroVirus.....</b>	<b>49</b>
<b>12.</b>	<b><i>Non- Viral Diseases .....</i></b>	<b>51</b>
<b>1)</b>	<b>Malaria .....</b>	<b>51</b>
a)	Development of Drug Resistance:.....	51
B)	2023 World Malaria Report – Published by WHO (Dec 2023) .....	51
C)	Global Technical Strategy For Malaria 2016-2030: WHO .....	51
D)	Vaccinations.....	51
E)	Malaria's COMback in USA.....	53
<b>2)</b>	<b>Important International Initiatives related to Malaria .....</b>	<b>53</b>
a)	E-2025 Initiative .....	53
B)	China certified malaria free after 70 years of flight: WHO (June 2021).....	54
C)	Major National Initiatives .....	54
<b>3)</b>	<b>Kala Azar (Visceral Leishmaniasis, Black Fever, and Dumduum Fever) .....</b>	<b>55</b>
A)	Other two form of Leishmaniasis.....	56
<b>4)</b>	<b>Filariasis .....</b>	<b>57</b>
<b>5)</b>	<b>Neurocysticercosis .....</b>	<b>57</b>
<b>6)</b>	<b>Tuberculosis .....</b>	<b>58</b>
A)	WHO's Global TB Report .....	59
<b>7)</b>	<b>Leprosy .....</b>	<b>59</b>
<b>8)</b>	<b>Meningitis (Both Viral and Bacterial Reasons) .....</b>	<b>60</b>
<b>13.</b>	<b><i>Neglected Tropical Diseases (NTDs).....</i></b>	<b>61</b>
A)	Inclusion of Noma on the WHO's list of NTD.....	62

<b>14.</b>	<b><i>Non-Communicable Diseases.....</i></b>	<b>63</b>
1)	<b>Hypertension (High Blood Pressure) .....</b>	<b>63</b>
A)	Benefits of reducing salt intake (Dec 2022) .....	64
2)	<b>diabetes and Insulin .....</b>	<b>64</b>
a)	What is diabetes? .....	64
B)	Type 1 diabetes leading cause of diabetes deaths in those below 25, easily preventable: Study published in Lancet	
C)	Insulin.....	65
D)	Non Sugar Sweetners.....	65
D)	Prelims Facts: Aspartame:.....	66
<b>15.</b>	<b><i>Rare Genetic Diseases .....</i></b>	<b>67</b>
1)	<b>National Policy for Rare Diseases, 2021 .....</b>	<b>67</b>
2)	<b>Some Rare Genetic Diseases in More Details .....</b>	<b>68</b>
A)	Sickle cell Anaemia.....	68
B)	Thalassemia: .....	70
C)	Hunter Syndrome or MPS-II.....	71
D)	Haemophilia A and Haemophilia B (already discussed with Biotechnology).....	71
<b>16.</b>	<b><i>Other diseases.....</i></b>	<b>71</b>
1)	<b>Dementia .....</b>	<b>71</b>
<b>17.</b>	<b><i>Mitochondrial Disease.....</i></b>	<b>72</b>
<b>18.</b>	<b><i>ANti-Microbial Resistance .....</i></b>	<b>73</b>
<b>19.</b>	<b><i>Smoking/Drinking Etc.....</i></b>	<b>75</b>
1)	<b>Spurious liquor/ Hooch Tragedies/ Methyl Alcohol .....</b>	<b>75</b>
<b>20.</b>	<b><i>International Initiatives.....</i></b>	<b>76</b>
2)	<b>The Lancet.....</b>	<b>76</b>
<b>21.</b>	<b><i>Food Safety .....</i></b>	<b>76</b>
1)	<b>Laws and Institutions .....</b>	<b>76</b>
A)	Food Safety and Standards Act, 2006 .....	76
B)	Food Safety and IPC .....	77
C)	State Food Safety Index (FSI) .....	77
<b>22.</b>	<b><i>Making Medicines Affordable .....</i></b>	<b>77</b>
1)	<b>Generic Medicines:.....</b>	<b>77</b>
2)	<b>Jan Aushadhi Kendras .....</b>	<b>78</b>

## 2. NATIONAL FAMILY HEALTH SURVEY – 5 (NFHS)

- **Details: About NFHS**
  - The NFHS is a large-scale, multi-round survey, conducted in a representative sample of households throughout India. First survey was done in 1992-94 and since then 5 rounds have been conducted.
- **Who conducts this survey?**
  - International Institute for Population Sciences (IIPS), Mumbai, is the National Nodal Agency.
  - MoHFW has decided to conduct integrated NFHS with a periodicity of three years in lieu of different surveys from 2015-16 onwards to meet the evolving requirements for frequent, timely and appropriate **data** at the National, State and District level.
- **NFHS-5: Key Highlights**

Sl. No.	Indicator	NFHS-5 (2019-21)	NFHS-4 (2015-16)
<b>Fertility and Family Planning</b>			
1	Total Fertility Rate (TFR)	2.0	2.2
2	Women age 15-19 years who were already mothers or pregnant at the time of the survey (%)	6.8	7.9
3	Current Use of Family Planning Methods-Any method (%)	66.7	53.5
4	Current Use of Family Planning Methods-Any modern method (%)	56.4	47.8
5	Total unmet need for Family Planning (%)	9.4	12.9
<b>Maternity and Delivery Care</b>			
6	Mothers who had an antenatal check-up in the first trimester (%)	70.0	58.6
7	Mothers who had at least 4 antenatal care visits (%)	58.5	51.2
8	Mothers who received postnatal care from a doctor/nurse/LHV/ANM/midwife/other health personnel within 2 days of delivery (%)	78.0	62.4
9	Institutional births (%)	88.6	78.9
<b>Child Vaccination and Child Feeding Practices</b>			
10	Children age 12-23 months fully vaccinated based on information from either vaccination card or mother's recall (%)	76.6	62.0
11	Children under age 6 months exclusively breastfed (%)	63.7	54.9
<b>Infant and Child Mortality Rates (per 1000 live births)</b>			
12	Neonatal Mortality Rate (NNMR)	24.9	29.5
13	Infant Mortality Rate (IMR)	35.2	40.7
14	Under-five Mortality Rate (U5MR)	41.9	49.7

## 3. REPORTS

## 1) 'HEALTHY STATES, PROGRESSIVE INDIA' – A REPORT BY NITI AAYOG

- **Introduction**
  - » It is a comprehensive health index report which ranks states and UTs innovatively on their year on year incremental change in health outcomes, as well as their overall performance with each other.
  - » The report has been prepared by NITI Aayog with technical assistance from WB, and consultation with MoH&FW.
  - » States and UTs have been ranked in 3 categories namely Larger states, smaller states, and Union Territories (UTs) to ensure comparison among similar entities.
  - » The health index is a weighted composite index based on 24 indicators grouped under **three domains**, with each domain assigned weights based on its importance and higher scores for outcome indicators.
    - Health Outcomes (70%);
    - Governance and Information (12%);
    - Key inputs and processes (18%),
- **Significance** - An annual systematic tool; regular assessment of health sector; nudge badly performing states to do well; helps to move towards SDG goals.

## 4. SCHEMES/PROGRAMS/INITIATIVES

### 1) AYUSHMAN BHARAT – PRADHAN MANTRI JAN ARYOGYA YOJNA (AB-PMJAY)

- **About AB-PMJAY** (Pradhan Mantri Jan Arogya Yojana)
  - **Ministry:** MoH&FW
  - AB-PMJAY is an entitlement based scheme that aims to provide health insurance cover of upto **5 lakh rupees per family** to **over 10 crore poor families** (about 50 crore population) for **secondary and tertiary care hospitalization**. There is **no cap on the size of the family or age of the beneficiary**.
    - All pre-existing conditions are also covered from day 1 of implementation of PM-JAY in respective states/UT.
    - It is the world's largest government funded health care program.
    - The **eligible poor families** are decided on the basis of **SECC, 2011 data** and include poor, deprived rural families and occupational category of urban worker's families (Roughly 8.03 crore rural families and 2.33 crore urban families (11 occupational criteria))
      - In addition the beneficiary of RSBY are also included.
      - Further, there is no capping on number of family members or age of members -> this ensures that senior citizens and girl children also get good health services.
    - The scheme provides **cashless and paperless** access to services for the beneficiary at the point of service. Eligible people can avail the benefits at both government and listed (empanelled) private hospitals.
      - In case of **hospitalization**, members of the beneficiary families **don't need to pay anything** under the scheme, provided one goes to a government or an empanelled private hospital.
    - It is a **centrally sponsored scheme**, so, there is a state component too (**60:40**).

- It is a **portable** scheme, which means beneficiary can avail benefits in any of the states that is implementing the scheme.
- It subsumes Rashtriya Swastha Bima Yojana and the Senior Citizen Health Insurance Scheme (SCHIS).
- **Adhaar card is not mandatory** - identity to avail benefit can be established through ration card or election ID card.

## 2) AYUSHMAN BHARAT – DIGITAL HEALTH MISSION (AB-DHM)

- **Details**
  - » The missions aim to create a **complete Digital Health Ecosystem** which will connect the digital health solutions of hospitals across the country with each other.
    - This digital ecosystem will enable a host of other facilities like Digital Consultation; Consent of Patients in letting medical practitioners access their records, etc. This will ensure that all medical records are stored digitally and are thus not lost. They would be accessible through app or web-portal.
    - All this will help in improving the quality, access, and affordability of health services by making the service delivery "quicker, less expensive, and more robust".
  - » **Unique Health ID:**
    - Any person wanting to be part of ABDHM will get a health ID, which is a **randomly generated 14-digit number**. It will be used for three purposes - Unique Identification; Authentication; and Threading of the beneficiary's health records, only with their informed consent, across multiple systems and stakeholders.
    - **Facilities:**
      - You can access your digital records right from admission through treatment and discharge.
      - You can access and link your personal health records with your health ID to create a longitudinal health history.
  - » **NDHM Sandbox**
    - It is a digital architecture that allows private players to be part of the National Digital Health Ecosystem as health information providers or health information users.
  - » **Privacy:**
    - Citizen's consent is vital for all access.
    - Users can delete or exit the services anytime he wants.
  - » **Upcoming features:**
    - Future features will enable access to verified doctors across the country.
    - The beneficiary can also create health ID for her child, a digital health records right from birth.
    - She can add a nominee to access her health ID and view or help manage the personal health records.

- Also, there will be much inclusive access with the health ID available to people who don't have phones, using assisted methods.
- **Why can't Aadhaar be used as Digital ID:**
  - » The Aadhaar Act and Supreme Court verdict restrict the use of Aadhaar ID for welfare schemes promoting government subsidies.
- **Significance:** (ease of living; optimal treatment; reduce re-testing; increased accountability; easy identification of specialists, doctors, labs; Big Data, Data Mining and Artificial intelligence-based solution etc.

#### A) E-SANJEEVANI – NATIONAL TELEMEDICINE SERVICE

- **Ministry:** MoH&FW
- It is an innovative, indigenous, cost-effective, and integrated cloud based telemedicine system application to enable patient to doctor teleconsultation to ensure a continuum of care and facilitate health services to all citizens in the confines of their home.
- **Two verticals of eSanjeevani**
  - **eSanjeevaniAB-HWC:** It endeavors to bridge rural-urban digital health divide by providing assisted teleconsultation, and ensuring that e-beneficiaries of AB Scheme are able to avail the benefits that they are able to entitled to.
    - It operates on Hub and Spoke Model wherein the 'Ayushman Bharat - Health and Wellness Centre' are set up at the state level, act as spokes, which are mapped with the hub (comprising MBBS/ Specialty/ Super Specialty doctors) at zonal level.
  - **eSanjeevaniOPD** is the latter vertical which caters to citizens in both rural and urban alike. It leverages technology via smartphones, tablets, laptops etc. enabling doctor consultation to be accessible from the patient's residence regardless of location.
- **Progress So far:**
  - As of Jan 2023, 1,12,553 HWC in rural areas and 15465 Hubs at tertiary level hospitals, and medical colleges in the states have been enabled in the eSanjeevani.
  - **Patients Served:** It has served 9.3 crore patients so far and is serving around 4 lakh patients daily.
- **E-Sanjeevani** is evolved into the world's largest outpatient Services system.
- It is a cohesive part of Ayushman Bharat Digital Health Mission (ABDM) and more than 45,000 ABHA IDs have been generated using eSanjeevani Portal.

#### 3) PM AYUSHMAN BHARAT HEALTH INFRASTRUCTURE MISSION (PMAB-HIM)

- PMABHIM, announced in the Budget 2021-22, is the largest pan-India Health Infrastructure Scheme which aims to strengthen the PAN-India health infrastructure.

- It is a centrally sponsored scheme with a budgetary outlay of Rs 64,180 crore for the FY 2021-22 to 2025-26 and will improve health care facilities from village to national level in this period.
- There are **three major aspects** of the ABHIM - Augmenting Healthcare facilities for treatment; Setting up of integrated public health labs for diagnosis of diseases; and Expansion of existing research institutions that study pandemics.

## 4) DECRIMINALIZATION OF MEDICAL NEGLIGENCE

- **Why in news?**
  - » Bhartiya Nyaya Samhita has kept the punishment for medical negligence lower than the punishment for causing death by other kinds of negligence (Dec 2023)
- **Introduction**
  - » As per the **Section 106(1)** of the Bhartiya Nyaya (Second) Sanhita (BNSS), doctors will continue to face a two year imprisonment and/or fine if convicted. This is lesser than the Sanhita's recommended punishment of five years for other cases of death by negligence (for e.g. by rash driving).
  - » **Note:** The maximum imprisonment of doctors with this amendment remain the same as it was under IPC section 304A - upto 2 years of imprisonment or fine or both.
    - Medical negligence has not been clubbed with other accidental deaths where punishment has been kept higher.
- **Need of lower punishment for medical negligence:**
  - » Doctor's shouldn't be punished for honest mistakes and negligence is a complex issue in medical field and therefore this shouldn't be clubbed with other kinds of negligence.
  - » It will also reduce harassment of doctors from frivolous lawsuits and harassment.
  - » It will ensure that doctors will be able to provide care without fear of persecution and patients can be assured of quality care.
- **Criticisms:**
  - » Critiques argue that doctors should be more careful and the scope of negligence should be lesser here.
  - » Owing to the "power imbalance" in the doctor-patient relationship, an act of negligence on the part of the doctor calls for a lower punishment but a higher one.

## 5) IMMUNIZATION PROGRAM IN INDIA/ VACCINATION

- **Various Initiatives**
  - » The government had launched **Expanded Program for Immunization** in 1978 which was further replaced by **Universal Immunization Program (UIP)** in 1985. It is the largest Immunization Program in the world, with the annual coverage of 2.6 crore infants and 2.9 crore pregnant women. Through this India has achieved groundbreaking success in eradicating/ eliminating life threatening vaccine preventable diseases like smallpox, Polio, Maternal Neonatal Tetanus etc.

- But despite a lot of efforts and improvements, the immunization coverage had been slow to increase with a coverage of **62%** according to NFHS-4 released in 2015-16.
- **Key Factors behind low Immunization Coverage**
  - » **Rapid and Unplanned urbanization**
  - » **Large migrating and isolated population** is difficult to cover
    - Difficult terrains, areas under LWE etc. are also difficult to cover.
  - » **Lack of awareness** among uninformed masses and unaware population leads to low demand of immunization.
- **Other problems with vaccination system in India**
  - » **Inequality in vaccine administration**
  - » **Vaccine Hesitancy: Rumor Mongering/ Misinformation among some population** also prevents full coverage.
- **Negative Impact of COVID-19 on routine vaccination**
- **Various Efforts to deal with above challenges:**
  - » **Mission Indradhanush** was launched by the MoH&FW in 2014. It is a strategic endeavor under UIP with an aim to target under-served, vulnerable and inaccessible populations.
    - It covers **8 vaccines** (Diphtheria, Whooping Cough, Tetanus, Polio, Measles, Childhood TB, Hepatitis B and Meningitis) across the country, **2 vaccines** (Pneumonia and Hemophilus influenza type B) in selected states and **2 vaccines** (Rotavirus Diarrhea and Japanese Encephalitis) in selected districts.
    - **MI** contributed to an increase of 6.7% in full immunization coverage after the first two phases of Mission Indradhanush.
  - » **Intensified Mission Indradhanush (IMI)** was launched in Oct 2017 - to achieve a coverage of 90% with focus towards districts and urban areas with persistently low levels.
  - » **In Dec 2019**, Government had launched **Intensified Mission Indradhanush 2.0 (IMI 2.0)** to be implemented between Dec 2019 - March 2020 that seeks to escalate efforts to achieve the goal of attaining a 90% national immunization coverage across the country.
  - » **Intensified Mission Indradhanush 3.0** aimed to reach those children and pregnant women who have been missed out of the routine immunization program. The first phase ran from 22nd Feb 2021 for 15 days.
  - » **Intensified Mission Indradhanush 4.0** launched in Feb 2022.
    - Three rounds of IMI 4.0 was planned to catchup on the gaps that might have emerged due to COVID-19 pandemic. The activity will be conducted in 416 districts across 33 states/Uts.
    - These districts were identified based on vaccination coverage as per the latest National Family Health Survey-5 report, Health Management Information System (HMIS) data and burden of vaccine preventable diseases.

- » **Intensified Mission Indradhanush 5.0 (IMI 5.0)** campaign was being conducted in three rounds:
  - 7-12 Aug 2023; 11-16 Sep 2023; and 9-14 Oct 2023 (**6 days every month**)
  - It aims to ensure immunization coverage of all vaccines provided under the UIP as per the National Immunization schedule.
  - **Special focus** is on improvement of Measles and Rubella vaccination coverage with the aim of Measles and Rubella elimination by 2023.
  - It ensures that routine immunization services reach the missed-out and dropped out children and pregnant women across country. This year, for the first time the campaign was conducted across all districts in the country and include children upto 5 years of age (previous campaigns included children upto 2 years of age)
  - It saw participation from ***Jan pratinidhis*** and **Social media** influencers have come in large numbers across all states/ Uts to appeal to people to visit nearest vaccination centres.
- » Since 2014, 11 phases of Mission Indradhanush have been completed.

## 6) BCG VACCINE – 100 YEARS AND COUNTING

- BCG was first used in humans in 1921.
- **Details about BCG vaccine (bacilli Calmette-Guerin)**
  - » BCG was developed by two Frenchmen, Albert Calmette and Camille Guerin.
    - It is a live attenuated strain derived from an isolate of Mycobacterium bovis and has been used widely across the world as a vaccine for tuberculosis. Currently, it is the only licensed vaccine available for the prevention of TB. It is the world's most widely used vaccine with about 120 million doses every year.
  - » **Interesting Fact:** Works well in some geographical locations and not so well in others. Generally, the farther a country is from equator, the higher is the efficacy. Therefore, it has high efficacy in UK, Norway, Sweden, and Denmark; and little or no efficacy in countries on or near the equator like India, Kenya, and Malawi, where the burden of TB is higher. These regions also have higher prevalence of environmental mycobacteria.
    - However, in children BCG provides strong protection against severe forms of TB. This protective effect appears to wane with age and is far more variable in adolescents and adults, ranging from 0-80%.
    - **A large clinical trial between 1968-1983 by ICMR's National Institute for Research** in TB in Chengalpattu district of TN, indicated that BCG offered no protection against pulmonary TB in adults, and a low level of protection (27%) in children.
- **Other uses of BCG**
  - BCG also protect against respiratory and bacterial infections of the newborns, and other mycobacterial diseases like leprosy and Buruli's ulcer.
  - It is also used as an immunotherapy agent in cancer of the urinary bladder and malignant melanoma.
- **BCG in India**
  - BCG vaccinations were first conducted in India in 1948 and it became part of the National TB control program in 1962.
  - It remains a part of basket of vaccines included under the **Universal Immunization Program**.

- **Other TB vaccines:**
  - Over the last ten years, 14 new Vaccines have been developed for TB and are in clinical trials.

## 5. MATERNAL HEALTH – SCHEMES

### A) UNDERSTANDING MATERNAL MORTALITY RATE

- Maternal death is the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of duration of pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes.

Table VI.18: Trends in Mortality indicators

	2014	2016	2018	2020
Maternal Mortality Ratio (per lakh live births)	167 (2011-13)	130 (2014-16)	113 (2016-18)	97 (2018-20)
Infant Mortality Rate (per 1000 live births)	39	34	32	28
Neonatal Mortality Rate (per 1000 live births)	26	24	23	20
Under 5 Mortality Rate (per 1000 live births)	45	39	36	32
Early Neonatal Mortality Rate – 0- 7 days (per 1000 live births)	20	18	18	15

Source: Sample Registration System

- As per the Sample Registration Survey (SRS) data, India has successfully achieved the major milestones to bring Maternal Mortality Ratio (MMR) to below 100 per lakh live births by 2020 [laid down in the National Health Policy, 2017]
- **Eight states** have already achieved the 2030 SDG targets to reduce MMR to less than 70 per lakh live births by 2030. These include Kerala (19), Maharashtra (33), Telangana (43), Andhra Pradesh (45), Tamil Nadu (54), Jharkhand (56), Gujarat (57), and Karnataka (69).

### B) NATIONAL HEALTH MISSION 2013

- With respect to mother's health, the NHM includes following initiatives:
  - Reproductive Maternal Neonatal Child and Adolescent Health (RMNCH+A) Program
  - **Janani Surakha Yojna (JSY)** to promote institutional delivery which is expected to reduce neonatal and maternal mortality.

### C) JANANI SURAKHA YOJANA (2005 SCHEME)

- The JSY is a safe motherhood intervention launched in 2005 as part of the NRHM to improve maternal and neonatal health by promotion of institutional deliveries (childbirth in hospitals).
- It is a 100% centrally sponsored scheme which integrates cash assistance with delivery and post-delivery care
- **Key Features**
  - » Financial assistance under JSY is available to all pregnant women in states that have low institutional delivery rates namely, UP, UK, Bihar, Jharkhand, MP, Chhattisgarh, Orissa, Assam, Rajasthan & J&K (categorized as low performing states).
  - » In remaining states (where institutional delivery are satisfactory, pregnant women from BPL/SC/ST households only are entitled for JSY benefits.

- » It is implemented through ASHA, the accredited social health activists, acting as an effective link between the Government and poor pregnant women under the scheme.

#### **D) JANANI SHISHU SURAKSHA KARYAKRAM**

- The program launched in 2011 entitles all pregnant women delivering in public health institutions to absolutely free and no expense delivery including Caesarean section.
  - The program stipulates free drugs, diagnostics, blood and diet, besides free transport from home to institution, between facilities in case of a referral and drop back home.
  - Similar entitlement has been put in place for all sick infants accessing public health institutions for treatment.

#### **E) MATERNITY BENEFIT SCHEME (MBS) / PRADHAN MANTRI MATRITVA VANDANA YOJANA (PMMVY)**

- **Details of the Scheme:**
  - Under PMMVY a 'cash incentive of Rs 5,000 is provided directly to the bank account of the pregnant or lactating mothers for the first living child of the family.
  - It is aimed at improving health seeking behavior, arresting MMR, ensuring proper nutrition and offsetting wage loss.
  - The scheme is being implemented from 1st Jan 2017.
- **Target Women**
  - Eligible PW&LM, excluding women in regular employment who are in receipt of similar benefits under any law for the time being.
- **Other key provisions of the scheme:**
  - Center: State Share: 60: 40
  - The benefit of Rs 5000 to PW&LM in three installments for the birth of first live child by MWCD and remaining incentives as per the approved norms towards maternity benefit under existing programs after institutional deliveries so that on an average women would receive Rs 6,000.
  - Conditional cash transfer scheme would be in DBT mode.
- **Limitation of the Scheme**
  - Only for first child
  - Amount too small
  - Several conditions attached
  - **Subsuming of Janani Surakha Yojana:** JSY which is a cash based incentive of Rs 14,00 for institutional deliveries, has been subsumed under this scheme. JSY is an older scheme started for a different purpose and should not be confused with maternity benefits for wage compensation.

## F) STATE GOVERNMENTS RUNNING THEIR EFFECTIVE SCHEMES (TN AND ODISHA)

- Dr. Muthulakshmi Reddy Maternity Benefit Scheme in TN provides for financial assistance of Rs 18,000 per child for the first two children.
- **MAMATA Scheme of Odisha** provides Rs 5,000 for first two children.
  - These two schemes are working reasonably well due to their wider coverage and simpler process.
  - In 2020-21, MAMATA showcased a 57% increase in women who received all installments, and PMMVY showcased a decrease.

## 6. NUTRITION

### 1) VARIOUS INITIATIVES TO FIGHT MALNUTRITION IN THE COUNTRY

- The government is implementing several schemes and programs under the Umbrella ICDS Scheme as direct target interventions to address the problems of malnutrition in the country.
- Initiatives like **PDS, Mid-Day Meal Scheme**.
  - In Sep 2021, the Mid day meal scheme has been renamed to PM POSHAN.
    - Under this not only Children of class 1 to 8 (around 11.8 crore) will be covered, but also around 24 lakh students receiving pre-primary education at government and government aided schools will also be brought under the ambit of the scheme from next year. This is in line with NEP which had recommended that the pre-school education should be formalized.
- **Poshan Abhiyan** (POSHAN -> PM's overarching scheme for holistic nutrition) (earlier known as **National Nutrition Mission**) is being implemented since 2017. It is aimed at reducing malnutrition in the country in a phased manner, through a lifecycle approach. It focuses on children, pregnant women, and lactating mothers.
  - » It has an aim to build a people's movement (Jan Andolan) around malnutrition.
  - » For implementation of **POSHAN Abhiyan** the four-point strategy/pillars of the mission are:
    - Inter-sectoral convergence for better service delivery
    - Use of Technology (ICT) for real time growth monitoring and tracking of children
    - Intensified health and nutrition for the first 1000 days
    - Jan Andolan
  - » Target was to bring down the stunting of the children in the age group of 0-6 years to 25% by the year 2022.
- **Mission Poshan 2.0**
  - » COVID-19 had worsened the situation and therefore, it was important to multiply our efforts towards **Poshan 2.0** with full vigour.
    - It is an umbrella program that encompasses ICDS (Anganwadi Services, Poshan Abhiyan, Scheme for Adolescent Girls, National Creche Scheme ). It was announced in Union Budget 2021-22 and has merged supplemental nutrition programs and the **POSHAN Abhiyan** to tap the synergies.
    - Under this, malnutrition hotspots and aspirational districts will get extra attention.

- Steps to promote AYUSH systems for prevention of malnutrition and related diseases.
- A program to support development of Poshan Vatikas at Anganwadis centres to meet dietary diversity gap leveraging traditional knowledge in nutritional practices.
- **NFSA, 2013** which provides for coverage of upto 75% of the rural population and upto 50% of the urban population for receiving highly subsidized food grains under TPDS.
- **Pradhan Mantri Garib Kalyan Anna Yojna (PMGKAY)**

## 2) MICRONUTRIENTS VS MACRO NUTRIENTS

### A) MICRONUTRIENTS

- These are the **vitamins and minerals** that our bodies need each day in order to properly function. Unlike macronutrients they are needed in small amounts.
  - **Vitamins** can be classified into **13 major types**: Vitamins A, B-Complex (Thiamine, riboflavin (Vitamin B2), niacin, pantothenic acid, biotin, vitamin-B-6, Vitamin B12, and folate), C, D, E and K.
    - They are organic compounds. They can be classified into two categories:
      - i. **Fat Soluble**
        - A,D, E and K
        - Important role in overall health by promoting healthy bones, skin, eyesight, lungs and digestive systems.
      - ii. **Water Soluble**
        - B-Complex and C
        - Not stored in fat (like fat soluble vitamins), so daily consumption is important.
        - They boost metabolism, act as powerful antioxidant and assist in the formation of collagen helping in healing wounds.
  - **Vitamin D**
    - » Vitamin D is an essential vitamin that helps regulate calcium and phosphorus in the body. It also plays a role in maintaining bone structure.
    - » There are different forms of Vitamin D, including **ergocalciferol (Vitamin D2)** and **Cholecalciferol (Vitamin D3)**.
      - It is found in fish, eggs and fortified milk. It's also made in the skin when exposed to sunlight. During periods of sunlight, Vitamin D is stored in fat and then released when sunlight is not available.
  - **Minerals** can be further classified as **major minerals** and **trace minerals**.
    - The six major minerals include sodium, potassium, chloride, calcium, phosphorus and magnesium. They are required in large amounts in body as compared to trace minerals. They are important for maintaining proper fluid balance and electrolytes (sodium and potassium) as well as help in supporting bones, hair, skin and nail health.

- Trace minerals are required in smaller quantities, but are as important as major minerals. The **nine trace** minerals include cooper, zinc, iron, iodine, manganese, molybdenum, cobalt, selenium and fluoride.

## B) MACRO-NUTRIENTS

- These are the main nutrients that make up the foods we eat. There are three macro-nutrients - **Carbohydrate, Protein and Fat**.

### FATS - SIGNIFICANCE - LIMITATIONS AND TYPES

- **Significance of fats as nutrients**
  - It is the most concentrated form of energy. Body uses fat as a fuel source and as major storage of energy.
  - It helps in absorbing vitamins like A, D, E and K.
  - They also provide cushioning for the organs.
  - They are an important constituent of cell membrane and provide taste, consistency, and stability.

#### A) TRANS FAT VS SATURATED FAT VS MONO-SATURATED FAT VS POLY-UNSATURATED FAT

- All fats have a similar structure - a chain of carbon atoms bonded to hydrogen atoms.
- The differentiating factor is the length and shape of the carbon chain and the number of hydrogen atoms connected to the carbon atoms.

##### 1) Trans Fat (worst type of dietary fat)

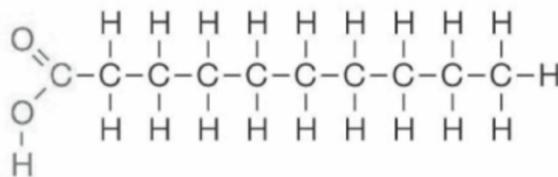
- According to the World Health Organization, approximately 5.4 lakh deaths take place each year globally because of the intake of industrially produced trans fatty acids. They come in both natural and artificial forms.
- Trans fats are the result of **partial hydrogenation of unsaturated fat**. This turns healthy oil into solids.
  - **Process:** Heating liquid vegetable oils in the presence of hydrogen gas and a catalyst, a process called hydrogenation.
  - **Advantages:**
    - Partial hydrogenation of vegetable oil makes them more stable and less likely to become rancid. The process also converts the oil into a solid, which makes it easy to handle.
    - Partial hydrogenation oils can withstand repeated heating without breaking down, making them ideal for frying fast foods.
  - **Note:** Partial hydrogenation is not the only source of trans-fat in our diet. Trans fats are also naturally found in beef fat and dairy fat in small amounts.
  - Trans fats have no known health benefits and no safe level of consumption.
- **Disadvantages:**
  - Trans-fats are worst type of fat for the heart, blood vessels, and rest of the body:

- Eating trans-fat increases harmful LDL (low density lipoprotein) cholesterol in the blood stream and reduces the amount of beneficial HDL (high density lipoprotein) cholesterol. It is linked to heart disease, stroke, diabetes, and other chronic conditions.
  - They contribute to insulin resistance.
- It is **banned** in many countries. India currently allows trans-fatty acids upto 3% (by weight).
  - In Jan 2020, FSSAI has capped the amount of trans fatty acids (TFA) in oils and fats to 3% for 2021 and 2% by 2022, from the current permissible limit of 5% through an amendment to the Food Safety and Standards (Prohibition and Restriction on Sales) Regulations.
  - **In May 2018**, WHO also gave a call to eliminate trans-fat in foods by 2023.
  - For this WHO has launched an initiative **REPLACE**, that will provide guidance for all countries on how to remove artificial trans fats from their foods, possibly leading to worldwide eradication.
    - It stands for **Review** dietary sources, **Promote** use of healthier fats, **legislate**, **assess** changes, **create** awareness, and **Enforce** regulation.
    - The initiative promotes countries to establish legislation to eliminate the trans-fats.

### 3) Saturated Fats

- A saturated fat is a type of fat in which the fatty acid chains have all or predominantly single bonds.

#### Saturated

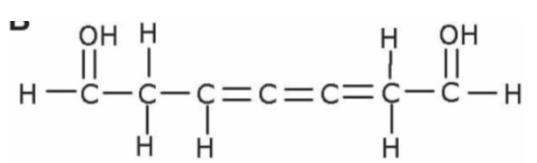
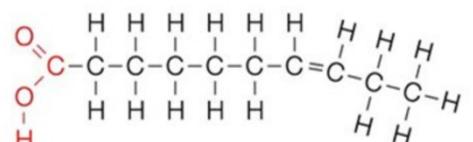


- Common **source** of saturated fats are red meat, whole milk and other whole milk dairy products, coconut oils etc.
- **Health Impacts**
  - Can drive harmful LDL cholesterol.
  - But recent research, have again raised the debate whether saturated fats are actually harmful and cause heart disease.

### 4) Monounsaturated Fat and Poly Unsaturated Fats

- **Monounsaturated Fats** are fatty acid chains that have one double bond in the fatty acid chain with all the remainder carbon atoms being single-bonded.
- **Poly Unsaturated Fats** are fatty acids with more than 1 double bond.
- Thus, these fats have fewer hydrogen atoms bonded to carbon atoms when compared to saturated fats.
- They are liquid at room temperature.
- **Sources of monounsaturated fats**

#### Monounsaturated Fat



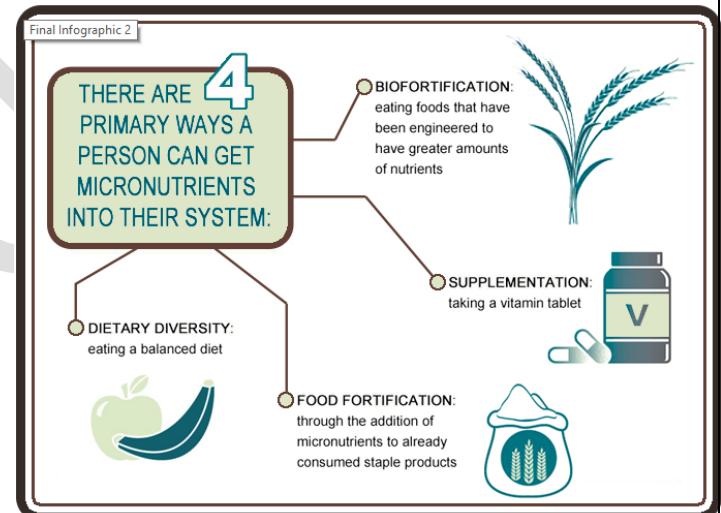
Polyunsaturated fatty acid

- Olive Oil, peanut oil, canola oil, avocados, nuts etc.
- **Sources of Polyunsaturated oils**
  - Corn oil, sunflower oil, and safflower oil, fish oil etc. are common examples.
  - These are **essential fats** and are required for normal body functioning, but our body can't make them. They are used in building of cell membrane and covering of nerves. They are also needed in blood clotting, muscle movement and inflammation.
- **Two Main types of Polyunsaturated Fatty Acids**
  - Omega-3 Fatty Acids
  - Omega-6 Fatty Acids

### 3) FORTIFICATION OF FOOD

#### A) FOOD FORTIFICATION

- Fortification means deliberately increasing the content of essential micronutrients in a food so as to improve the nutritional quality of food and to provide public health benefits with minimal risk to health.
- **Advantages of Food Fortification** over other nutrition fulfillment mechanisms:
  - **Cost Effective:**
  - **Well Proven Method:**
    - » It has been used around the world since 1920s.
    - » WHO, UNICEF, FSSAI all approve it.
  - **Eating Habits not needs to be changed**
  - **Socio-culturally more acceptable**
  - **Scalable and Sustainable:** Can be introduced quickly and can provide nutritional benefit to people in short period of time.
- **Different ways in which people get micro-nutrients** and why food fortification can be effective.
  - Since most population in resource-poor settings do not have access to adequate quantities of fruits, vegetables, and meats where micronutrients are abundant, and because providing vitamin tablets poses logistical and economic constraints, food fortification is a practical and inexpensive alternative.



#### B) BIOFORTIFICATION:

- » Biofortification is the process by which the nutritional quality of the food crops is improved through agronomic practices, conventional plant breeding, or modern biotechnology.
- » It aims to increase nutrient level in crops during plant growth rather than through manual means during processing of the crops.

- » Biofortification may therefore present a way to reach population where supplementation and conventional fortification activities may be difficult to implement and/or limited.
- » Scientists at ICAR have been developing biofortified crops in India with a view to eradicating malnutrition amongst the poor sections of society. As per ESI 2021-22, currently in India the number of biofortified varieties have increased to **87**.
  - None of these are GM crops. They have been developed through conventional crop breeding techniques.
- » E.g.
  - Zinc biofortification of wheat, rice, beans, sweet potatoes and maize

### C) RICE FORTIFICATION: EXTRUSION TECHNOLOGY:

- » In his Independence Day Speech (Aug 2021), PM Modi announced fortification of rice distributed under various government schemes, including the PDS and midday meals in schools, **by 2024**.
- » **Various technologies** are available for rice fortification - coating, dusting etc. But '**extrusion**' is considered the best technology. This involves the production of fortified rice kernels (FRKs) from a mixture using an extruder machine. The fortified rice kernels are then blended with regular rice to produce fortified rice.
- » **How does extrusion technology to produce FRK work?**
  - Dry rice flour is mixed with a premix of micronutrients, and water is added to this mixture. This mixture then goes into twin-screw extruder with heating zones, which produce kernels similar to shape and size to rice. These kernels are dried, cooled and packaged for use. FRK have shelf life of at least 12 months.
  - As per the guidelines issued by the Ministry of Consumer Affairs, Food and Public Distribution, the shape and size of the fortified rice kernel should "resemble the normal milled rice as closely as possible". According to the guidelines, the length and breadth of the grain should be 5 mm and 2.2 mm respectively.
- » **According to FSSAI norms, 1 kg of fortified rice will contain the following:**
  - Iron (28 mg-42.5 mg), folic acid (75-125 microgram), and vitamin B-12 (0.75-1.25 microgram).
  - Rice **may also be fortified** with zinc (10 mg-15 mg), vitamin A (500-750 microgram RE), vitamin B-1 (1 mg-1.5 mg), vitamin B-2 (1.25 mg-1.75 mg), vitamin B-3 (12.5 mg-20 mg) and vitamin B-6 (1.5 mg-2.5 mg) per kg
- » **Why is rice fortification needed?**
  - High levels of Anaemia and malnutrition in India. Rice is a stable crop of India.
- » **Cost of fortification:**
  - The Ministry estimates that the cost of producing FRK with three micronutrients - iron, folic acid, and vitamin B-12 - will come to around Rs 0.6 per kg. This cost is shared between centre and states and government will pay this cost to rice millers.
- » **Identification:**

- Fortified rice will be packed in jute bags with the logo ("+F") and the line "Fortified with Iron, Folic Acid, and Vitamin B12" will be mandatorily printed on them.

» **Has any other country done this?**

- Rice fortification is mandatory in 7 countries: The USA, Panama, Costa Rica, Nicargua, Papua New Guinea, Phillipines, and the Solomon Islands.

#### 4) DISEASES DUE TO NUTRITIONAL DEFICIENCIES

Disease	Deficiency of	Other comments
Rickets	Vitamin D along with calcium and potassium	<ul style="list-style-type: none"> <li>- Rickets is characterized by <u>weak and soft bones, bowed legs and bone deformities</u>.</li> <li>- <u>Fish, fortified dairy products, liver, oil and sunlight</u> are some rich sources of vitamin D.</li> </ul>
Osteoporosis	Vitamin D with Calcium	<ul style="list-style-type: none"> <li>- Deficiency of <u>Vitamin D</u> and calcium in the body can <u>negatively affect the health of the bones and spine</u>. It leads to <u>unhealthy, soft and brittle bones</u> that are prone to fractures and defects in the spine structure.</li> <li>- <u>Bananas, spinach, milk, okra, soy and sunlight</u> are natural sources of Vitamin D and calcium that act to eliminate this deficiency</li> </ul>
Pellagra	Vitamin B3 or Niacin	<ul style="list-style-type: none"> <li>- <b>4D's:</b> Dementia, diarrhea, dermatitis and death are the four Ds that characterize Pellagra.</li> <li>- <u>Tuna, whole grains, peanuts, mushrooms, chicken etc.</u></li> </ul>
Scurvy	Vitamin C or ascorbic acid	<ul style="list-style-type: none"> <li>- Scurvy basically <u>inhibits the production of collagen</u> in the body which is the <u>structural protein that connects the tissues</u>.</li> <li>• <u>Decaying of skin and gums, abnormal formation of teeth and bones, delay or inability to heal wounds and bleeding</u> are the effects of scurvy</li> <li>- <b>Vitamin C</b> can be derived from <u>Citrus fruits</u> like oranges, lemon, strawberry etc. and <u>Broccoli</u> regularly.</li> </ul>
Beri-Beri	Vitamin B1 or Thiamin	<ul style="list-style-type: none"> <li>- The most common symptoms of this illness are <u>altered muscle coordination, nerve degeneration and cardiovascular problems</u>.</li> <li>- <u>Meat, eggs, whole grains, dried beans</u> etc are rich in thiamine and thus, should be consumed in proper amounts every day to avoid this painful ailment</li> </ul>

Xerophthalmia or Night Blindness	Vitamin A	<ul style="list-style-type: none"> <li>- Xerophthalmia or night blindness is characterized by <u>blindness due to the poor growth, dryness and keratinisation of epithelial tissue or chronic eye infection.</u></li> <li>- In worsened situations, night blindness can <u>aggravate to complete loss of vision</u></li> <li>- The safest way to enhance the Vitamin A levels in the body is by <u>consuming natural food sources like carrots, green and leafy vegetables, cantaloupes etc</u></li> </ul>
Goitre	Iodine	<ul style="list-style-type: none"> <li>- Goitre leads to <u>enlarged thyroid glands</u> causing <u>hypothyroidism, poor growth and development of infants in childhood, cretinism and even mental retardation</u></li> <li>- This disease is commonly found to occur in places having <u>iodine deficit soil</u>. <u>Iodised salt and saltwater fish are rich sources of iodine</u>, and must be consumed regularly to avoid goitre.</li> </ul>
Anaemia	Iron	<ul style="list-style-type: none"> <li>- It is characterized by a <u>decrease in the red blood cell count or haemoglobin in the body</u>, resulting in <u>fatigue, weakness, dyspnoea and paleness of the body</u>.</li> <li>- It can be easily treated by changing to a <u>healthy diet and consuming iron supplements</u> on a regular basis. <u>Squashes, nuts, tofu, bran etc</u> are rich sources of iron for the body.</li> <li>- </li> </ul>
Kwashiorkor	Protein and Energy	<ul style="list-style-type: none"> <li>- It is characterized by anorexia, <u>an enlarged liver, irritability and ulcerating dermatoses</u>.</li> <li>- These are one of the <u>nutritional deficiencies in children, especially from famine-struck areas</u> and places with poor food supply, <b>Kwashiorkor is caused by malnutrition.</b></li> <li>- A healthy and balanced diet enriched with protein and carbohydrate sources like eggs, lentils, rice etc helps combat this problem</li> </ul>
Depression	deficiency of Vitamin B7 or biotin	<ul style="list-style-type: none"> <li>- This deficiency can be <u>fatal if present in an aggravated form</u>.</li> <li>- <u>Consume poultry products, dairy items, peanuts, nuts etc</u> that are rich sources of biotin. These must be consumed along with supplements to recover and prevent these illnesses</li> </ul>

## 7. SOME NUTRITION BASED UPDATES

### 1) ANAEMIA

- **What is Anaemia:**
  - » It is a condition in which number of red blood cells or the hemoglobin concentration within them is lower than normal or there are abnormal red blood cells.
  - » This negatively hampers the ability of blood to carry oxygen to tissues (Note: It is the hemoglobin which attaches to oxygen).
  - » It results into symptoms such as fatigue, weakness, dizziness, shortness of breath etc.
- **Causes:**
  - » **Nutritional Deficiency** - particularly iron deficiency, deficiency of folate (vitamin B-9 is important for RBC formation and for healthy growth and function), vitamin B12 and Vitamin A.
  - » **Haemoglobinopathies:** (hemoglobin C disease, hemoglobin S-C disease, Sickle Cell Anemia, and Thalassemia)
  - » **Infectious** diseases which impact blood such as malaria, TB, HIV and parasitic infections may also cause Anaemia.
- **Impact:**
  - » Anaemia compromises immunity and impedes cognitive development.
- **Global Situation:**
  - » As per WHO, around 42% of children under 5 and 40% of pregnant women worldwide are anaemic.
- **Anaemia Situation in India:**
  - » Between 2005 - 2015, the anaemia situation declined marginally in India.
  - » **But, as per the NFHS-5, the incidence of Anaemia in under-5 children (from 58.6 to **67%**), women (53.1% to 57%) and men (22.7% to 25%) has worsened in all states of India (20%-40% is considered moderate) (when compared to NFHS-4)**
- **Factors which cause high levels of Anaemia?**
  - » Cereal centric diet with less consumption of iron rich food groups like meat, fish, eggs, and Dark Green Leafy Vegetables (DGLF).
  - » Poor sanitation situation; lack of women empowerment etc.
- **India's great anaemia mystery – class discussion**

## 8. VIRAL DISEASES VS BACTERIAL DISEASES

### i. Why can't we cure virus infection?

- **Bacteria** are living cells. They have outer antigens which can be targeted by human immune system and form the basis of vaccines. The cells of a bacteria contain unique (to bacteria) structures which can be disrupted by bactericidal antibiotics without affecting human cells too

much; these provide broad targets for therapy. The majority of bacteria find a place to grow inside a human/further invade tissues, but don't actually enter and live within a human cell. This gives them greater exposure to antibiotics and easier exposure to immune system.

- **Bacteria are virulent by two mechanisms.**
  - **Toxin production**
  - **Invasion/inflammation**
  - Exotoxins in particular are often treated with formaldehyde, acid, or heat in order to convert them into toxoids, which means they are still antigenic but have lost their toxicity. This provides another critical target for vaccines and treatments of bacteria that doesn't exist in (most) viruses. **Component of bacterial vaccines include these inactivated toxoids**, the outer capsular antigens of bacteria without the bacteria inside or other purified bacterial proteins, killed bacteria, or live (attenuated) bacteria.
  - Furthermore, antitoxins (pre-formed immune globulins which will target the bacterial antigens) are available to counteract the toxins of such bacteria as tetanus, diphtheria etc.
- **Bacteria** can also be targeted by several branches of immune system at its own.
- **Viruses** on the other hand are not cellular. We can't kill them simply by disrupting their cells. They are infective nucleic acid that cannot replicate outside living cells.
  - Some viruses replicate inside human cells and then bud off from the human cell inside an "envelope" made from the human cell's membrane, which helps them evade the immune system on their way to infecting another human cell.
  - Many viruses are protected by protein capsids, which are extremely protective -- unlike a bacterial cell wall or membrane, the virus doesn't have to be alive inside the capsid or exchange nutrients and waste with environment across the capsid; the capsid is merely there to protect the nucleic acid of the virus.
  - **Each virus uses a different receptor**
    - Viruses need to match some sort of receptor in order to gain entry into human cells, and in some viruses, this receptor is one of the few good targets for drug therapy; however, unlike antibacterial, the drug will only work for that particular virus/receptor, because each virus uses a different receptor

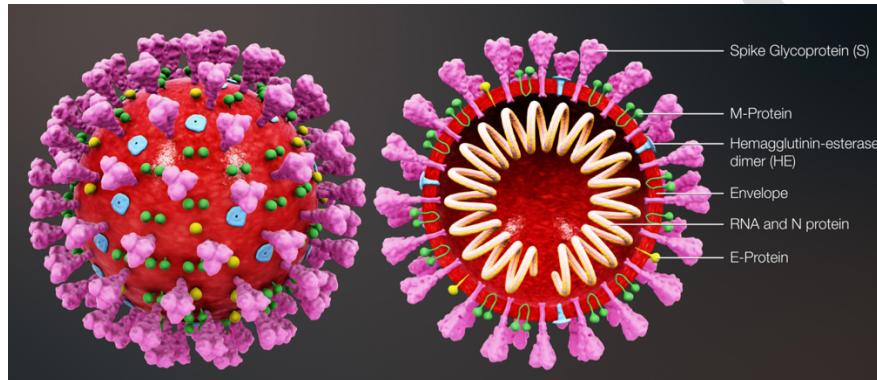
## 9. COVID-19

### 1) CORONA VIRUSES

- Coronaviruses are a group of viruses in the **subfamily Orthocoronavirinae**, in the **family Coronaviridae**. In humans they are known to cause infection in upper respiratory tract (sinuses, nose and throat) and/or lower respiratory tract (windpipe and lungs).
  - » **Most** of these viruses are harmless, but **some** can cause less severe common cold to more severe diseases such as severe acute respiratory syndrome (SARS), Middle East Respiratory Syndrome (MERS) and COVID-19.

- Coronaviruses were first identified in the 1960s. Almost everyone gets a coronavirus infection at least once in their life, most likely as a young child. The symptoms of most coronavirus are similar - a runny nose, coughing, sore throat and sometimes a fever.
- Many Coronaviruses are zoonotic i.e., they are transmitted from animals to humans.
  - » **SARS** coronavirus is believed to be an animal virus from an as-yet-uncertain animal reservoir, perhaps bats, that spread to other animals (civet cats) and first infected humans in the Guangdong province of Southern China in 2002.
  - » The **MERS** coronavirus was passed on from dromedary camels to humans in Saudi-Arabia in 2012.
  - » **SARS-COV-2** also seems to have transmitted from bats to humans (not confirmed yet). Pangolin may have acted as intermediary.
    - Note: SARS-COV-2 is a coronavirus very similar to the one that causes SARS.

- **Structure**



- » They are enveloped viruses with a positive sense single stranded RNA genome and a nucleocapsid of helical symmetry.
- » The genome size of the coronaviruses ranges from approximately 26 to 32 kilo bases, one of the largest among RNA viruses.

## 2) SARS-COV-2: NAMING, STRUCTURE AND PHYSIOLOGY

- SARS-COV-2 is one of the seven known types of known Corona virus, including SARS and MERS.
  - » **Naming of the Virus:** The Coronavirus Study Group of the International Committee on Taxonomy of Viruses, which had assessed the novelty of the human pathogen, has named the virus as "Severe Acute Respiratory Syndrome Coronavirus 2", or "**SARS-COV-2**".

## 3) STRUCTURE OF THE VIRUS

- Like other Coronaviruses, SARS-COV-2 virus particles are spherical in shape and have mushroom shaped protein called spikes protruding from their surface.
  - » The **spike binds and fuses with human cells**, allowing the virus to gain entry.
  - » The spike protein of the novel coronavirus **shares 98% sequence identity** with the spike protein of the bat coronavirus.
  - » The spike of the virus has something called a receptor binding domain (RBD) which facilitates the virus entry into the target cells by binding with the cellular receptor called Angiotensin

**Converting Enzyme 2 (ACE2)**, which serves as the entry point into human cells. SARS corona virus also used the same mechanism for entry into the cells.

- But unlike SARS the case of SARS Corona, the **spike protein of the novel coronavirus binds to the cell receptor with much higher affinity - 10 to 20-fold higher**.
- This much higher binding affinity to the cell receptor explains high human to human transmission of the virus compared to SARS coronavirus.
- The virus (or virus particle) is **50-200 nm** in diameter.

#### 4) NAMING OF THE DISEASE – CORONA VIRUS DISEASE-19 (COVID-19)

- On Feb 11, 2020, the **WHO officially announced COVID-19** as the name for the disease caused by the n-COV (novel Coronavirus)
  - » The name has a **standard format** to be used in any future corona virus disease.
- **Why was it important to name the disease?**
  - » To prevent the use of other names that can be "inaccurate or stigmatizing".
- Based on WHO's May 2015 guidelines.

#### 5) COVID-19 DISEASE CAUSED BY INFECTION OF SARS-COV-2 (2019 N-COV)

- **Early symptoms** include - Fever, Dry Cough and Fatigue.
- The virus can lead to **pneumonia, respiratory failure, septic shock**, and **death**.
- **How does SARS-CoV-2 spread?**
  - It mainly spreads from person to person.
    - When a sick person coughs or sneezes, droplets containing virus are released in air, on various surfaces. If you inhale or swallow this virus, the virus gets into your body.
- **Vertical Transmission across Placenta**
  - » A study has found evidence that confirms vertical transmission of SARS-CoV-2 virus from the mother to foetus. The route of infection is **through the womb (in utero)** well before onset of labor and delivery of baby.
- **What is community transmission?** (Class discussion)
- **Reproduction Number (R₀)** (pronounced R naught) is used to describe the intensity of an infectious disease outbreak.
  - » Early studies of **COVID-19** in Wuhan estimated the average R₀ between 2.2 and 2.7.

#### 6) DIAGNOSIS

- Antibody test
- RTPCR

## 7) CYTOKINE STORMS AND ITS IMPACT ON COVID-19 DEATHS

- What are Cytokines and what is their role in immune system?
  - » Cytokines are small proteins released by many different cells in the body, including those of the immune system where they coordinate the body's response against infection and trigger inflammation.
  - » Cytokines are signalling proteins that are released by cells at local high concentration.
- However, sometimes the body's response to infection can go to overdrive: Cytokine Storm Syndrome  
-> Immune system over reacts

## 8) MUCORMYCOSIS OR BLACK FUNGUS

- Details
  - » The disease is caused by a group of molds known as mucormycetes present naturally in the environment.
    - It mainly effects people who are on medication for health problems that reduce their ability to fight environmental pathogens. It generally doesn't pose a serious threat to individuals with healthy immune system.
- Treatment: Antifungal medicines; Surgery may be required in worse cases.
- Management of COVID-19 patients with Mucormycosis is a team effort involving microbiologists, internal medicine specialists, intensivist neurologist, ENT specialists, ophthalmologists, dentists, surgeons and others.
- Life after Mucormycosis:
  - It can lead to loss of upper jaw and sometimes even the eye.
    - » Once the patient stabilizes, prosthetic replacement of the missing facial structures can commence.

## 9) VARIANTS OF CONCERN

- Variant of Concern: WHO classifies a variant as Variant of Concern when it is associated with an increase in transmissibility or detrimental change in COVID-19 epidemiology; increase in virulence; or decrease in effectiveness of the public health measure or available diagnostics, vaccines, therapeutics.
- So far, WHO has 5 variants of concerns (Omicron was the fifth one)



### A) DETAILS OF DELTA VARIANT

- » The original Wuhan variant mutated into the **Alpha, Beta, Gamma and Delta Variants**.
  - » Note: All mutations don't mean that they are more harmful.
- The Delta variant, or the B.1.617.2 lineage was **first discovered in Maharashtra, India, in Oct 2020**.
    - » It has **mutation in its spike protein**, which helps it bind to the ACE2 receptors present on the surface of the cells more firmly, making it more transmissible and capable of evading the body's immunity.
  - Key characteristics of Delta Variants:
    - » Delta variant spreads faster and reduces protection gained from previous infections or vaccines
    - » Doesn't cause more severe illness
    - » Vaccines are effective (a bit less) on delta variants. It's just that delta variant is less sensitive to neutralizing antibodies.
  - Why Delta variant spreads faster?
    - » Evolution (Class discussion)

## B) DETAILS OFOMICRON VARIANT (VARIANT B.1.1.529)

- » Omicron is WHO's fifth variant of concern.
- » It was first reported to WHO on 24th Nov 2021 and was classified as a variant of concern by WHO on 26th Nov 2021.
- » It spreads much easily than original virus and the Delta variant.
- » It generally causes less severe disease than infection with prior variants.
- » Symptoms: Similar to previous COVID-19 symptoms.

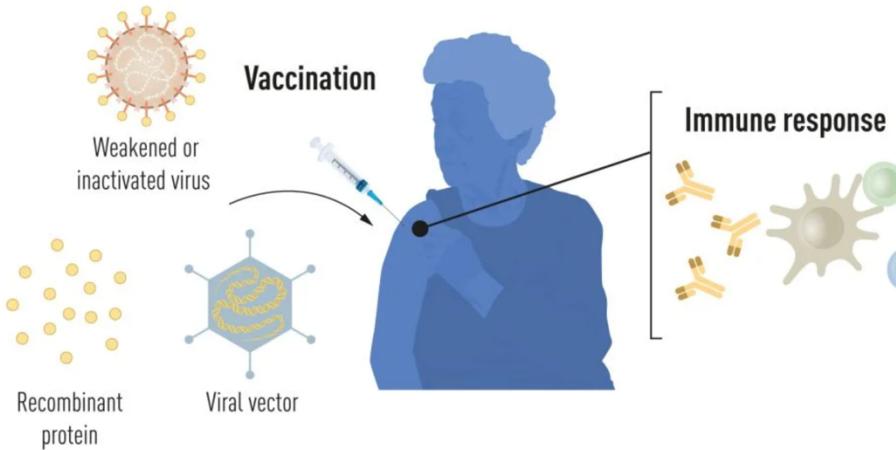
## C) RECENT MUTATIONS IN NEWS:

**FLip:** The omicron subvariant JN.1. is likely to soon become the dominant lineage of the SARS-CoV-2 virus worldwide, according to researchers at the University of Tokyo. The subvariant has a mutation in its spike protein, L455S, also called a "FLip" mutation.

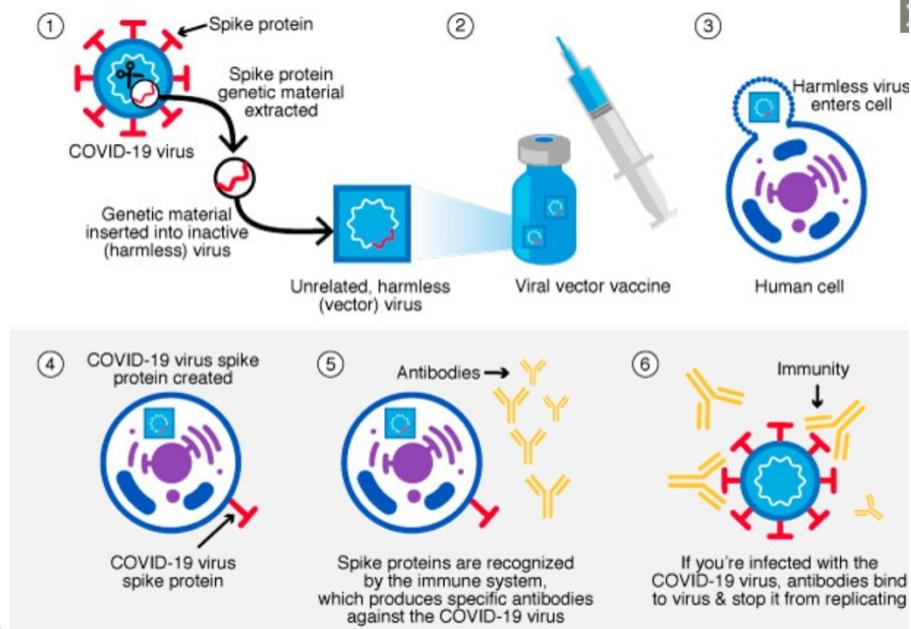
## 10. VARIOUS TYPES OF VACCINES:

- 1) **Live Attenuated virus vaccines** such as the combined rubella-mumps-measles vaccines and the yellow fever virus vaccine, induce robust and long-lived antibody and T-cell mediated immunity.
  - Note: For the development of yellow fever vaccine, Max Theiler was awarded the Nobel Prize in Physiology or Medicine in 1951.
  - These vaccines induce effective but transient immune responses, requiring repeated boosting.
  - COVID-19 vaccine developed using this mechanism - Covaxin developed by Bharat biotech.
- 2) **Viral Vector Vaccines:** It uses a safe virus (not harmful) which serves as a platform to produce target proteins to generate immune response.

- Such viral vector efficiently enter cells where the encoded antigen are produced by the bodies protein synthesis machinery.
  - The first example of a licensed viral vector vaccine was the Vesicular stomatitis virus - based vaccine against Ebola, approved in 2019, which was soon followed by an adenovirus based Ebola vaccine.



- During COVID-19 various vaccines
  - Oxford-AstraZeneca (ChAdOx1 nCoV-19) used adenovirus route.
    - Covishield used in India is a version of this.
  - Sputnik V Vaccine also has gone adenovirus route.



- Both the above methods (live attenuated virus or viral vector vaccine) used cell culture based manufacturing facilities which is resource intensive. Further they may also introduce diseases and is safer and stable than vaccine containing whole pathogens.
- Therefore, researchers have focused upon **sub-unit vaccines** that circumvent the need of large-scale cell cultures by delivering nucleic acid (DNA or mRNA) directly to vaccine recipients, exploiting the body's own capacity to produce proteins.

### 3) Sub-Unit Vaccines: (Protein subunit vaccines)

- Protein subunit vaccines include only the parts of virus that best stimulate immune system. These vaccines contain single protein components of the respective virus and are referred as subunit vaccine.
  - It includes Hepatitis B Vaccine (HBV) and Human papillomavirus (HPV) vaccine.
- **advantages:**
  - » No risk of introducing the disease and is safer and stable than vaccine containing whole pathogens.
  - » Suitable for immunocompromised individuals.
  - » Well established tech
- **Disadvantage**
  - Relatively complex to manufacture (compared to other vaccines like RNA vaccines)
  - May require multiple doses.
- **COVID-19 vaccine** developed using this method:
  - **Corbevax** is a protein subunit COVID-19 vaccine developed by Texas Children hospital. It delivers spike protein to the body directly.
    - **How was protein manufactured?**
      - Add gene of spike protein into yeast to produce large amount of proteins. After isolating the virus spike protein from the yeast and adding an adjuvant, which helps trigger an immune response, the vaccine was ready.

### 4) DNA and RNA subunit vaccines:

- » **Advantages** of sub-unit vaccines (DNA or mRNA vaccines)
  - **Less Resource intensive** and thus easy to manufacture.
  - **More flexibility** - Since the sequence can be easily changed to encode different antigens.
  - This also makes iterative testing of new candidate vaccines and generation of updated vaccines rapid and efficient.
- » **Initially DNA vaccine was thought to be more promising** but didn't translate into success. A likely reason for it was that injected DNA must cross two barriers, the plasma membrane and the nuclear membrane, to reach the cellular compartment where transcription takes place (DNA conversion to mRNA). In contrast, mRNA-based vaccines only need to gain access to the cell cytoplasm where translation takes place (mRNA conversion to protein)
- » **Another advantage of mRNA vaccine:** Delivered nucleic acid can't integrate into the host genome. This is an additional safety aspect of this method.
  - **E.g for mRNA vaccine** (developed for COVID-19): Moderna COVID-19 (mRNA-1273) vaccine.

## 1) 2023 NOBEL PRIZE IN PHYSIOLOGY OR MEDICINE

- The 2023 Nobel Prize in Physiology or Medicine has been awarded to **Katalin Kariko** (Hungary) and **Drew Weissman** (USA) for their discoveries concerning nucleoside base modifications that enabled the development of effective mRNA vaccine against COVID-19. Through their groundbreaking findings, which have fundamentally changed our understanding of how mRNA interacts with our immune system, the laureates contributed to the unprecedented rate of vaccine development during the COVID-19 crisis.

- **Background:**

- During the 1980s, efficient methods of producing mRNA without cell culture were introduced, called in-vitro transcription. Ideas of using mRNA technologies for vaccine and therapeutic purposes also took off, but roadblocks lay ahead.

<b>In vitro transcription</b>	In vitro transcription is a laboratory technique used to synthesize RNA molecules outside of a living cell. This process involves using a DNA template and the enzyme RNA polymerase to generate a complementary RNA strand. In vitro transcription is a fundamental tool in molecular biology and biochemistry, and it has various applications, including the production of RNA molecules for research, such as RNA probes, RNA sequencing, and gene expression studies
-------------------------------	---

- In vitro transcribed mRNA was considered unstable and challenging to deliver. It required development of sophisticated carrier lipid systems to encapsulate the mRNA.
  - This mRNA also gave rise to inflammatory reactions.
  - These problems limited the enthusiasm for developing the mRNA technology for clinical purposes.

- **Contributions:**

- In 1990s, Kariko was an assistant professor at the University of Pennsylvania and met immunologist Drew Weissman there.
  - They worked together to prevent the immune system from launching an inflammatory reaction against lab-made mRNA, previously seen as a major hurdle against therapeutic use of mRNA.
    - They found that inflammatory response was almost abolished when base modification was included in the mRNA. Therefore, in 2015 they published those adjustments (modifications) to nucleosides, can keep the mRNA under the immune system's radar.
    - Later, they also showed that the delivery of mRNA generated with base modification markedly increased protein production compared to unmodified mRNA. This effect was due to the reduced activation of an enzyme that regulates protein production.

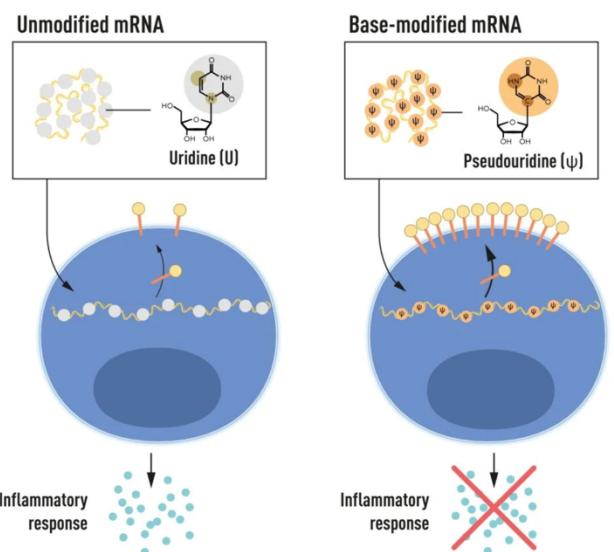
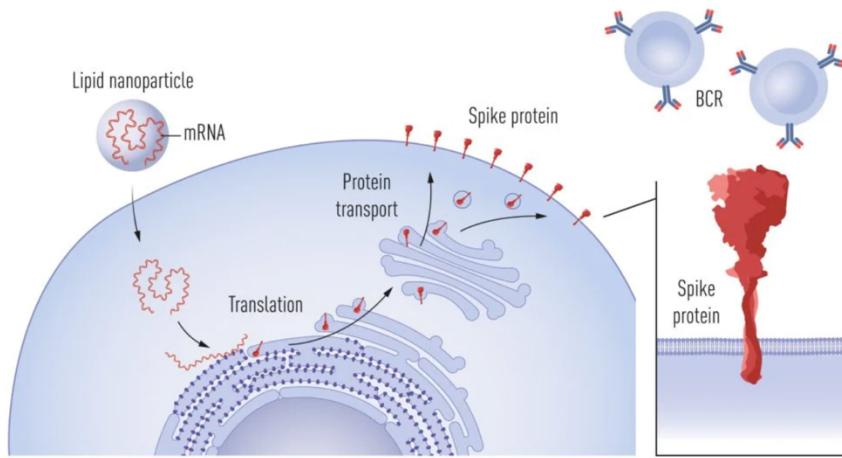


Figure 2. mRNA contains four different bases, abbreviated A, U, G, and C. The Nobel Laureates discovered that base-modified mRNA can be used to block activation of inflammatory reactions (secretion of signaling molecules) and increase protein production when mRNA is delivered to cells.

© The Nobel Committee for Physiology or Medicine. III, Mattias Karlén

- **Development of Vaccines:**
  - After the above discoveries, interest in mRNA technology picked up. Vaccines for Zika and MERS-CoV were pursued.
  - **After the outbreak of COVID-19 pandemic**, two base-modified mRNA vaccines encoding the SARS-CoV-2 surface protein were developed at record speed. Protective effects of around 95% were reported, and both vaccines were approved as early as Dec 2020.
  - The impressive flexibility and speed with which mRNA vaccines can be developed pave the way for using the new platform also for vaccine against other infectious diseases.
  - In the future, the technology may also be used to deliver therapeutic proteins and treat some cancer types.

- **How mRNA vaccine protects you against COVID-19:**



**Figure 4. Spike production following mRNA vaccination and recognition of spike by B cells.**  
Following uptake of mRNA into cells, facilitated by lipid nanoparticles, the mRNA acts as a template for spike protein production. Spike is then transiently expressed on the cell surface, where it is recognized by B cells via their B cell receptors (BCRs), stimulating the secretion of spike-specific antibodies.

© The Nobel Committee for Physiology or Medicine. Ill. Mattias Karlén

- Through their fundamental discoveries of the importance of base modification in mRNA, this year's Nobel Laureates critically contributed to this transformative development during one of the biggest health crisis of our time.

## 11. OTHER VIRAL DISEASES

### 1) MEASLES

- **Measles** is a highly contagious infectious disease caused by measles virus. It spreads through air when an infected person coughs or sneezes. It is an acute respiratory illness. **Infection** is characterized by a prodrome of fever (as high as 105 degree F) and malaise, cough, coryza, and conjunctivitis - the three "C"s, followed by maculopapular rash. The rash spreads from the head to the trunk to the lower extremities.
  - It can severely sicken young children, but is normally kept under check due to large-scale vaccination.
- **About the Virus:**

- It is a single stranded, enveloped RNA virus with 1 serotype. It is classified as a member of the genus Morbillivirus in the Paramyxoviridae family.
  - Humans are the only natural host of the measles virus.
- **Detection:** RT-PCR; Anti-body test
- **Vaccinations:** Measles can be prevented with **Measles-containing vaccine**, which is primarily administered as the combination of measles-mumps-rubella (MMR) vaccine.
  - It can be used for children aged 12 months through 12 years. One dose of MMR vaccine is approximately 93% effective and two doses are approximately 97% effective.
- **Rise of Cases in 2022:** Covid-19 led to disruption in routine vaccination in 2020 and 2021.
- **WHO Report and India's Response (Nov 2023)**
  - A new report from the WHO and US Centre for Disease Control and Prevention (CDC) said measles cases in 2022 have increased by 18%, and deaths by 43% globally, compared to 2021.
    - **Cases:** 9 million & **Deaths** - 1,36,000
  - The report also said that globally 22 million children and in India 1.1 million infants didn't get the first dose of vaccine.
  - **India has differed from this report:**
    - MoH&FW says that just over 21,000 Indian children didn't get the shot.

## 2) RUBELLA

- Rubella is a contagious viral disease. Most people who get Rubella usually have a mild illness, with symptoms that can include a low-grade fever, sore-throat, and a rash that starts on the face and spreads to the rest of the body. It can cause a miscarriage or serious birth defects in a developing baby if a woman is infected while she is pregnant.
- **The best protection** against rubella is **MMR** (Measles, Mumps, Rubella) vaccine.

## 3) HUMAN IMMUNODEFICIENCY VIRUS (HIV) AND AIDS (ACQUIRED IMMUNODEFICIENCY SYNDROME)

- **Why in news?**
  - » Hopes dashed as last HIV vaccine trial in Africa for his decade ends in failure (Dec 2023: Source - DTE)
- **Introduction:**
  - » **About virus:**
    - HIV are two species of Lentivirus (genus) of Retroviridae family. The virus first emerged in 1920 in Kinshasa (then Leopoldville), Belgian Congo.
  - » The Human Immunodeficiency **Virus (HIV)** targets the immune system and weakens people's surveillance and defence systems against infections and some types of cancers.

- As the virus destroys and impairs the function of the immune cells, infected individuals gradually become immunodeficient. Immune function is typically measured by CD4 cell count (a type of white blood cells).
  - The most advanced form of HIV infection is **acquired immunodeficiency syndrome (AIDS)**, which can take from 2 to 15 years to develop depending on individual. It is defined by developments of certain cancers, infections, or other severe chemical manifestations.
- **Transmission**
- » Exchange of a variety of body fluids - blood, breast milk, semen and vaginal secretion
  - » **Note:** Individual can't be infected through ordinary day to day contact such as kissing, hugging, shaking hands, sharing food or water etc.
- **Behaviours or conditions which can put individual on risk:**
- » Unprotected sex (including anal); use of contaminated syringes; unsafe blood transfusion; from mother to unborn child etc.
- **Diagnosis**
- » **Three types of tests:**
    - **Antibody test**
    - **RNA (viral load) test (RT-PCR)**
    - **A Combination test.**
      - It detects both antibodies and viral protein called p24 (antibody-antigen test, or HIV Ab-Ag test).
      - P24 forms part of the core of the virus (an antigen of the virus).
- **Prevention**
- » **Avoid risk behaviours** (i.e. use condoms, test and counsel for HIV and STIs, Voluntary medical male circumcision, using only sterile injecting instruments)
  - » **Antiretroviral (ART) use for prevention.**
    - **ART as Prevention** - If an HIV positive person adheres to an effective ART regimen, the risk of transmitting the virus to their uninfected sexual partner can be reduced by 96%.
    - **Pre-exposure prophylaxis (PrEP) for HIV negative partner:** Oral PrEP of HIV is the daily use of ARV drugs by HIV uninfected people to block the acquisition of HIV.
    - **Post Exposure prophylaxis for HIV (PEP):** PEP is the use of ARV drugs within 72 hours of exposure to HIV in order to prevent infection. PEP includes counselling, first aid care, HIV testing, and administering of a 28-day course of ARV drugs with follow up care.
  - » **Drug releasing Vaginal Ring Cap:** To prevent HIV-AIDS in Women
    - The ring is made of flexible silicon matrix polymer. The woman inserts it into the vagina, where it, over the course of a month, releases the antiretroviral drug dapivirine. It has to be changed after 28 days.

---

#### A) STEM CELL THERAPY TO TREAT HIV HAVE SHOWN SUCCESS:

- » In 2022, a US patient was reported cured of HIV after stem cell transplant. By July 2023, six persons had been cured by this method.

- » In the first five cases, the treatment teams specifically looked for donors with CCR5 delta 32 mutation. It is associated with lower risk of HIV.
  - People who inherit CCR5 delta 32 mutation from both parents don't have the receptors which are used by HIV virus to enter the cells. Those who inherit the mutation from one of the parents have fewer receptors and are less likely to get infection.
  - Only 1% of the people on earth carry 2 copies of CCR5-delta 32 mutation.
- » **Why can't stem cell transplant become routine treatment for HIV?**
  - Finding matching donor for all 40 million patients would be impossible.
  - The CCR5 delta 32 mutation occurs mostly in Caucasians whereas most of the cases are in the African continent.
  - Further, stem cell transplant is a complex process and comes with its own risks.
- **SDG Goal 3.3:** To achieve the end of AIDS by 2030 i.e. zero new infection by 2030.

---

#### B) GLOBAL SITUATION OF HIV:

- **Successes Achieved in HIV Response:**
  - » As per UNAIDS, in 2022, 39 million people globally were living with HIV, of whom 29.8 million were accessing ART.
    - Coverage of ART has become 4 times of the number in 2010.
  - » **New Cases:** Around 1.3 million people got newly infected with HIV in 2022 - which is 59% lower from the peak in 1995.
  - » It is possible to end AIDS by 2030: UNAIDS.

---

#### C) VACCINATION EFFORTS:

- **Hopes Dashed as last HIV vaccine trial in Africa for this decade ends in failure (Dec 2023)**
  - » The study, known as **PrEPVacc**, was led by African researchers with support from European Scientists.
    - They were testing two different vaccine regimes on about 1500 volunteers in Uganda, Tanzania, and South Africa.
  - » After, multiple other high-profile trials failed in the past, PrEPVacc researchers were quite optimistic and had described the latest study as the final trial of the decade.

---

#### D) HIV SITUATION IN INDIA

- » More than 2 million people in India live with HIV.
  - HIV Epidemic has an overall decreasing trend in the country with estimated annual new HIV infections declining by 37% between 2010 and 2019.
- » **Success in controlling AIDS.**
  - 2015 HIV estimates results reaffirm the country's success story in responding to HIV/AIDS epidemic. India has successfully achieved 6th Millennium Development Goal (MDG6) of halting and reversing the HIV epidemic.

- » **Emergence of three north Eastern States as new HIV Hotspots: Mizoram (1.19%), Nagaland (0.82%), Meghalaya (0.73%), Tripura (0.56%) and Manipur (0.47%)**
  - Reasons: Injecting Drug Users and Unsafe Sexual Practices.
  
- **Steps taken by government of India in recent times to Reduce HIV transmission.**
  - **National Aids Control Program** was launched in 1992 and its four phases have been completed so far. It is a central sector scheme.
    - » It has been extended for five years (1st April 2021 to 31st March 2026)
    - » It is a comprehensive program for prevention and control of HIV/AIDS in India.
    - » Under this, ART Centres run by National AIDS Control Office (NACO) provide lifetime free medicines, diagnostic kits and other essentials for those in need.
  - **National Aids Control Organization (NACO)**, under MoH&FW, provides leadership to HIV/AIDS program.
  - **HIV & AIDS Prevention and Control Act 2017** provides a legal framework for protecting the rights of HIV positive people.
  - Implementation of **90:90:90** strategy adopted by UNAIDS
  - **Other steps** include - Multimedia campaigns; Red ribbon clubs in colleges; training and sensitization program for SHGs; etc;

## 4) POLIO

- **Basics:**
  - » Polio is a highly infectious disease caused by a virus. It invades the nervous system and can cause total paralysis in a matter of hours.
  - » **Transmission:** The virus is transmitted by person to person and spread mainly through faecal-oral routes, or less frequently by, a common vehicle (e.g., contaminated water or food) and multiplies in the intestine.
  - » **Affect:** 1 in 200 infections leads to irreversible paralysis (usually in legs). Among those paralyzed, 5% to 10% die when their breathing muscles become immobilized.
  - » **People most at risk**
    - Polio mainly affects children under five years of age
  - » **Prevention and Cure**
    - There is no cure
    - It can only be prevented. **Polio vaccine** given multiple times can protect a child for life.
  
- **Three Different strains of Polio Virus**
  - » 3 strains of poliovirus (type 1, type 2, and type 3).
  - » Wild polio virus **type 2 was eradicated in 1999**.
  - » Wild Polio virus **type 3 was eradicated in 2019**.
    - WPV3 is the **second strain of the polio virus to be wiped out**, following the certification of the eradication of WPV2 in 2015.
    - The **last case of WPV3** was detected in Northern Nigeria in 2012.

---

## A) TWO TYPES OF VACCINES: OPV AND IPV

- **Oral Polio Vaccine (OPV)** is taken orally as drops. It has served as the main preventive measure against polio and is easily administered not requiring very trained health workers. Further, the cost per dose of OPV is much less than IPV. It also leads to passive immunization.
  - **Other Advantages**
    - **Passive immunization**
  - **Limitations**
    - Virus may mutate and turn virulent Or;
    - Virus may multiply in intestine and spread through excreta and over the period mutate to become virulent.
- **Inactivated Polio Vaccine (IPV)** is given through an injection by a trained health worker.
  - It is not a "live" vaccine (i.e. it is inactivated) and thus carries no risk of vaccine associated paralysis.
  - In countries still using OPV, IPV hasn't replaced OPV but is used to strengthen a child's immune system and protect them from polio.

---

## B) ISSUE OF VACCINE DERIVED POLIO VIRUS

- **How vaccines may lead to infection**
  - Oral Polio Vaccine (OPV) contains an attenuated vaccine-virus. This weak form of the virus is used to activate an immune response in the body, which protects the child when challenged by WPV.
  - But when child is immunized with OPV, the virus replicates in the intestine and during this time the virus is excreted.
- **WHO recommendations**
  - » Use of OPV must eventually be stopped (starting with OPV containing Type-2 poliovirus) worldwide and at least one dose of IPV must be introduced, to protect against Type-2 Polio virus and to boost population immunity.
  - » **Why??**
    - Since, wild Polio virus of type 2 was eradicated in 1999, the risk of paralytic disease due to OPV type 2 now outweighs its benefits.
    - A single dose of IPV before OPV protects against VAPP (Vaccine Associated Paralytic Poliomyelitis).
- **IPV is very safe** vaccines in humans, whether used alone or in combination vaccines.
  - » No serious adverse events have been reported, only minor side effects.
- **Situation in India**
  - » India was declared Polio free in 2014, 3 years after the last case of Polio in 2011. But we still see cases of **vaccine derived Polio**.
  - » Further, there have been cases of Non-Polio Acute Flaccid Paralysis (NPAFP) which are associated with OPV.

## 5) EBOLA VIRUS DISEASE (EVD)

- **Introduction:**
  - » The Ebola virus causes an acute, serious illness which is often fatal if untreated.
  - » Ebola Virus Disease first appeared in 1976 in two simultaneous outbreaks, one in Nzara, Sudan, and the other in Yambuku, Democratic Republic of Congo. The later occurred in a village near the Ebola River, from which the disease takes its name.
  - » **2014-2016 outbreak:** This outbreak in Wet Africa was the largest and most complex Ebola outbreak since the discovery of virus. It had mostly impacted **Guinea, Sierra Leone and Liberia**.
- **Virus:** The virus family Filoviridae includes the Ebolavirus genus. This Ebolavirus Genus has 5 identified species so far: Zaire, Bundibugyo, Sudan, Reston and Tai Forest. The first three Zaire Ebola virus, Bundibugyo Ebolavirus, and Sudan Ebolavirus have been associated with large outbreaks in Africa. 2014 outbreak has been caused by Zaire Ebolavirus.
- **Transmission**
  - **Introduction in Human:** It is believed that fruit bats of the Pteropodidae family are natural Ebola virus hosts.
  - **Human to Human:** Via direct contact (through broken skin or mucous membranes) with the blood, secretions, organs or other fluids of infected people, and with surface and materials (e.g., bedding clothing) contaminated with these fluids.
- **Diagnosis**
  - **Difficult to distinguish EVD from other infectious diseases** such as malaria, Typhoid fever and meningitis.
  - **Confirmation tests:** Electron Microscopy, ELISA, RT-PCR etc.
- **Treatment and Vaccine**
  - Supportive care rehydration with oral or intravenous fluids - and treatment of specific symptoms, improves survival.
  - There is as yet no proven treatment available for EVD.
  - **Vaccines** has been developed and is being used in DRC.
    - Vaccine rVSV-ZEBOV (tradename "Ervebo") was approved by US FDA in Dec 2019.
  - **Monoclonal Anti-Bodies** have also been found effective in treatment: WHO

## 6) RABIES

- **About Rabies:**
  - » It is a vaccine preventable viral disease which occur in more than 150 countries in the world.
    - » **Dogs** are the main source of human rabies deaths, contributing to 99% of all rabies transmission to humans.
      - It is spread when infected animal bites or scratches a human or other animal. Saliva from an infected animal can also transmit rabies if the Saliva comes into contact with the eyes, mouth, or nose.

- » **Interrupting transmission** is feasible through vaccination of dogs and prevention of dog bites.
- » **Immediate, thorough wound washing with soap and water** after contact with a suspected rabid animal is crucial and can save lives.
- » **Rabies** is virtually 100% fatal once the clinical symptoms appear. And it is also **100% vaccine preventable**.
- » **WHO** is also leading a collective “**United Against Rabies**” to drive progress towards “Zero Human Deaths from dog mediated rabies by 2030”.
- » **World Rabies Day** is held on 28th September.
  
- » **About the Virus:**
  - » It is caused by lyssaviruses, including the rabies virus and Australian bat lyssavirus.
  - » The virus infects the central nervous system. If a person doesn't receive the appropriate medical care after potential rabies exposure, the virus can cause disease in the brain, ultimately resulting in death.

- **Situation of Rabies in India**

- As per WHO India is endemic to rabies and suffers approx. 36% of the world's human rabies deaths, transmitted by dogs.

- **Key Highlights about Efforts in India:**

- The ministers have urged all the States to make Rabies a notifiable Disease.
- They launched 'Joint Inter-Ministerial Declaration Support Statement' for elimination of Dog Mediated Rabies from India by 2030 through One Health Approach.
- On the occasion of the World Rabies Day (28<sup>th</sup> Sep), the MoH&FW and the Minister of Fisheries, Animal Husbandry and Dairying unveiled the National Action Plan for Dog mediated Rabies Elimination by 2030 (NAPRE).

## 7) HUMAN PAPILLOMA VIRUS (HPV)

- **What is HPV?**

- » HPV is a group of 150 related viruses.
- » **Cancer Causing:** Some HPV can lead to cancer, especially cervical cancer.
- » There are more than 40 HPV that can infect genital areas of males and females.

- **How do people get HPV?**

- » Transmitted through intimate skin to skin contact which can happen during vaginal, anal or oral sex with someone who has virus. **Most common sexually transmitted disease**. HPV is so common that nearly all sexually active men and women get it at some point in their lives. HPV can be passed even if the infected person has no signs or symptoms.

- **Does HPV Cause Health Problem?**

- » In most cases, HPV goes away on its own and doesn't cause any health problems. But when HPV doesn't go away, it can cause health problems like genital warts and cancer.
  - **Genital Warts** usually appear as a small bump or group of bumps in the genital area.

- » **Cancer:** HPV can cause cervical cancer and other cancers including cancer of vulva, vagina, penis and anus. The types of viruses that cause genital warts are not the same as types of HPV that cause cancers.
- **How can I avoid HPV and the health problems it can cause?**
  - » **Get Vaccinated:**
  - » **Get screened for cervical cancer:** Routine scanning for women aged between 21 to 65 years old can prevent cervical cancer.
  - » **For Sexually Active people:** Use condoms:
    - But HPV can infect areas that are not covered by condoms - so condoms may not give full protection against getting HPV
    - Be in mutually monogamous relationship
- **Can I be treated for HPV or health problems caused by HPV?**
  - » No treatment for virus itself, but there are treatments for health problems associated

## 8) CERVICAL CANCER

- Nine out of 10 women who die of cervical cancer live in low and middle-income countries, according to WHO.
- **Details:**
  - » The low- and middle-income countries have low rate of vaccination against the HPV, which causes the cancer.
    - Most HPV vaccination consignments go to wealthier nations, driving a gap in access similar to the inequitable distribution of vaccines against the COVID-19.
    - Vaccines haven't been introduced in 80 countries and these countries record 2/3rd the incidences of cervical cancer.
    - Globally, just 13% of girls between nine and fourteen years were vaccinated against HPV in 2020. This was a reduction from 15% girls in 2019.
- **4th HPV Vaccine:**
  - » In Oct 2021, WHO has given approval to Ceolin, manufactured by Xiamen Innovax Biotech Co Ltd to bridge the gap.

## 9) DENGUE

- **Dengue fever**, also known as break bone fever, is a mosquito borne tropical disease caused by the dengue virus.
  - » **Dengue Virus (DENV)** in one of the five serotypes is the cause of Dengue fever. It is a mosquito borne single positive stranded RNA virus of the family Flaviviridae; genus Flavivirus.
  - » **Dengue hemorrhagic Fever (DHF)** is a specific syndrome that tends to affect children under 10 years of age. It causes abdominal pain, hemorrhage (bleeding), and circulatory collapse (shock).
- **Possible to get dengue multiple times**
- **Symptoms:** Severe joint and muscle pain, swollen lymph nodes, headache, fever, exhaustion, and rash. The presence of fever, rash, and headache (**the dengue "triad"**) is characteristics of dengue fever.

- **Geographical Region:** Prevalent throughout the tropics and subtropics.
- **Transmission**
  - » The virus is contracted from the bite of a **striped Aedes aegypti** mosquito that has previously bitten an infected person. The virus is not contagious and cannot spread from person to person directly. There must be person to mosquito to another person pathway.
- **Treatment:** Symptomatic
- **Prevention:** Prevent mosquito bite
- **Vaccine:**
  - » Since there are around 5 serotypes of dengue virus known, vaccine making is difficult. It's because different vaccine is needed against each serotype.
  - » A vaccine against dengue, **DENGVAXIA**, from Sanofi Pasteur is approved in several countries and shows efficacies ranging from 42% to 78% against four serotypes of the virus.
  - » In India, Zydus Cadila has been developing a DNA vaccine against dengue

## 10) ZIKA FEVER / ZIKA DISEASE

- **About Zika Virus**
  - » Zika virus (ZIKV) is a member of the Flaviviridae virus family and the Flavivirus genus, transmitted by daytime active Aedes mosquitoes, such as A. aegypti, A. Africanus, A. furcifer etc. Virus can also get transferred during sexual contacts, across the placenta (affecting unborn child). A mother already infected with Zika virus near the time of delivery can pass on virus to the newborn around the time of birth, but this is rare.
  - » Zika virus is related to dengue, yellow fever, Japanese Encephalitis, and West Nile virus. The illness it causes is similar to mild form of dengue fever, is treated by rest, and cannot yet be prevented by drugs or vaccine.
- **Earliest discovery**
  - » Virus was first isolated in 1947 from a rhesus macaque monkey that had been placed in a cage in the Zika Forest of Uganda, near Lake Victoria, by the scientists of yellow fever research institute.
- **Spread among Humans:**
  - » For the first 60 years after detection, only 14 human cases have been reported from Tropical Africa and Asia (including India in 1952-53).
  - » The **first ever outbreak (185 cases)** of Zika virus was reported in 2007 in the island of Yap (a federated state in **Micronesia**) in the **Pacific**.
  - » In 2015 to Mexico, Central America, the Caribbean, and South Africa, where the Zika outbreak has reached pandemic levels.
    - The outbreak was associated with higher incidences of microcephaly as well as GB syndrome.
- **Symptoms and treatment**
  - » Common symptoms include mild headaches, **maculopapular rash**, fever, joint pains etc.
    - Thus far, Zika fever has been a relatively mild disease of limited scope, with only one in five persons developing symptoms, with no fatalities, but its true potential as a viral agent is unknown.

- » As of 2022, no WHO approved vaccine or preventing drug is available. Symptoms can be treated.
- Zika's link with Microcephaly and GB Syndrome
  - » **Microcephaly** is a condition where a baby has a head size much smaller than other babies of the same age and sex. According to WHO this condition may be caused in newborn by mother to child Zika virus transmission.
  - » **GBS (Guillain-Barre Syndrome)** is a rapid onset of muscle weakness as a result of damage to the peripheral nervous system. In a French Polynesian epidemic, 73 cases of GBS and other neurological conditions occurred in a population of 270,000, which may be complications of Zika virus.

## 11) JAPANESE ENCEPHALITIS

- It's a viral fever that affects the brain and is considered extremely dangerous for children, and it also has a high "mortality and morbidity rate".
- **About JE Virus**
  - » Japanese Encephalitis virus (JEV) is a flavivirus. It is the main cause of viral encephalitis in many countries of Asia with an estimated 68,000 clinical cases every year.
  - » **Symptoms** of JE includes sudden onset of fever, vomiting, headache, neck stiffness, and seizures.
- **Transmissions**
  - » The virus is maintained in a cycle between mosquitoes and vertebrate hosts, primary pigs, and wading birds. Humans are incidental or dead-end hosts because they don't develop high enough concentration of JE virus in their bloodstream to infect feeding mosquitoes.
    - **So It is not transmitted from human to human**
  - » JE virus transmission often occurs in primarily rural agricultural areas, often associated with rice production and flooding irrigation.
  - » **Transmitted by** the bite of **Culex tritaeniorhynchus, and Culex vishnui mosquitoes**.
- **Management Control and Prevention**
  - » **Vaccination:** In the **mission Indradhanush** - JE vaccination was included in May 2016.
  - » **Controlling mosquitoes**
  - » **Pigs act as a carrier** for the virus - so it is also important to control mosquito population around the pig domestication areas.
- **Treatment**
  - » No specific treatments: Symptomatic care

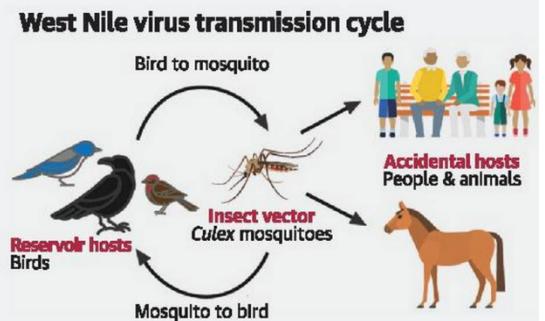
## 12) ACUTE ENCEPHALITIS SYNDROME (AES)

- **What is AES?**
  - » AES is a **complex syndrome that affects central nervous system**, mostly in children and young adults. It starts with fever, then hampers neurological functions causing mental disorientation, seizure, confusion, delirium, coma etc.

- » **Causes:** It may be caused by virus, bacteria, fungi, and a range of agents. Japanese Encephalitis (JE) is the most common cause of AES in India. But the syndrome is also caused by scrub typhus, dengue, mumps, measles, even Nipah or Zika virus.
- **Relation between Hypoglycemia, children, and AES**
  - » Some researchers have claimed that there is an increasing correlation between death due to AES and hypoglycaemia. So, **AES may affect undernourished children more**.
- **Any relation between Litchi and AES**
  - » **More research** needs to be done in this aspect.
    - Some toxin/virus/bacteria found in Litchi **may** be responsible for AES.
    - Unripe fruit contains **toxins** hypoglycin A and methylenecycloprophyglycine (MCPG) which cause vomiting if ingested in large quantities
  - » **Note:** AES is called "Chamki Bukhar" in Bihar
- **Prevention**
  - » **Preventing Mosquito bite**
  - » **Drink plenty of water** and **ensuring proper nutrition** flushes out toxins which may be causing AES from the body.
  - » **Properly washing fruits** before consuming them properly.

### 13) WEST NILE VIRUS

- **About the Virus**
  - » It is a member of flavivirus genus and Flaviviridae family.
  - » It was first isolated in a woman in the West Nile District of Uganda in 1937. It was also identified in birds (including crows) starting 1953 and have also been found to be pathogenic for them (birds).
  - » The WNV is commonly found in Africa, Europe, the Middle east, North America and West Asia.
- **Human Infection** is most often the result of bites from infected mosquitoes. Mosquitoes get infected by feeding on infected birds, which circulate the virus in their blood for a few days. It may also be transmitted through contact with other infected animals, their bloods or other tissues. There are also reports about few transmissions through organ transplant, blood transfusion, mother to child etc.



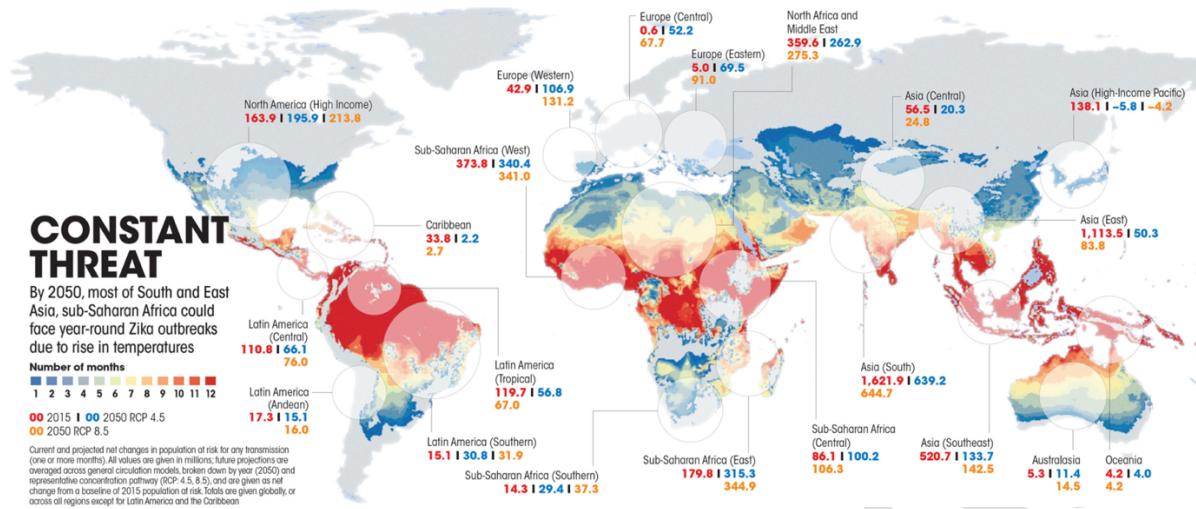
### 14) CHIKUNGUNYA

- **Basics about Chikungunya:**
  - » **Virus:** Chikungunya is a viral disease caused by an RNA virus that belongs to the aphavirus genus of the Togaviridae family.
  - » **Vector:** The bites of infected female mosquitoes, most commonly, Aedes Aegypti and Aedes Albopictus.
  - » **Symptoms:** Fever, severe joint pain, muscle pain, nausea, fatigue and rash.
  - » **Shares clinical signs with dengue** - They can be misdiagnosed with dengue.
  - » **Diagnosis:** RT-PCR (testing serum or plasma for detection of virus or viral nucleic acid)>

- » **Treatment:** No cure available, treatment is mostly symptomatic.
  - » **People at risk:** People living in the proximity of mosquito breeding sites.
  - » **Prevention and Control -> Prevent Mosquitoes and Mosquito bites**
  - » **Less dangerous than dengue** -> rarely leads to fatalities. However, it does affect patients severely, leaving them with pain in the joints and swelling.
- **India and Chikungunya:**
- » India has become an endemic reservoir for the virus with persistent global transmission from the country.
- **Vaccine Efforts:**
- » **BBV87:**
    - A multi-country Phase-II/III clinical trial of a vaccine led by the **International Vaccine Institute (IVI)** in partnership with Bharat Biotech International Ltd (BBIL) began in **Costa Rica** in Aug 2021.
    - The vaccine is called **BBV87**. It is an inactivated whole virion vaccine based on a strain derived from an East, Central and South African genotype.
- **Vaccine: No**
- **Treatment:** Symptomatic
- **Prevention:** Mosquito control.

## 15) MOSQUITOES ARE EMERGING AS BIG ISSUE

- **Details**
- » **Aedes Aegypti** is native to sub-Saharan Africa, and in its native environment it lives in tree holes and small pools of water and bites non-human primates. These mosquitoes may have first moved to nearby human settlements during droughts when the tree holes dried up. During trans-Atlantic slave trade, the mosquitoes moved out of Africa. The first case of Yellow fever reported outside Africa in Yucatan, Central America in 1648.
  - » **Aedes albopictus** is native to tropical SE Asia, where it was originally a forest species that fed on wild animals. During 1980s it spread to islands in the Indian and Pacific Oceans and then during the 1980s extended its range across temperate regions in Europe, Africa and the Americas.
  - » A modelling study published in Nature Communications on May 1, 2020, shows that the **world became about 1.5% more suitable per decade** for the development of **A aegypti** during 1950-2000.
  - » Another study showed that by 2050, 49% of the World's population will live in places where **A aegypti** and **A albopictus** are present if greenhouse gas emissions continue at the current rates.



- Climate change is increasing vector population:
  - » Mosquitoes are now able to breed throughout the year.
  - » Breeding behaviours of mosquitoes have also changed over the years. Now, they can lay eggs in dirty waters too. There is evidence that Aedes mosquitoes can breed in brackish water too.
  - » Artificial lights have increased the feeding period of Aedes mosquitoes.
- Other factors
  - » Aedes aegypti has also developed resistance to common insecticide permethrin.

## 16) WORLD MOSQUITOE PROGRAM (WMP)

- Intro
  - » WMP is a not-for profit initiative that works to protect the global community from mosquito-borne diseases such as Zika, Dengue, Chikungunya.
  - » Pioneered by Australian researchers, the WMP uses safe and natural bacteria called Wolbachia to reduce the ability of mosquitoes to transmit these viruses.
  - » WMP was first launched in Australia in 2011 and has expanded rapidly since then.
- About Wolbachia
  - » Wolbachia is a natural bacteria present in upto 60% of insect species, including some mosquitoes. It is one of the most common parasitic microbes and is possibly the most common reproductive parasite in the biosphere.
  - » However, they are naturally not found in Aedes aegypti mosquito.
- WMP research has shown that when introduced in Aedes aegypti mosquito, Wolbachia can help reduce the transmission of these virus in people. When introduced into this mosquito's cells, this parasite competes successfully against other parasites such as the viruses that cause dengue, chikungunya, yellow fever, Zika etc. Thus, it can be used to fight life-threatening diseases.
  - In a study in Djakarta, the number of cases saw a decline of 77% in the number of cases and a decline of 86% in hospitalizations due to dengue.
  - » Video link: [World Mosquito Program - Our Wolbachia method](#)

## 17) KYASANUR FOREST DISEASE (KFD) / MONKEY FEVER

- **Introduction**
  - » KFD is caused by KFDV, a member of virus family **Flaviviridae**. It was first identified in 1957 when it was isolated from a sick monkey in Kyasanur Forest in Karnataka state India.
  - » Since then, about 400-500 cases are reported every year from the state.
- **Reservoirs for Virus**
  - » **Hard Ticks** (*Hemaphysalis spinigera*) are the reservoir of the KFD virus and once infected, remain so for life.
  - » **Monkeys, shrews, and Rodents** are common hosts for KFDV after being bitten by an infected tick.
- **KFDV can cause epizootics** with high fatality in primates.
- **Transmission**
  - » Infected tick bite or contact with an infected animal (monkey, shrew etc.). No person-to-person transmission has been known so far.
  - » Transmission from other infected animals like goats, cows etc is extremely rare.
- **Symptoms**
  - » Chills, fever, headache, muscle pain, low platelet, low RBCs and WBCs.
- **Treatment:** No specific treatment -> hospitalization and support therapy like hydration and usual precautions is important.
- **Vaccine:** Yes; Used in endemic areas of India.
- **Distribution** Historically limited to western and central district of Kar, India. However, some samples have also been found from Tamil Nadu and Kerala.

## 18) INFLUENZA

### A) INFLUENZA A VIRUS

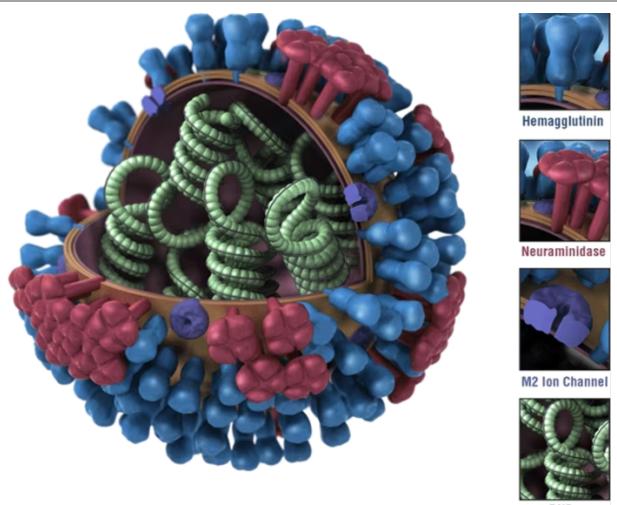
There are four types of Influenza viruses: A, B, C, and D. Influenza A and B viruses cause seasonal epidemics of diseases.

Influenza A viruses are the only influenza viruses known to cause flu pandemics (i.e. global epidemics of flu diseases)

Influenza A virus is the only species of the genus *Alphainfluenzavirus*. It is an RNA virus.

Influenza A viruses are divided into subtypes based on two proteins on the surface of the virus: hemagglutinin (H) and neuraminidase (N).

- There are 18 hemagglutinin subtypes (H1 - H18) and 11 different neuraminidase subtypes (N1 - N11)



More than **130 influenza A subtype combinations** have been identified in nature, primarily from birds, there are potentially many more influenza A subtypes combinations given the propensity of virus "**reassortment**".

**Reassortment** is a process by which influenza viruses swap gene segments. It can occur when two influenza viruses infect a host at the same time and swap genetic information.

- The influenza A virus subtypes that have been confirmed in humans, ordered by the number of known human pandemic deaths, are:
  - » **H1N1** caused Spanish Flu in 1918 and the 2009 swine flu pandemic.
    - A variant of H1N1 was responsible for the Spanish Flu pandemic that killed some 50 million to 100 million people worldwide in 1918 and 1919.
  - » **H2N2** caused "Asian Flu" in the late 1950s.
  - » **H3N2** caused "Hongkong Flu" in the late 1960s.

## B) SWINE FLU

- **Swine Flu** is a respiratory disease caused by **influenza A viruses** that infects respiratory tract of pigs and result in barking cough, decreased appetite, nasal secretion, and restless behavior; the virus can be transmitted to human.
- **The first case of influenza A H1N1** was reported in Mexico in **April 2009**. Since then, this infection has affected almost all the countries of the world.
  - » **The Virus**
    - Most common virus causing swine flu is H1N1 but the flu virus can sometimes also come from other subtypes such as **H1N2, H3N1, and H3N2**. Since 2017, H3N2 is becoming a dominant strain.
  - » **Cross Species infections** (swine to humans, humans to swine) etc. have **mostly remained local and haven't caused national or worldwide infections** in either pig or humans.
  - » **Transmission to humans:**
    - Most common way for humans to catch swine flu is through contact with an infected pig (not through properly cooked pork)
    - Swine flu is transmitted from person to person by inhalation or ingestion of droplets containing virus from people sneezing or coughing.
  - » **Symptoms**
    - Similar to most influenza infections: - fever, cough, nasal secretion, fatigue and headache.
  - » **Prevention and cure**
    - **Vaccination** is the best way to prevent or reduce the chances of becoming infected with influenza virus.

- Two antiviral agents, **zanamivir (Relenza)** and **oseltamivir (Tamiflu)**, have been reported to help prevent or reduce the effects of swine flu if taken within 48 hours of the onset of symptoms.

### C) AVIAN INFLUENZA: BIRD FLU

- **Intro**
  - Bird flu (Avian Influenza) is caused by influenza A viruses.
    - Only viruses of the H5 and H7 subtypes are known to cause the highly pathogenic form of the bird diseases.
      - Most avian influenza virus don't infect humans; however, some such as A(H5N1) and A(H7N9), have caused serious infections in people.
    - Recently, China reported that H10N3 has also infected humans.
- **There are several subtypes of Avian Influenza**
  - **AH5N1** is the most common virus causing bird flu, or avian influenza. It is largely restricted to birds, and often fatal (**high pathogenicity**) to them. It can sometimes cross over to other animals, as well as human.
    - According to WHO, the H5N1 was first discovered in humans in 1997 and has killed almost 60% of those infected. Though, it is not known to transmit easily among humans, the risk remains.
  - **A-H7N9**: It was reported in China in 2013. An outbreak of H7N9 strain killed around 300 people in 2016 and 2017.
- **Risk Factors for human infections**
  - The primary risk factor for human infection appears to be direct or indirect exposure to infected live or dead poultry or contaminated environments, such as live bird markets.
- **Impacts**
  - Outbreaks of AI in poultry may raise global public health concerns due to their effect on poultry population, their potential to cause serious disease in people and their pandemic potential.
  - Can impact local and global economies and international trade.
- **Note**
  - There is no evidence to suggest that the virus can be transmitted to humans through properly prepared poultry or eggs.

### D) THE EUROPEAN UNION IS EXPERIENCING THE LARGEST BIRD FLU OUTBREAK IN EUROPE: REPORT BY EUROPEAN FOOD SAFETY AUTHORITY (EFSA) (2022 AND 2023)

More than 50 million birds culled between Oct 2021 to Sep 2022

### E) FIRST CASE OF AVIAN FLU FOUND IN ANTARCTIC REGION (OCT 2023 )

- Avian flu has been detected for the first time in Antarctic region and has raised concerns for birds and mammals which feed on these bids.
- **Which type?**
  - Highly Pathogenic Avian Influenza (HPAI) was detected in brown skua (a predatory seabird) populations on Bird Island, South Georgia, making it the first known case in the Antarctic region.
- **Risk Assessment:**
  - Sea-Gulls and Skuas are the most threatened avian group. They are followed by bird's prey such as hawks and carcasses, terns and shorebirds.
  - Among marine mammals, fur seals and sea lions are reportedly most vulnerable, followed by southern elephant seals and dolphins.

## 19) NIPAH

### A) NIPAH

- **Why in news?**
  - » There has been an outbreak of the deadly Nipah virus in Kerala which have infected five people and killed two of them (Sep 2023)
- **Introduction**
  - » According to WHO Nipah Virus (NiV) infection is a newly emerging zoonosis (a disease that can be transmitted from animals to humans) that can infect both humans and animals.
    - It is classified as a "highly pathogenic paramyxovirus" and handling it requires the highest grade of facilities called BS-4.
  - » The natural host of the virus are fruit bats of the Pteropodidae family, Pteropus genus. Humans are generally infected by fruit bat or pigs. Human to human transmission is also known including in the hospital setting.
- **First identification**
  - » First identified during the outbreak of disease that took place in Kampung Sungai Nipah, Malaysia in 1998. In this case pigs were intermediate hosts. Since, then there have been several outbreaks even without intermediate hosts.
  - » In India it was first detected in Siliguri in 2001 and Nadia in 2007. This was a spillover of the outbreak in Bangladesh.
  - » Later in 2018, 19, 21 and again in 2023 it appeared in Kerala.
    - **Why?**
      - Kerala has several fruit plantations that host several species of bats.
      - Better health facilities in Kerala may be leading to better detection, surveillance etc., whereas in other states the cases may go undetected.
- **Symptoms** of NiV can be **neurological, respiratory and pulmonary**. They include:
  - i. **Encephalitis (brain swelling) due to Inflammation of the brain**
  - ii. Confusion, disorientation and even persistent drowsiness
  - iii. Headache, fever, nausea and dizziness (flu like symptoms)

- **Fatality:** Around 40-70% depending on the local capability for epidemiological surveillance and clinical management.
- **Prevention** (Avoid date palm sap; avoid close contact with NiV Patient; avoid direct contact with pigs/bats in endemic area)
- **Treatment / Vaccine**
  - » **Intensive Support care (no treatment or vaccine is available)**

According to NCDC (National Centre for Disease Control), Ribavirin, an antiviral, may have a role in reducing mortality among patients with encephalitis caused by NIPAH virus disease.

## B) WHY ZOONOTIC DISEASES ARE INFECTING HUMANS MORE AND MORE

- » **Dramatic increase in population and mobility** -> Environmental changes, Deforestation etc. -> increase human contact with pathogens.
- » **Increased demand for animal protein**
  - Livestock production is moving closer to towns in the form of poultry farms etc.
- » **Rise in intense and unsustainable farming**
- » **Increased use and exploitation of wildlife**
- » **Unsustainable utilization of natural resources**
- » **Many Indian villages are located within or around forests**
  - Thus, significant number of people interact with forests in their day-to-day lives
- » **Global Warming**
  - Increases the population of insects like ticks that harbour and transfer the virus
- » **Poor Preparation in terms of infra and human resource**
  - Zoonotic diseases become more problematic in countries where health infrastructure is poor (e.g., Ebola in Africa, Zika in South America, Nipah in Asia etc.)
- » **Lack of awareness** especially in rural areas also

## 20) HEPATITIS

- **About Hepatitis**
  - Hepatitis refers to inflammatory condition of liver. It's commonly caused by viral infections, but there can be other causes too (e.g., auto-immune hepatitis that occurs as a secondary result of medication, drugs, toxins etc.)
- **5 Types of Viral Hepatitis**
  - Hepatitis A, B, C, D, and E.
    - A different virus is responsible for each of these types.
  - » **Hepatitis A** by Hepatitis A Virus (HAV)
    - Transmitted by consuming food or water contaminated by faeces from a person infected with hepatitis A.
  - » **Hepatitis B** (HBV) is transmitted through contact with infectious body fluids, such as blood, vaginal secretion, semen etc.
  - » **Hepatitis C** (HCV) is transmitted through direct contact with infected blood fluids typically through injection drug use and sexual contact.

- Injecting drug use is a major contributor to the number of people newly infected with Hepatitis C globally.
- » **Hepatitis D (HDV)**, also called Delta Hepatitis is transmitted through direct contact with infected blood.
- » **Hepatitis E (HEV)**, is mostly found in areas with poor sanitation and typically results from injecting fecal matter that contaminates the water supply.
- **Hepatitis B and C** are responsible for more than 96% of cases.
  - » Vaccine for Hepatitis B is available
  - » Vaccine for Hepatitis C is not available
- **National Viral Hepatitis Control Program** (launched in July 2018)
  - » By MoH&FW
  - » It is aimed at eliminating the deadly condition by 2030.
  - » It has been launched in collaboration with WHO.
  - » Under the program, government will be providing free drugs and diagnosis for **Hepatitis B and C**.
  - » **Key strategies under the program include** - Preventive and promotive intervention through awareness generation; safe injection practices; sanitation and hygiene; safe drinking water; infection control and immunization; collaboration and coordination among different ministries; access to testing and management; building capacities at district, state, and national levels.
- **World Hepatitis Day - 28th July**
  - » Aims at raising awareness of hepatitis (A,B,C,D,E) and encourage prevention, diagnosis and treatment.
  - » World Hepatitis Day is one of the 8 global public health campaigns marked by WHO, along with World Health Day (7th April), World Blood Donor Day (14th June), World Immunization Week (last week of April), World Tuberculosis Day (24th March), World No tobacco day (31st May), World Malaria Day (25th April), and World Aids Day (1st December)

## 21) NOROVIRUS

- **Norovirus:**
  - » Norovirus is thought to be the most common cause of acute gastroenteritis (diarrhea and vomiting illness) around the world. It spreads easily through food and drink and can have a big impact on people's health.
  - » Noroviruses also are sometimes called food poisoning because they can be transmitted through contaminated food. They aren't always the result of food contamination.
- » **Transmission of Norovirus:**
  - Having direct contact with an infected person.
  - Consuming contaminated food or water or touching contaminated surface.
- » **Symptoms:** Diarrhea, Vomiting, Nausea, and Stomach Pain.
- » **Prevention:**

- **General Hygiene:** Regular hand wash; rinse fruits and vegetables etc.
- » **Treatment:** Not available - generally goes away on its own within 1 to 3 days.

## 12. NON- VIRAL DISEASES

### 1) MALARIA

- **Cause of Malaria:** It is caused by plasmodium pathogens.
  - » There are five human malaria parasites: Plasmodium falciparum (deadliest of the five) and Plasmodium vivax are the most common causes. The list also includes P. ovale, P. malarie, and P. knowlesi.
  - » **Mosquitoes inject sporozoite (Spore-like) stage** of the parasite into the skin when they bite, and the sporozoites travel to the liver. The parasite multiply in liver, and then infect the red blood cells.
- **Mosquito Vector:** Female Anopheles Mosquito (e.g. A. gambiae, A. culicifacies, A. fluviatilis etc.)
- **Note:** Malaria is the largest parasitic killer in the world.
- **Key Interventions to control Malaria:**
  - » Prompt and effective treatment with artemisinin-based combination therapies.
  - » **Reducing Mosquitoes** and Mosquito bites (female Anopheles Mosquito (e.g. A. gambiae, A. culicifacies, A. fluviatilis etc.)

#### A) DEVELOPMENT OF DRUG RESISTANCE:

A study from Africa has found that P. falciparum has developed resistance to the primary drug used to treat the disease i.e. Artemisinin and Artemisinin based combination therapies.

- Resistance was earlier shown in Asia, but experts are more worried about the development of resistance in Africa as it has 90% of the world's Malaria cases

#### B) 2023 WORLD MALARIA REPORT – PUBLISHED BY WHO (DEC 2023)

- **India:**
  - » In 2022, India accounted for 66% of the cases in the WHO South-East Asia region. This region accounted for only 2% of the global cases.
    - Plasmodium vivax was responsible for almost 46% of all cases in the region.
- **WHO Africa region** accounts for around 95% of the cases.
- **Crucial milestone of the WHO Global Technical Strategy for Malaria 2016-2030** have been missed in 2020.
- **Key factors** impacting fight against Malaria:
  - » Covid-19 disruptions; Drug and Pesticide Resistance; Humanitarian Crisis; climate change response; delays in program implementation.

#### C) GLOBAL TECHNICAL STRATEGY FOR MALARIA 2016-2030: WHO

- Aimed at dramatically lowering the global malaria burden over the 15 year period

#### D) VACCINATIONS

As of Dec 2023, RTS/AS01 and R21/Matrix-M vaccines are recommended by WHO to prevent malaria in Children. Malaria vaccines should be provided to children in a schedule of 4 doses from around 5 months

of age. These malaria vaccines act against P. falciparum, the deadliest malaria parasite globally and the most prevalent in Africa.

## RTS,S

- The WHO has recommended widespread use of the RTS,S/AS01 (RTS,S) malaria vaccine (Commercial name: Mosquirix) among Children in regions of moderate to high P. falciparum malaria transmission.
- RTS, S has been developed by PATH Malaria Vaccine Initiative (MVI) and GlaxoSmithKline (GSK) with support from Bill and Melinda Gates foundation.
  - » It is a **recombinant vaccine**. It consists of the P.falciparum circumsporozoite protein (CSP) from the pre-erythrocytic stage (i.e. the CSP is secreted at the sporozoite stage of this plasmodium). The CSP antigen causes the production of antibodies capable of preventing the invasion of hepatocytes and additionally elicits a cellular response enabling the destruction of infected hepatocytes.
  - » **Note:** Mosquito bites transfer the CSP and sporozoites into the human bloodstream, and the CSP nudges the parasite towards the liver, where it enters liver cells, matures and proliferates. The release of mature merozoites marks the onset of the symptoms of malaria

## R21 MALARIA VACCINE

- **Why in news?**
  - » A malaria vaccine manufactured by the biotechnology company Serum Institute of Technology of India and University of Oxford have passed the next round of regulatory approval by the WHO (Dec 2023)
    - R21/Matrix-M meets the WHO standards for vaccine quality, safety, and efficacy.
- **Details about the vaccine:**
  - » R21 is a modified form of a vaccine called RTS,S or Mosquirix.
  - » Vaccine is highly effective and can reduce malaria cases by 75% over a year.
  - » It is the second malaria shot approved by WHO, following the RTS,S/AS01 one, which was approved in July 2022.
  - » R21 is designed to be both more potent and cheaper to produce than Mosquirix. .
    - **Note1:** R21 and Mosquirix both target the malaria parasite in the sporozoite phase of its life cycle - the phase in which it enters the human body from its mosquito host. The vaccines include a protein (Circumsporozoite Protein (CSP)) secreted by the parasite at that stage, in the hope of stimulating an antibody response against it. R21 includes a higher concentration of these proteins.
    - **Note2:** Each of the vaccine is administered with a chemical called an adjuvant, which boosts immune responses to the inoculation. But the Adjuvant used with R21 is easier to make than that used with Mosquirix, raising hopes that it could be cheaper as well.
- **WHO's Approval:**
  - WHO has added the vaccine to the WHO's list of prequalified vaccines.

- This was also recommended for use for the prevention of malaria in Children by the global health agency on 2nd Oct 2023.
- **How is a vaccine added in the WHO list of pre-qualified vaccine?**
  - If a vaccine has undergone through evaluation of relevant data, testing of samples and WHO inspection of relevant manufacturing sites - and the outcome is positive - it is included in the WHO list of Prequalified Vaccines.
  - Pre-qualification is also a pre-requisite for vaccine procurement by UNICEF and funding support for development by Gavi, the Vaccine alliance.

#### E) MALARIA'S COMBACK IN USA

- **USA** has recorded its first homegrown malaria cases in decades. In the year 2023, 9 indigenous cases have been reported (7 in Florida, one in Texas, and one in Maryland)
- **How?**
  - » Anopheles mosquitoes capable of carrying malaria are still very much present in the USA they've just had very few opportunities to transmit the parasite because there are so few infected people to feed on.
    - **Experts believe that** a person infected with Malaria traveled to the USA from a malaria-endemic area and was bitten by a local Anopheles mosquito, which picked up the parasite and then bit someone else, passing on the parasite.
  - » **Climate change** is making environment more suitable for Malaria. Higher temperature also enhance the growth rate and transmissibility of the parasites responsible for malaria. Higher rainfall and sea level rise may also make the situation more suitable for malaria.

## 2) IMPORTANT INTERNATIONAL INITIATIVES RELATED TO MALARIA

### A) E-2025 INITIATIVE

- Under this initiative WHO has identified 25 countries, including 3 from Africa, with the potential to eradicate malaria by 2025.
  - » The WHO will provide specialized support and technical guidance to these countries under the initiative.
- The initiative is built on the foundation of the E-2020 initiative. The countries were identified by WHO across four key criterias:
  1. The generation of government endorsed elimination plan
  2. Meeting a defined threshold of Malaria case reductions in recent years
  3. A designated government agency for Malaria elimination and the capacity to confirm 100% of suspected malaria cases in a laboratory
  4. Selected by the Malaria Elimination Oversight Committee

- Countries selected for the E-2025 initiative:

Automatically Nominated	Newly Added
1- Mexico 2- Costa Rica 3- Ecuador 4- Suriname 5- Belize 6- Cabo Verde 7- Saudi Arabia 8- Islamic Republic of Iran 9- Nepal 10- Bhutan 11- Republic of Korea 12- Malaysia 13- Comoros 14- Botswana 15- Eswatini 16- South Africa 17- Timor-Leste	1- Panama 2- Vanuatu 3- Honduras 4- Thailand 5- Guatemala 6- Dominican Republic 7- Sao Tome And Principe 8- Democratic People's Republic of Korea

#### B) CHINA CERTIFIED MALARIA FREE AFTER 70 YEARS OF FLIGHT: WHO (JUNE 2021)

- In 1940s, China used to report 30 million cases annually. Now, it has gone for four consecutive years without an indigenous case.
- **Requirement of WHO's Malaria Free status:** 3 Consecutive years of zero indigenous cases. The country must also present rigorous evidence and demonstrate the capacity to prevent transmission re-emergence.
- **China** has become the 40th territory to be certified malaria free. The other recent countries to get Malaria free status include - El Salvador (2021), Algeria and Argentina (2019), and Paraguay and Uzbekistan (2018).
  - China is also the first country in WHO's Western Pacific region to be awarded a malaria-free certification in more than three decades. The only others with certified status are Australia (1981), Singapore (1982) and Brunei (1987).
- **Key initiatives by China** which has made this possible?
  - Discovery of Artemisinin in 1970s -> most effective anti-malarial drug.
  - Among the first countries to test the use of insecticide treated net to prevent Malaria and China distributed millions of nets

#### C) MAJOR NATIONAL INITIATIVES

- **National Framework for Malaria Elimination (2016-2030)**
  - Released by MoH&FW and aims to make India Malaria free by 2030.

### 3) KALA AZAR (VISCERAL LEISHMANIASIS, BLACK FEVER, AND DUMDUM FEVER)

- As per WHO, there are three main forms of Leishmaniases of which Kala-azar is the most serious form.
- **Basics of Kala Azar (Black Fever)**
  - **Parasite:** Protozoan parasite called '**leishmania donovani**'. (Genus: Leishmania)
  - **Vector:** female Sand fly.
    - » The parasite is spread to humans by bites from infected female sand flies.
  - **Second largest parasite killer** in the world (after malaria)
  - It is one of the most neglected Tropical Diseases (NTD).
  - The parasite migrates to the internal organs such as liver, spleen (hence visceral), and bone marrow, and, if left untreated, will almost always result in the death of the host.
  - **Other factors:**
    - » The disease affects some of the poorest people in the world and is linked to malnutrition, population displacement, poor housing, a weak immune system and a lack of financial resources.
    - » It is also linked to environmental changes such as deforestation etc.
  - **Symptoms:** Irregular fever, weight loss, anaemia, and swelling of the spleen and liver.
  - **Only infects humans** (no other animal known to harbour the infection in Asia), and **humans are considered the only reservoir of the parasite**.
  - **Treatment:** Anti-leishmanial medicines are available for treatment. Vector control is another aspect.
- **Cases of Visceral Leishmaniasis or Kala Azar in India (Jan 2023)**
  - **Kala Azar cases in India fell to 834 in 2022 from 44,533 in 2007 - a 98.7% decline**: Union health Ministry.
  - After missing deadlines thrice, India is poised to achieve the elimination target for visceral leishmaniasis or Kala Azar this year with no block in the country reporting more than 1 case per 10,000 people. (Dec 2023)
    - India needs to sustain the momentum over the next 3 years in order to receive the WHO certification.
  - India contributes to 11.5% of total cases reported globally.
  - 89% of the cases were reported from eight countries - Brazil, Eritrea, Ethiopia, India, Kenya, Somalia, South Sudan and Sudan.
- In October 2023, Bangladesh became the first country in the world to be officially validated by the WHO for elimination of Kala Azar as a public health problem
- **National Kala Azar Elimination Program (NKEP)**
  - Though the initial 2015 deadline has been missed, the numbers have been brought down significantly.
  - **Key steps taken:**

- India has also expanded vector control interventions:
    - Indoor residual spraying to control the population of sandflies.
  - Since sandflies have developed resistance to DDT, the NVBDCP introduced a synthetic pyrethroid for indoor residual spraying in 2015.
  - Reducing Crevices in 'Kuccha' walls to reduce breeding areas.
  - ASHA (Accredited Social Health Activist) network was tasked with ensuring that people with PKDL complete treatment.
- Note:
- Since 2003, National Vector Borne Disease Control Programme (NVBDCP) is in charge of coordinating with endemic states to eliminate disease.
    - NVBDCP now funds consultants at state and district level and Kala-Azar Technical Supervisors (KTS) at the State's blocks (or clusters of village panchayats) to conduct surveillance.
- International efforts to control Kala Azar
- An initiative was launched by WHO to eliminate VL as a public health problem from SE Asia region by 2020. The deadline has now been extended to 2023.

### **POST KALA-AZAR DERMAL LEISHMANIASIS (PKDL)**

- » It is a complication of Kala-Azar, in which the disease-causing protozoan invades the patient's skin cells. These cases act as reservoirs of the pathogens.
- » **PKDL treatment is a bigger problem**
  - **Diagnostic is difficult**
    - PKDL cannot be diagnosed by the trademark rapid diagnostic kits. So, a skin snip examination is required. But not all PHCs are equipped with such tools.
- » **Longer dose and greater quantity of drugs**
  - PKDL requires a longer dose and greater quantity of drugs than primary Kala Azar.
- » **Why treating PKDL is important?**
  - It is not life threatening but can act as a source for Kala Azar infection to others.

### **A) OTHER TWO FORM OF LEISHMANIASIS**

#### **CUTANEOUS LEISHMANIASIS (CL)**

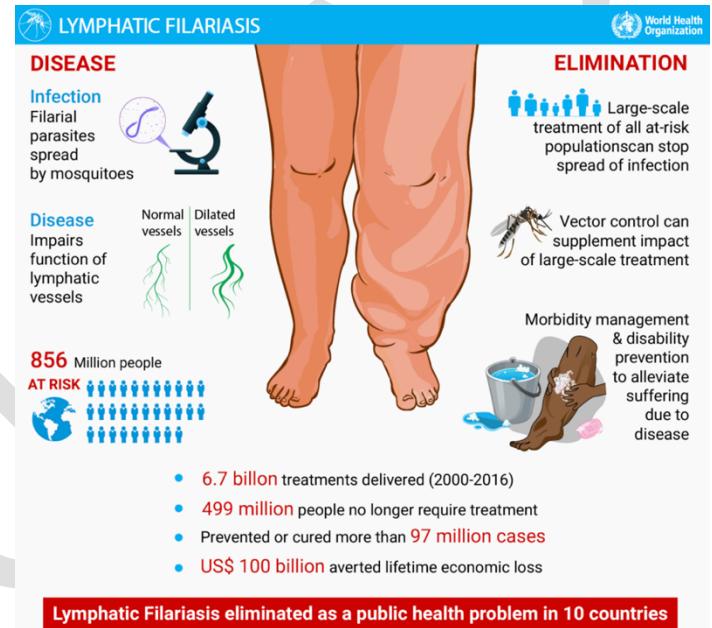
- It is the most common form of leishmaniasis.
- It is caused by 15 different species of the protozoan parasite Leishmania, transmitted by infected female sandflies.
- They are not life threatening, but can cause skin lesions, mainly ulcers, on exposed parts of the body, leaving life-long scars and serious disability or stigma.
  - » About 95% of CL cases occur in the Americas, the Mediterranean basin, the Middle East and Central Asia.

## MUCOCUTANEOUS LEISHMANIASIS

It leads to partial or destruction of mucous membranes of the nose, mouth, and throat. More than 90% of the cases come from Bolivia, Brazil, Peru, and Ethiopia.

## 4) FILARIASIS

- **Basics:**
  - » It is a parasitic disease caused by infection with roundworms of the **Filarioidea** type.
  - » **Lymphatic Filariasis** impairs the lymphatic system and can lead to the abnormal enlargement of the body parts, causing pain, severe disability, and social stigma. It is also known as elephantiasis and is a Neglected Tropical Disease.
- **Vectors: Mosquitoes** are infected with microfilariae (immature larvae) when biting an infected host. This larva matures in the mosquito and when the mosquitoes bite people, people are infected with mature parasite larvae. The larvae then migrate into lymphatic vessels where they develop into adult worms.
  - » It may be transmitted by different types of mosquitoes including the Culex Mosquito.
- The disease is prevalent in more than 50 countries.



## 5) NEUROCYSTICERCOSIS

- **Details**
  - » Neurocysticercosis (NCC) is caused when a human consumes meat from (or is indirectly in contact with) - a pig infected with tapeworm.
    - The eggs of tapeworms invade muscles of the human body to make cysts. Sometimes these cysts get into human brains, triggering epileptic seizures, headaches, difficulty with balance and excess fluid around the brain.
  - » A study published in the ***Nature journal*** in 2021 reported higher prevalence (42.2%) of NCC among patients with active epilepsy in the tea gardens of Assam. These findings were in sync with the older findings that NCC was one of the leading causes of seizures in developing countries, particularly in areas without proper sanitation and where pig rearing was widespread.

## 6) TUBERCULOSIS

- **Introduction**
  - » TB is an infectious **bacterial disease** caused by bacillus Mycobacterium tuberculosis, which most commonly affects the lungs (pulmonary TB) but can affect other sites as well (extra pulmonary TB)
- **Symptoms:**
  - » Healthy people -> often no symptoms (immune system wall off the bacteria)
  - » **Symptoms of active TB of the lung** include coughing (sometimes with sputum or blood), chest pains, weakness, weight loss, fever, night sweats etc.
- **Diagnosis**
  - » **Sputum Smear Microscopy** - used since more than 100 years.
  - » **Rapid Molecular Test** - developed recently - uses polymerase chain reaction (**PCR**)
  - » **Culture Methods** - needs developed laboratory capacity.
- **Treatment**
  - » The effective drug treatments were **first developed in the 1940s**.
    - The most effective first-line anti-TB drug, rifampicin, became available in the 1960s.
    - The currently recommended treatment for new cases of drug-susceptible TB is a six month regimen of four first line drugs: rifampicin, isoniazid, ethambutol and pyrazinamide. Treatment success rates of 85% or more for new cases are regularly reported to WHO by its member states.
  - » Additionally, social determinants of TB such as under-nutrition, overcrowding and poor ventilation in slums and clinical risk factors such as diabetes mellitus, smoking etc. should be addressed simultaneously.
  - Treatment for **Multi drug resistant TB (MDR-TB)**, defined as resistance to isoniazid, rifampicin (the two most powerful anti TB drugs) is longer, and requires more expensive and more toxic drugs. For most patients with MDR-TB, the current regimens recommended by WHO last 20 months, and treatment success rates are much lower.
- **Vaccine**
  - » Not yet (BCG is not effective in tropical countries)
- **Steps Taken**
  - i. **For Detection**
    - **National Policy of Mandatory Reporting** of detected cases since 2012
    - Launch of **Nikshay Platform** - a nation wide web-based and case-based reporting system that facilitates reporting of detected cases by care providers in public and private hospitals.
  - ii. **National Strategic Plan for Tuberculosis Elimination (2017-2025)**



- **Goal**
  - » Achieving rapid decline in the burden of TB, morbidity and mortality while working towards elimination of TB by 2025
- **100% case finding by 2020**
- **Elimination of TB 2025 (< 1 per 1,00,000 population)**
  
- **Updated MDR-TB Recommendations from WHO (Aug 2018)**
  - Replace all injectable with oral regime for MDR-TB patients.
    - Injectables have been found to be less effective
  - Prioritize newer drugs like **Bedaquiline** in the fully oral regime.
    - Data has shown that newer drugs show greater success in treatment and lower mortality rate.
  
- **24 March: World Tuberculosis Day**
  
- **New Vaccines and Medicines**
  - i. New BCG based TB vaccine, VPM1002 has shown promise in animal and small-scale human trials. It is to be supplied by Pune based Serum Institute of India.
  - ii. **Bedaquiline** - a new drug for drug resistant TB - launched by Union Health Ministry on 24th March 2016 (Worth TB Day)

---

#### A) WHO'S GLOBAL TB REPORT

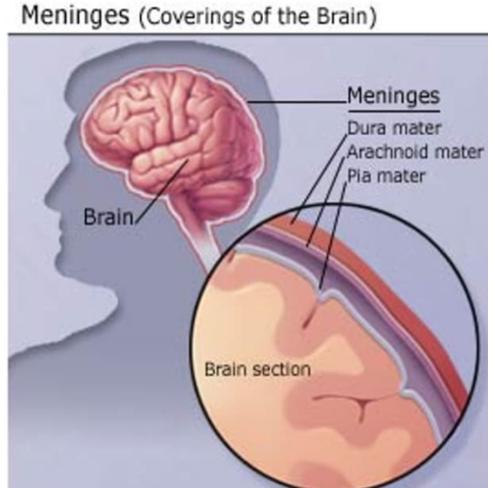
## 7) LEPROSY

- **Introduction**
  - » Leprosy, also known as Hansen's disease, is a chronic infectious disease caused by *Mycobacterium leprae*. It is one of the oldest diseases known to humans and despite advances in all spheres of medical science, continues to be a public health challenge in India.
  - » The disease mainly affects the skin, the peripheral nerves, mucosal surfaces of the upper respiratory tract and the eyes. The deadening of hands and feet leaves patients prone to kinds of disabling injuries that have become stigmatizing symbol of leprosy.
  - » Leprosy is known to occur at all ages. Leprosy is a leading cause of permanent physical disability.
  - » It is included under the list of Neglected Tropical Diseases of WHO.
  - » India, Indonesia and Brazil constitute around 81% of the cases with India contributing to more than 50% of the cases.
- **Transmission**
  - » The exact mechanism of transmission of leprosy is not known.
  - » Till recently, most widely held belief was that the disease was transmitted by **contact** between cases of leprosy and healthy persons.
  - » More recently, possibility of transmission by **respiratory route** is gaining ground. There are other possibilities like transmission through insects which can't be ruled out.
- **Treatment**
  - » Leprosy is curable with combination of drugs known as **multidrug therapy (MDT)** (to prevent drug resistance)

- » Treatment, before nerve damage occurs, is the most effective way of preventing disability due to leprosy.
- **Leprosy Situation in India**
- India currently accounts for 60% of the total new leprosy cases in the world. Though, technically, WHO declared India leprosy free in 2005(<1 case per 10,000 population), the disease is still widespread in the region where poverty and stigma have kept patients hidden and untreated.
    - Bihar, Jharkhand, Odisha, West Bengal, Madhya Pradesh, Chhattisgarh, Odisha and Maharashtra account for 76% of the new leprosy cases.
  - Further, another worrying trend is that Leprosy is impacting the marginalized population more. For e.g. an analysis by ORF indicates that Adivasis account for 18.8% of India's new cases and this percentage has been increasing over the last decade.
- **Steps taken by India towards eradicating Leprosy:**
- a. **National Leprosy Eradication Program (NLEP)**, running since 1983 - a centrally sponsored health scheme of MoH&FW, GoI.
    - NLEP is aimed at eradicating the disease from the country. India was able to eliminate leprosy (bring the number of cases to less than 1 per 10,000 population) by 2005, but complete eradication has not taken place yet.
  - b. **Sparsh Leprosy Awareness Campaign (SLAC)** under NLEP was launched in 2017.
  - c. **Personal Laws (Amendment) Act, 2019** is aimed at removing leprosy as a ground for divorce in India family laws.
    - The act amends five acts - The Divorce Act, 1869, the Dissolution of Muslim Marriage Act, 1939, the Special Marriage Act, 1954, the Hindu Marriage Act, 1955, and the Hindu Adoption and Maintenance Act, 1956 - on provisions related to marriage, divorce, and separation of Hindu and Muslim couples.

## 8) MENINGITIS (BOTH VIRAL AND BACTERIAL REASONS)

- **What is Meningitis?**
  - » It is inflammation of the meninges (three membranes that cover the brain and spinal cord). It occurs when fluid surrounding the meninges becomes infected.
- **Causes:** Viral and bacterial infections; Cancer; chemical irritation; fungi; and drug allergies.
  - » **Bacterial Meningitis:** It is an extremely serious illness. It can be caused by several bacteria including Streptococcus pneumoniae (pneumococcus), Neisseria meningitidis (meningococcus) etc.
    - **Meningococcal meningitis** (caused by the Neisseria meningitidis bacteria), is associated with high fatality rate. It primarily affects small children (though can infect everyone) and can cause severe brain damage if left untreated. It holds the potential to cause large epidemics as it has the potential to transfer from person to person through respiratory droplets.
      - This is vaccine preventable.



- *Haemophilus influenzae type b* (Hib) was a common cause of meningitis in babies and young children until the Hib vaccine became available for infants.
- » **Viral Meningitis** is more common but generally less serious than bacterial meningitis.
- » **Fungal Meningitis** is very rare. Generally, people with weak immune system are vulnerable to it.
- » **Parasitic and Amoebic meningitis** are also rare.
- » **Noninfectious meningitis** is caused by diseases like cancer or in case of injury due to accident, surgery or reactions to medications.
- **Contagious?**
  - » Some viral and bacterial meningitis are contagious. They can be transmitted by coughing, sneezing, or close contact.
- **Symptoms:** In the beginning the viral and bacterial meningitis have similar symptoms. However, bacterial meningitis symptoms are usually more severe. These symptoms also vary depending on your age.
- **Regions most affected:** Meningitis epidemics have occurred in the last decade in all regions of the world. But it is most common in the 'Meningitis Belt', which spans 26 countries across sub-Saharan Africa.
- **Vaccines:**
  - » Several vaccines protect against meningitis, including meningococcal, Haemophilus Influenza type b and Pneumococcal vaccines.
- **"The Global Roadmap to Defeat Meningitis by 2030" by WHO (Sep 2021)**
  - » It aims to eliminate the epidemic of bacterial meningitis - the deadliest form of the disease - and to reduce deaths by 70 percent and halve the number of cases.
  - » Focus on urgently expanding access to existing tools like vaccines, spearheading new research to prevent, detect, and treat the various causes of the disease and improving the rehabilitation for the affected.

## 13. NEGLECTED TROPICAL DISEASES (NTDS)

- **WHO Definition:**
  - NTDs are a diverse group of 20 conditions that are mainly prevalent in tropical areas, where they mostly affect impoverished communities and disproportionately affect women and Children.
    - The epidemiology of NTDs is complex and often related to environmental conditions.
    - They are caused by variety of pathogens - viruses, bacteria, protozoa, and parasitic worms (helminths).
- **Which are the diseases included in NTDs:**

- Buruli Ulcer, Chagas Disease, Dengue & Chikungunya, dracunculiasis (Guinea-worm disease), echinococcosis, foodborne trematodiases, human African trypanosomiasis (sleeping sickness), leishmaniasis, leprosy (Hansen's disease), lymphatic filariasis, mycetoma, chromoblastomycosis and other deep mycoses, onchocerciasis (river blindness), podoconiosis, rabies, scabies, and other ectoparasitoses, schistosomiasis, soil-transmitted helminthiases, snakebite envenoming, taeniasis/cysticercosis, trachoma, and yaws and other endemic treponematoses.

- **Note:**
  - 'Noma' is the latest addition to WHO's list of neglected tropical diseases (Dec 2023)
- These diseases are **contrasted with the "big three" infectious diseases** (HIV/AIDS, tuberculosis, and malaria), which generally receive greater treatment and research funding.
- **Jan 30: World NTD Day**
  - In May 2021, the delegates at the 74th World Health Assembly unanimously adopted a proposal to declare Jan 30 as 'World NTD Day.'
- **WHO's new roadmap for 2021-2030 calls for three strategic shifts to end NTDs:**
  - From measuring process to measuring impact.
  - From disease-specific planning and programming to collaborative work across sectors.
  - From externally driven agendas reliant to programmes that are country-owned and country-financed

#### A) INCLUSION OF NOMA ON THE WHO'S LIST OF NTD

It is a severe gangrenous disease of the mouth and face. It primarily affects young children (between the ages of 2 years to 6 years) in regions of extreme poverty.

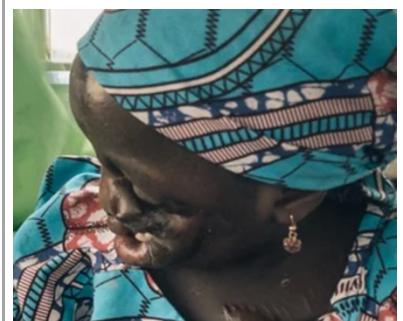
It starts as an inflammation of gums, which, if not treated early, spreads quickly to destroy facial tissues and bones.

**Cause:** Evidence indicate that NOMA is caused by bacteria found in the mouth. There are multiple risk factors associated with the disease. It includes malnutrition, weakened immune system, infections, and extreme poverty. If the child is malnourished and has recently been sick with an infectious disease, such as measles or chickenpox, they are at more risk for developing noma.

It is not contagious but tends to strike when the body's immune system is weak.

**Impact:** It can be fatal and may also cause severe disfigurement for survivors.

**Treatment:** It involves antibiotics, advice and support on practices to improve oral hygiene with disinfectant mouth wash and nutritional supplements. In case of early diagnosis, proper wound healing without long-term consequences may take place. In severe cases, surgery may be necessary.



NOMA is sometimes called the 'Face of Poverty' as it is a social marker of extreme poverty and malnutrition.

**Significance of Including NOMA in the NTD's list:**

- Amplify global awareness.
- Catalyze research, stimulate funding and boost efforts to control

**Cases** are mostly found in sub-Saharan Africa. Some cases are also reported from Americas and Asia.

the disease through multisectoral and multi-pronged approaches.

**Accurate estimation** of the number of noma cases is challenging due to rapid progression of the disease and the associated stigma.

## 14. NON-COMMUNICABLE DISEASES

### 1) HYPERTENSION (HIGH BLOOD PRESSURE)

- **Why in news?**
  - » Who releases its first-ever report on global impact of high BP, states approximately four in every five not treated adequately (Sep 2023)
- **What is Blood Pressure?**
  - » **Blood pressure** is a measure of how much the blood moving through your arteries pushes against the vessel walls. According to medical standards, the reading on a doctor's BP monitor going above 140/90 accounts for hypertension. **High Blood Pressure (Hypertension)** is a serious medical condition that significantly increase the risks of heart, brain, kidney and other diseases.
  - » A large number of people who suffer from hypertension are unaware of this, therefore it is also sometimes referred as a silent killer.
  - » It is a condition that knows no boundaries affecting people of every age and different socio-economic conditions. It can't be cured but can be managed through lifestyle changes, medication, and regular monitoring.
- **WHO Report on Global Impact of High BP (Sep 2023)**
  - » Hypertension affects 1 in 3 adults worldwide and around 1/3rd of the adults with hypertension are unaware of their conditions. Nearly 4/5 people with hypertension are inadequately treated. Scaling up coverage can avert 76 million deaths between 2023-2050.
- The number of people living with hypertension (blood pressure of 140/90 mmHg or higher or taking medication for hypertension) doubled between 1990 and 2019, from 650 million to 1.3 billion.
- **Hypertension Situation in India:**
  - » **As per a paper published in *The Lancet*:**
    - Hyper Tension is the most important risk factor for death and disability in India.
      - Less than 1/4th of hypertensive patients in India had their blood pressure under control during 2016-2020.
      - There is a growing prevalence of hypertension amongst younger adults and those from lower socioeconomic backgrounds.
  - » **NFHS-5** reported a hypertension prevalence of 24% in men and 21% among women, an increase from 19% and 17% respectively from the previous round (NFHS-4)

- **Key Issues with Hypertension situation in India:**
  - Lack of Awareness:** As per WHO, 1/3rd of the hypertension patients don't even know that they are suffering from hypertension.
  - Limited Access to healthcare services**
  - Inadequate adherence** to medication and lifestyle modifications

---

#### A) BENEFITS OF REDUCING SALT INTAKE (DEC 2022)

- Adding less salt to food -> Fewer heart attacks and strokes.
  - This was found to be true even in participants who were following DASH diet (Dietary Approaches to Stop Hypertension).
  - **DASH** is the best recommended diet to prevent cardiovascular events. It involves eating fruits, vegetables, lean meat, poultry, nuts, whole grains, and reducing intake of saturated fats, cholesterol, and sugar.
  - WHO recommends only 5 gm of salt per day.
- **Other key things to know:**
  - **Sodium** intake from processed and restaurant food contributes to high rates of high blood pressure, heart attack, and stroke. Reducing sodium intake could prevent thousands of deaths annually.
  - **How does salt raise blood pressure** -> Class discussion?

## 2) DIABETES AND INSULIN

---

#### A) WHAT IS DIABETES?

- A medical condition when person's blood sugar level is too high.
- It is classified in **two types**:
  - » **Type 1 diabetes:** This type of diabetes appears in childhood where body can't make insulin or make insufficient Insulin, a hormone that regulates blood sugar level. It helps glucose get into cell. This condition occurs because body's immune system attacks the cells in the pancreas that make insulin.
  - » **Type 2 diabetes:** The body doesn't make enough insulin or when cells are not responding to insulin. This type of diabetes is associated with **obesity** and can lead to blindness, strokes, heart disease and even death.

---

#### B) TYPE 1 DIABETES LEADING CAUSE OF DIABETES DEATHS IN THOSE BELOW 25, EASILY PREVENTABLE: STUDY PUBLISHED IN LANCET

- » **Type 1** diabetes in those below 25 years accounted for at least 73.7% of the overall 16,300 diabetes deaths in this age group in 2019. This is despite fatalities from this condition being largely curable.
- » The **death rate** varied based on the Socio-demographic index (SDI) of a country.
  - Countries on the higher end of the SDI spectrum recorded 0.13 deaths per 100,000 people.

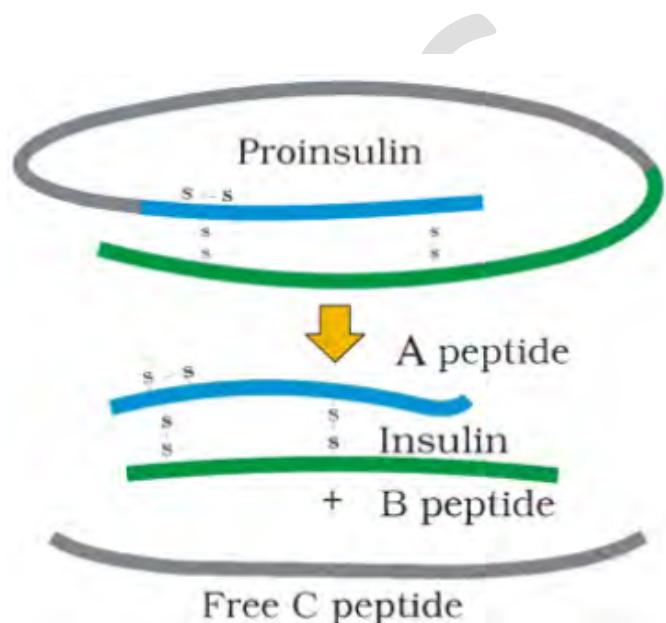
- Countries on the low middle SDI spectrum recorded 0.6 deaths per 100,000 people.
- Countries on low SDI spectrum recorded a 0.71 per 100,000 population death rate.
  - Myanmar (1.93/1,00,000 population), Papua New Guinea (1.78 per 100,000 population) and Haiti (1.57 per 100,000 population) had the highest age-standardized death rates for diabetes.

### C) INSULIN

- **Details**
  - » Insulin is a peptide hormone produced by pancreas. Inside the pancreas, the hormone insulin is made in the beta cells, which are part of islets of Langerhans. With each meal, beta cells release insulin to help the body use or store the blood sugar it gets from the food.
  - » In the beta cells, insulin is first created as a big molecule called "proinsulin". Proinsulin is broken into two pieces: Insulin and C-Peptides.
  - » **Note:** Insulin cannot be taken as pill as it would be broken down during digestion just like the protein in food. It must be injected into the fat under your skin for it to get into your blood.
- **Discovery of Insulin:**
  - » Insulin was discovered in 1921 by **Sir Frederick G Banting**, Charles H Best, and JJR Macleod at the University of Toronto in 1921 - after which it was purified by James B Collip for safer testing on humans. It was the **greatest medical breakthrough of the 20th century** and remains the go-to treatment for type-1 diabetes globally today.
    - **Note:** Back in the 19th century, those suffering from type-1 diabetes were rarely expected to live longer than a year or two after detection. This happens because type-1 diabetes is an autoimmune disease where the body destroys the cluster of cells in the pancreas
  - » In **Jan 1922**, Leonard Thompson was administered first dose. **Banting and Macleod** went on to win the **Nobel prize in Physiology** or Medicine on Oct 25, 1923.
  - » **Important Video:** 100 years of insulin use: How it was discovered and where we stand today
- **Situation today:**
  - » Globally, 15/1 lakh people suffer from type-1 diabetes. The international diabetes federation have estimated that 451 million adult suffered from diabetes worldwide in 2017. This would increase to 693 million by 2026 if not effective prevention methods are adopted.

### D) NON SUGAR SWEETNERS

- **What are non-Sugar Sweeteners?**



- » Non-Sugar Sweeteners (NSS) or Non-Nutritive Sweeteners (NNS) are substances used in place of sweeteners that have sugar (sucrose) or sugar alcohols. They have negligible or zero calories because, unlike sugar, they don't get broken down by the body into products that provide energy or calories.
- » They are used as tabletop sweeteners as well as in food items marked as 'Sugar Free', 'Diet' etc.
- » They are of primary two types - i) Artificial, ii) Natural
  - **Artificial:** These NSS are prepared in laboratories. Examples include Aspartame, Saccharine, Acesulfame-potassium, Sucratose, Neotame (derived from aspartame), Advantame (derived from aspartame) etc.
  - **Natural:** These are extracted from plants (e.g. Stavia, Thaumatin, Monk Fruit etc.)
- » All the six artificial NSS and 3 natural NSS are approved by the US Food and Drug Administration. India's FSSAI has also approved all of them (except Advantame, and Monk Fruit).

- **Why are they used?**
  - » **TO reduce consumption of sugar** (which has led to global rise in diabetes and obesity).
- **Market:**
  - » As per a report by global market consultancy The Business Research Company the market for these NSS was worth \$20 billion in 2022 and it is expected to reach about \$30 billion by 2027.
- **Criticisms:**
  - Little Evidence to substantiate the benefits of NSS** in controlling diabetes and obesity.
  - Growing body of research** says that these NSS may lead to cardiovascular diseases, cancers, and type-2 diabetes.
    - For e.g. WHO in its July 2023 guidelines have classified Aspartame as "possibly carcinogenic to humans".

#### D) PRELIMS FACTS: ASPARTAME:

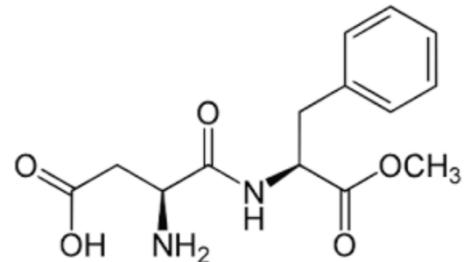
Aspartame is an artificial sweetener which was invented in 1965 and has been in use in USA since early 1980s.

It is a compound of carbon, hydrogen, nitrogen, and oxygen with chemical formula  $C_{14}H_{18}N_2O_5$ .

It is among the most popular sugar substitute used in the world.

**Several Studies have highlighted problems associated with Aspartame:**

- The **WHO** analyzed some 1,300 studies, and cited the following three, to declare aspartame "possibly carcinogenic to humans" -> European Journal of Nutrition, 2016; Cancer Epidemiology, 2022; Cancer Epidemiology, Biomarkers & Prevention, 2022;



- **WHO has placed aspartame in Group 2B.** This group consist of those substances which are possibly carcinogenic.
- **Details about various Groups:**

- » **Group-1: Carcinogenic:** These substances have shown sufficient evidence in humans and animals to be treated as carcinogenic. It includes tobacco smoking, alcohol consumption, Solar Radiation, ionizing radiation.
- » **Group-2A: Probably Carcinogenic:** Limited evidence in humans but sufficient evidence in animals. It includes insecticide DDT, Red Meat, Night Shift Work, Emission from high temperature frying etc.
- » **Group-2B: Possibly Carcinogenic:** Limited evidence in humans or sufficient evidence in animals. It includes aspartame, gasoline engine exhaust, heavy metal lead;
- » **Group-3: Not classified as carcinogen:** Inadequate evidence in humans and in animals. It includes coffee, Mercury, Paracetamol, crude oil etc.

## 15. RARE GENETIC DISEASES

- **Introduction**
  - » A rare disease is a health condition of low prevalence that affects a small number of people compared with other prevalent diseases in general population.
    - They generally include genetic diseases, rare cancers, infectious tropical diseases, degenerative diseases etc.
  - » The most common rare diseases recorded in India are Haemophilia, Thalassemia, sickle cell anaemia, primary immuno-deficiency in children, auto-immune diseases, Lysosomal storage disorders such as Pompe disease, Hirschsprung disease, Gacher's disease, Cystic fibrosis etc. These diseases may be impacting around 70 million people from India, 50% of which are children.
- **Why special focus is needed for rare diseases / Need of a separate policy on Rare Diseases**
  - » **High cost of treatment** or no treatment -> not affordable for most of the citizens -> health insurance generally excludes rare diseases.
    - Available are primarily expensive because pharma companies are not interested in R&D as the number of patients for each disease is very less (Orphan Drugs)
    - As per WHO, only 5% of the identified rare diseases have treatment.
  - » **Difficult to diagnose.**
  - » **Early screening generally doesn't happen** because of lack of awareness among primary care physicians, lack of adequate screening and diagnostic facilities etc. There are very few medical professionals who can deal with these diseases
  - » Currently there is inadequate insurance cover and treating practitioners are lacking management practices.

### 1) NATIONAL POLICY FOR RARE DISEASES, 2021

- MoH&FW came up with the policy in March 2021.
- It aims to lower the high cost of treatment for rare diseases with increased focus on indigenous research with the help of a National Consortium to be set up by Department of Health Research, MoH&FW as convenor.

- It envisages creation of a national hospital based registry of rare diseases so that adequate data is available for definition of rare diseases and for R&D.
- It focuses on **early screening and prevention** through primary and secondary healthcare infrastructure such as H&W Centres and District Early Intervention Centres (DEICs) and through counselling of high risk parents.
  - Screening will also be supported by NIDAN Kendras set up by the DBT.
- The policy aims to strengthen tertiary health care facilities for prevention and treatment of rare diseases through designating 8 health facilities as Centre of Excellence and these CoEs will also be provided one-time financial support of upto Rs 5 crores for upgradation of diagnostic facilities.
- **Provision for financial support:** The policy was amended in May 2022. It now provides a financial assistance of upto Rs 50 lakh for treatment of rare diseases of all categories.
- The policy also envisages a **crowd funding mechanism** in which corporates and individuals will be encouraged to extend financial support through a robust IT platform for treatment of rare diseases.
  - Funds so collected will be utilized by CoEs for treatment of all three categories of rare diseases as first charge and then the balance financial research could also be used for research.
- **Performance of the policy (Critical Analysis)** (Jan 2023)
  - LS MP Varun Gandhi have written to Union Health Minister and have said that more than 4,000 identified patients of rare diseases - mostly children - are yet to receive the Rs 50 lakh financial assistance for treatment guaranteed by the Union Government under the National Policy for Rare diseases, 2021.
    - More than 10 children who were awaiting treatment have already lost their lives.
  - The 10 CoEs constituted under the policy are yet to seek financial assistance (crowdfunding) for patients with rare diseases.

## 2) SOME RARE GENETIC DISEASES IN MORE DETAILS

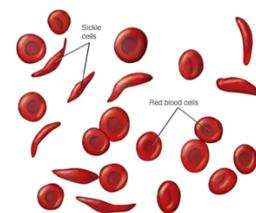
### A) SICKLE CELL ANAEMIA

- **Why in news?**
  - » The first therapy based on gene editing technology Crispr-Cas9 for Sickle cell disease and thalassemia has been approved in UK (Nov 2023)

#### About Sickle Cell Anaemia:

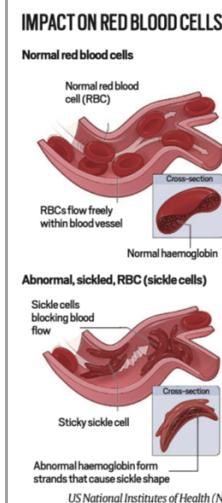
It is one of a group of inherited disorders known as Sickle Cell Diseases. It affects shape of the red blood cells which carry oxygen to all parts of the body.

RBCs are usually round and flexible so that they move easily through the blood vessels. But, in sickle cell Anaemia, some of the RBCs are shaped like sickle and also become rigid and sticky. This slows or blocks blood flow.



**Note:** Both Sickle Cell Anaemia and thalassemia are caused by errors in the gene for haemoglobin, a protein in the red blood cells that carry oxygen to organs and tissues.

**Symptoms:** Anaemia -> fatigue; Episodes of extreme pain called pain crises; Swelling of hands and feet; delayed growth and puberty; Vision problems etc.



## THE UK DRUG REGULATOR, IN A LANDMARK BREAKTHROUGH, IN NOV 2023 APPROVED A GENE THERAPY FOR THE CURE OF SICKLE CELL DISEASE AND THALASSEMIA.

- This therapy is called **Casgevy**. It is the first licensed therapy in the world based on gene editing technology CRISPR-CAS9. This therapy edits the faulty gene that leads to these blood disorder, potentially curing person for life.
- **How does the therapy work?**
  - » The therapy uses the patient's own blood stem cells, which are precisely edited using Crispr-Cas9. A gene called BCL11A, which is crucial for switching from foetal to adult is targeted in the therapy.
  - » Foetal haemoglobin, which is naturally present in everyone at birth, doesn't carry the same abnormalities as adult haemoglobin. The therapy uses the body's own mechanisms to start producing more of this foetal haemoglobin, alleviating the symptoms of the two conditions.
- **How is the therapy prepared and given:**
  - » **Casgevy** is one time treatment for which the doctor has to first collect blood stem cells from the bone marrow using a process called apheresis - used to filter out the blood for different components. The cells are then sent to the manufacturing site where it takes about six months for them to be edited and tested.
  - » **Then the edited cells are then transplanted**. Before this doctor gives a conditioning medicine for a few days to clear the bone marrow of other cells that will be replaced by modified cells.
  - » **The patient has to stay in hospital for at least one month** so that the edited cells take up the residence in bone marrow and start making RBCs with normal haemoglobin.
- **Side effects** from the treatment are similar to those associated with autologous stem cell transplants, including nausea, fatigue, fever and increased risk of infection.
- **Key challenges of the treatment:**
  - » **Very Costly**: it is estimated that the therapy will cause around \$2 million per patient, which is in line with other gene therapies.

- » **Absence of local manufacturing technology:** This means that the harvested blood stem cells have to be sent across countries.
- » **Preventing the misuse of CRISPR-CAS9:**

- **Situation in India:**
  - An estimated 30,000 - 40,000 children in India are born with this disorder every year. Thus, India has one of the highest burdens of sickle cell anaemia in the world.
- **Steps taken by India:**
  - In Budget 2023-24, a Mission to Eliminate Sickle Cell Anaemia by 2047 was announced. It entails awareness creation, universal screening of 7 crore people in the age group of 0-40 years in affected tribal areas, and counselling through collaborative efforts.

## B) THALASSEMIA:

- Thalassemia is an inherited blood disorder in which the body makes an abnormal form of hemoglobin.

- If both of your parents are carriers of thalassemia, you have a greater chance of inheriting a more serious form of disease.

- The disorder results in excessive destruction of RBCs, which leads to anemia.

- **Treatment Option**

- Blood Transfusion
  - Bone Marrow transplantation
  - Medication and supplements
  - Possible surgery to remove spleen or gallbladder.

- **Situation in India**

- India is the thalassemia capital of the world with 40 million carriers (highest in the world) and over 1,00,000 patients (Majors) under blood transfusion every month. It is the most common genetic blood disorder that is prevalent in India.
  - People suffering from the disease are unknowingly transferring on this genetic disorder to their children.

- Around 10,000 births of Thalassemia major are taking place every year.

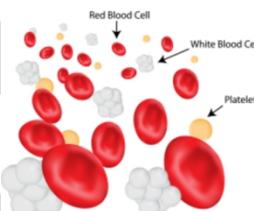
- Most of the thalassemia treatment takes place in private sector with out-of-pocket expenses.
  - The 2021 policy and associated benefits haven't been operationalized yet.

- **World Thalassemia Day**

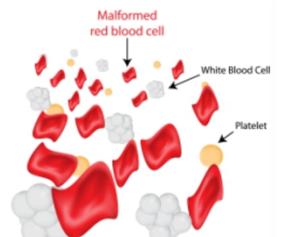
- It is observed on May 8 every year to commemorate Thalassemia victims and to encourage those who struggle to live with the disease.
  - The day was created by Thalassemia International Federation (TIF) in 1994.
  - **Theme for 2023:** "Strengthening Education to Bridge the Thalassemia Care gap"

**Thalassemia**

**Normal**



**Thalassemia**



### C) HUNTER SYNDROME OR MPS-II

1. It is a very rare inherited, genetic disorder caused by a missing or malfunctioning enzyme iduronate 2-sulfatase. This enzyme's job is to break down certain molecules (large sugar molecules called glycosaminoglycans), and without enough of this enzyme, the molecule build up in harmful amounts.
2. The buildup of massive amounts of these harmful substances eventually causes permanent, progressive damage affecting appearance, mental development, organ function and physical disabilities.
3. The condition is one type of a group of inherited metabolic disorders called mucopolysaccharidoses (MPSs). Hunter syndrome is also known as MPS II.
4. **Cure:** There is no cure for hunter syndrome. Treatment involves managing symptoms and complications.
5. **It mainly affects males.**
  - It is caused by a defective X chromosome. For females, even if one X chromosome is defective, the other may provide the correct gene. But males have only one X chromosome and hence the defective X chromosome would lead to Hunter Syndrome.

### D) HAEMOPHILIA A AND HAEMOPHILIA B (ALREADY DISCUSSED WITH BIOTECHNOLOGY)

## 16. OTHER DISEASES

### 1) DEMENTIA

- **Details**
  - **What is dementia?**
    - It is the loss of cognitive functioning - thinking, remembering, and reasoning - to such an extent that it interferes with a person's daily life and activities.
    - Dementia is more common as people grow older (about 1/3rd of all the people aged 85 or older may have some form of dementia) but it is not a normal part of aging. Many people live in 90s and beyond without any sign of dementia.
    - There are different forms of dementia including Alzheimer's disease which is responsible for 70% of the cases.
  - **Situation in India:**
    - According to a 2020 report published by the Alzheimer's and Related Disorder Society of India, there are 5 million people in India living with dementia.
  - **Cause:** When healthy neurons, or nerve cells, in the brain stop working; sometimes genetic mutation may also be responsible.
    - The exact causes of Alzheimer's are still unknown, but a classical feature of the disease is the build up of two proteins in the brain: beta amyloid and tau.

- In people with Alzheimer's, **beta-amyloid** is usually found in large quantities outside of neurons (brain cells), and tau "tangles" are found inside axons, the long, slender projection of neurons.
- Three genes have been linked to Alzheimer's disease in the young: **amyloid precursor protein (APP)**, **presenilin 1 (PSEN1)** and **presenilin 2 (PSEN2)**.
  - These genes are involved in producing a protein fragment called **beta-amyloid peptide**, a precursor to the previously mentioned beta-amyloid. If the gene is faulty, it can lead to an abnormal build-up (plaques) of beta-amyloid in the brain – a hallmark of Alzheimer's disease and a target for treatments such as the recently approved drug **lecanemab**.
  - People only need **one of APP, PSEN1 or PSEN2** to be faulty to develop **Alzheimer's disease**.
- Prevention of Dementia:
  - No proven prevention
  - In general, **leading a healthy lifestyle** may help reduce the risk factors that have been associated with these diseases.
- A 19-year-old from China is the youngest person to be diagnosed with Alzheimer's disease - the cause is a mystery (Feb 2023)
  - Nearly, all cases of Alzheimer's disease in people younger than 30 are due to **inherited faulty genes**. In fact, the previous youngest case - a 21-year-old - had a genetic cause.
  - But, in this case, **genetic cause was ruled out**.
- Lecanemab gains FDA approval for early Alzheimer Disease (Jan 2023)
  - This is a treatment that may **moderately slow mild cognitive decline and reduce amyloid-B plaques in the patients with early Alzheimer disease**. It gained **accelerated approval from the US FDA**.

## 17. MITOCHONDRIAL DISEASE

- Introduction
  - » Mitochondrial disease is a group of disorders **caused by dysfunctional mitochondria**, the organelles that generate energy for the cell.
  - » It is an **inherited chronic illness** that can be **present at birth or develop later in life**. It causes debilitating physical, developmental, and cognitive disabilities with symptoms including poor growth; loss of muscle coordination; muscle weakness and pain; seizures; vision and/or hearing loss; gastrointestinal issues; learning disabilities; and organ failures. About 1 in 2000 people have this disease in USA. It's **progressive and there is no cure**.
  - » There are many forms of mitochondrial disease, and it is inherited in a number of ways.
- What causes Mitochondrial diseases?
  - » For many patients, mitochondrial disease is an **inherited genetic condition**. Some percentage of patients **acquire symptoms** due to **other factors, including mitochondrial toxins**.
  - » The types of inherited mitochondrial diseases inherited include:
    - **DNA inheritance** (DNA contained in the nucleus of the cell). Also called autosomal inheritance

- **MtDNA Inheritance (DNA contained in mitochondria)**
  - There is **100% chance of trait occurring in other siblings, since all mitochondria are inherited from mother**, although symptoms might be more or less severe.
  - Note: Mitochondrial DNA is separate from DNA found in the cell nucleus and does not affect human characteristics such as hair or eye color, appearance or personality traits.
- » **Other causes**
  - Diseases specifically from deletions of large parts of mitochondrial DNA molecule are usually sporadic without affecting other family members.
  - Medicine or other toxic substances can trigger mitochondrial disease.
- **Treatment**
  - » The goal is to improve symptoms and slow the progression of diseases.
    - Use vitamin therapy.
    - Conserve energy
    - Pace activities
    - Maintain an ambient environmental temperature.
    - Avoid exposure to illness.
    - Ensure adequate nutrition and hydration.
- **Three Parent Babies**
  - » In 2015, Britain became the first country in the world to allow a three-parent baby to prevent some inherited incurable diseases.
  - » It is considered only hope for women who carry defective mitochondria to have healthy children. It is designed to help couples with mitochondrial disease, incurable condition passed down the maternal line that affect around one in 6500 children worldwide.
  - » The treatment is known as "three-parent" in vitro fertilization (IVF) because the babies, born from genetically modified embryos, would have DNA from mother, a father and from a female donor.
- In 2018, UK doctors selected first women to have 'three person babies'.
  - They carried genetic mutations which caused rare genetic disease.

How to make a three-person embryo



## 18. ANTI-MICROBIAL RESISTANCE

- **Why in news?**
  - » **Genes fuel antibiotic resistance in Yemen Cholera Epidemic (Sep 2023)**
    - The Cholera outbreak in Yemen, which began in 2016, is the largest in modern history and anti-biotic resistance has become widespread among V. cholerae bacteria since 2018.

- A study has found the **presence of a new plasmid** - a small, circular DNA molecule - in *V. cholerae* from late 2018 to the bacterial strain behind the epidemic. This plasmid introduced **genes encoding resistance to multiple clinically used antibiotics**, including macrolides (such as azithromycin).
- **Introduction:**
  - » Antibiotic resistance occurs **when an antibiotic has lost its ability to effectively control or kill bacterial growth**; in other words, the **bacteria become "resistant" and continue to multiply in the presence of therapeutic levels of antibiotic**.
- Why do bacteria become resistant to antibiotic?
  - » **Natural Phenomena: Evolution** - Selective pressure for the survival of resistant strains of bacteria.
  - » **Human Action:** **Current higher levels of antibiotic resistant bacteria are attributed to the overuse and abuse of antibiotics**.
- **How do bacteria become resistant?**
  - » Some bacteria are naturally resistant to certain type of antibiotics.
  - » However, bacteria may also become resistant **in two ways**
    - **By Genetic Mutation**
    - **By acquiring resistance from another bacterium**.
- **Why Anti-biotic resistance is more prevalent in India: Key Factors**
  - » **India is the largest consumer of anti-microbials globally** and the use of **last resort anti-microbials like cephalosporins is soaring**.
    - **Easy availability and overuse** of anti-biotics is the most important factor: Over the Counter Availability; Irrational Use; over-prescription by doctors
  - » **Poor Health Sector** -> improper treatment -> Development of anti-biotic resistance
    - Further, **exposure to subtherapeutic levels of anti-microbials or non-adherence to prescribed medications** has also been cited as a driver of AMR
    - E.g.: in case of TB
  - » Increasing and completely **unregulated use of antibiotic in Agriculture, live stocks and Poultry sector**.
    - **Amount of antibiotics used in the farm animal and food industry is three to four times more than those used by humans**.
    - For instance, **Colistin is extensively used in veterinary practices as a growth promoter**. This leads to generation of colistin-resistant bacteria in poultry and fresh water fish.
  - » **Poor Sanitation conditions** -> More diseases -> More use of medicines -> More AMR development
  - » **Unchecked discharge of effluents by the pharmaceutical industries** -> high concentration of pharmaceutical substances are found in **surface and ground water systems near production facilities** -> anti-biotics cause development of anti-microbial resistance in environment.
- **Impact of increasing anti-microbial resistance**
  - » **Damage to Public Health:**

- In 2019, drug-resistant superbugs killed about 1.27 million people globally - a toll more than HIV/AIDs or malaria - and according to the UN estimates, the number could reach 10 million by 2050.
  - Demands complicated treatment pattern, with longer stay in hospitals -> increase in cost of treatment.
  - Stronger antibiotics which are used after the first line of drugs fail generally have toxic side effects
  - Resistance also emerging for second line of drugs (e.g. XDR-TB emerging)
  - Without functional anti-microbials to treat bacterial and fungal infections, even the most common surgical procedures, as well as cancer chemotherapy, will become fraught with the risk of untreatable infections.
  - All this is compounded by the fact that no new class of anti-biotics have made it to the market in the last three decades, largely on account of inadequate incentives for their development and production.
- » **Economic damages** due to AMR can be equivalent to what 2008-09 economic shocks resulted into: UN Report
- » **Environmental Damages**
  - Extensive amount of anti-biotics lead to development of AMR in some micro-organisms. It impacts the microbial biodiversity and thus the environmental balance needed.
- **Steps that government has taken:**
  - **National Policy** for Containment of Antimicrobial Resistance, 2011
  - Guidelines for appropriate antibiotic usage which have revised Schedule H drugs to make over-the-counter availability of certain antibiotics nearly impossible
  - Programs such as Red Line Campaign
  - Sanitation campaigns such as Swatch Bharat Mission etc.
  - National Surveillance system for AMR (April 2017)
  - **National Action Plan on Antimicrobial Resistance (April 2017):** Focused on enhancing awareness, strengthening surveillance, improving rational use, promoting research and supporting neighboring countries.

## 19. SMOKING/DRINKING ETC.

### 1) SPURIOUS LIQUOR/ HOOCH TRAGEDIES/ METHYL ALCOHOL

- **Why do spurious drinks become poisonous sometime?**
  - » **Excess Methanol:** Illicit brewing is unscientific, hooch brewers inadvertently mix excessive amounts of methanol in their liquor every once in a while, leading to mass death.
  - » **Why is Methyl Alcohol (Methanol) used?**
    - It is similar in appearance and test to Ethyl Alcohol
    - It is easily available.
      - In Industry it is used as antifreeze, solvent, fuel, and ethanol denaturant.
  - » The potential lethal dose of methanol is variable, adverse effects has reportedly occurred at 30 ml. The toxicity of methyl alcohol manifests as permanent blindness or ultimately death due to respiratory failure.
  - » **Why is Methanol poisonous?**

- Due to accumulation of formic acid, a metabolite of methanol metabolism.
- Why do people go for this kind of drink?
  - » Cheap Price:
  - » Availability
  - » Strong effect
- Other reasons Spurious liquor prosper-> Corruption

## 20. INTERNATIONAL INITIATIVES

### 2) THE LANCET

- Details about the Lancet:
  - » The Lancet is a weekly peer-reviewed general medical journal and one of the oldest of its kind. It is also world's highest-impact academic journal. It was founded in 1823.
  - » It publishes original research articles, review articles, editorials, book reviews etc.
  - » The journal has editorial offices in London, New York City, and Beijing.
- The Lancet announced a new commission on Dec 15, 2022, to address public health threats.
  - » The scope of work by The Lancet Commission on 21st-Century Global Health Threats includes demographic changes and inverted population pyramids, high body mass index, anti-microbial resistance, eroding sexual and reproductive rights for women, food security, and fraying multilateralism.
  - » In 2024, the body will release its report after detailed study of 2 years.

## 21. FOOD SAFETY

### 1) LAWS AND INSTITUTIONS

#### A) FOOD SAFETY AND STANDARDS ACT, 2006

- Came into force in 2011.
- Key Provisions
  - i. **Consolidation of existing mechanisms**
    - The FSS Act consolidated a number of food legislations, rules, orders etc and established a single law for all matters relating to food safety and standards.
    - It subsumes acts like Prevention of Food Adulteration Act, 1954, The Fruit Product Order, 1955 etc.
  - ii. **Classification into standardized and non-standardized**
    - **Standardized Food products** - Standards are prescribed and do not require product approval prior to manufacture, sale distribution, or import. The first time manufacturer or importer only requires an FSSAI license to begin a food business.
    - **Non-standardized food products** - don't have standards as their safety parameters are either not known or either not yet ascertained.

- iii. **Statutory Authority: Food Safety and Standards Authority of India (FSSAI) and State Food Safety Authorities**
  - FSSAI is the apex body for food quality regulation in the country. It is responsible for setting standards and regulate, manufacture, storage, distribution, sale and import of food items to ensure food safety.
- iv. **Commissioner of Food Safety of state**
  - Appointed by respective state governments.
  - For efficient implementation of the Food Safety Act and various rules and regulations regarding food safety
  - Commissioner also responsible for appointing Food Safety Officers for various local areas
- v. **Graded Punishment and penalties** for contravention of the Act
- vi. **Adjudicating and Appellate Tribunal**

## B) FOOD SAFETY AND IPC

- **Section 272 of IPC** prescribed punishment for adulteration of food or drink intended for sale.
- **Section 273 of IPC** punishes sale of noxious food or drink.
  - These two sections provides for imprisonment (upto six months) and/or fine (upto 1,000 rupees)

## C) STATE FOOD SAFETY INDEX (FSI)

- **Details**
  - SFSI is an index developed by FSSAI. It aims to measure the performance of states and UTs on selected parameters of food safety.
  - It is aimed at encouraging states and Uts to improve their performance and work towards establishing a proper od safety ecosystem in their jurisdiction.
  - It is an annual report which has been released since 2018-19.
  - **Key Parameters used:**
    - » **Human Resources and Institutional Data (20%):**
    - » **Compliance (30%)**
    - » **Food Testing - Infrastructure and Surveillance (20%):**
    - » **Training and Capacity Building (10%)**
    - » **Consumer Empowerment (20%)**

## 22. MAKING MEDICINES AFFORDABLE

### 1) GENERIC MEDICINES:

- **Why in news recently?**
  - » On Aug 2023, the National Medical Council (NMC) directed all doctors to prescribe only generic names and not brand names which led to protest. Following the Indian Medical Association's protest, the NMC has withdrawn the order on 'generic prescribing' since Aug 23, 2023.
    - **Why the protest?**

- Doctors trust certain brands
- The control over which brands to take will go to chemist shops.
- **What is a generic drug?**
  - Generic drug is a low cost version of pharmaceutical drug that is equivalent to a brand-name product in dosage, strength, route of administration, quality, performance and intended use.
  - They usually enter market after patent protection of the original drug expires.
- **Note:** Broadly Medicines can be of three types:
  - **Branded:** These are still on patent
  - **Branded Generic:** Off-Patent and Generic, but nonetheless produced by a reputed company, with a brand.
  - **Generic:** Off Patent, and unbranded.
- **Advantages**
  1. Affordable healthcare
  2. Breaks the doctor-pharma nexus
    - Reduce unnecessary prescription
  3. Promotes domestic pharma companies.
  4. Difficult for quacks to function
- **Limitations**
  1. Quality concerns
  2. Erode doctor-patient relationship
  3. Low profit margins for retailers
  4. Shortage
  5. Difficult for common person to understand, especially the multiple salt names in a FDC.
  6. May discourage big pharma companies to launch their new medicines in India

## 2) JAN AUSHADHI KENDRAS

- **Intro:**
  - » Pradhan Mantri Bhartiya Janaushadhi Pariyojna (PMBJP) was launched by Department of Pharmaceuticals, Ministry of Chemical and Fertilizers, Government of India as a direct market intervention scheme in 2008.
- It aims to make quality generic medicines available to all at affordable prices through Jan Aushadhi Stores (JAS) opened in each district of the states.
  - » First Jan Aushadhi Store (JAS) was opened at Amritsar Civil Hospital in 2008.
- Other key focus of the scheme is to create awareness and demand for generic medicine.
- **Incentives given:**
  - » The scheme provides an excellent opportunity of self-employment with suitable and regular earnings.

- » An incentive of **Rs 5,00,000** is provided to the Jan Aushadhi Kendras as financial assistance and one-time additional incentive of Rs 1 lakh (as reimbursement for IT and infra expenditure) is provided to Jan Aushadhi Kendra opened in **North-Eastern India, Himalayan state, island territories, and backward areas identified by NITI Aayog as aspirational districts or if opened by women entrepreneurship, Ex-Serviceman, Divyangs, SCs and STs.**
- As of Jan 2023, **9,000 Jan Aushadhi Kendras** are functional across the country.
  - » The government has set up a target to increase the number of Jan Aushadhi Kendras to **10,000 by March 2024.**
    - It offers **1759 medicines, and 280 surgical devices** covering all major therapeutic groups.

PYQs:	
1	<p>Living organisms require at least 27 elements, of which 15 are metals. Among these, those required in major quantities include: [Prelims 1995]</p> <p>(a) Potassium, manganese, molybdenum and calcium          (b) Potassium, molybdenum, copper and calcium          (c) Potassium, Sodium, Magnesium, and Calcium          (d) Sodium, Magnesium, Copper and manganese</p>
2	<p>Which of the following hormones contains iodine? [1995]</p> <p>(a) Thyroxine          (b) Testosterone          (c) Insulin          (d) Adrenaline</p>
3	<p>Which of the following are associated with <i>Diabetes mellitus</i>, a common disease in adults? [1996]</p> <ol style="list-style-type: none"> <li>1. Higher sugar level in blood</li> <li>2. Low sugar level in blood</li> <li>3. Lower insulin level in blood</li> <li>4. Higher insulin level in blood</li> </ol> <p>Select the correct answer by using the codes given below:</p> <p>A. 2 and 4          B. 1 and 2          C. 2 and 3          D. 1 and 3</p>
4	<p>Consider the following statements: [1996]</p> <p>AIDS is transmitted</p> <ol style="list-style-type: none"> <li>1. By sexual intercourse</li> <li>2. By Blood Transfusion</li> <li>3. By Mosquito and other blood sucking insects</li> <li>4. Across the placenta</li> </ol> <p>Select the correct answer using codes provided below:</p> <p>A. 1, 2 and 3          B. 1, 2 and 4</p>

	C. 1, 3 and 4 D. 1 and 3										
5	Which of the following leads to malnourishment? [1996] 1. Overnutrition 2. Undernutrition 3. Imbalance nutrition Select the correct answer using the codes given below: A. 2 only B. 2 and 3 only C. 1 and 3 only D. 1, 2 and 3										
6	Antigen is a substance which: [1997] (a) lowers body temperature (b) destroys harmful bacteria (c) triggers the immune response (d) is used as an antidot to poison										
7	Consumption of fish is considered to be healthy when compared to flesh of other animals because fish contains: [1997] (a) polyunsaturated fatty acids (b) saturated fatty acids (c) essential vitamins (d) more carbohydrates and proteins										
8	Match List-I with List-II and select the answer using the codes given below: [1998] <table border="1"> <thead> <tr> <th>List-1</th> <th>List-2</th> </tr> </thead> <tbody> <tr> <td>A - Malaria</td> <td>1 Fungi</td> </tr> <tr> <td>B - Polio</td> <td>2 Bacteria</td> </tr> <tr> <td>C - TB</td> <td>3 Virus</td> </tr> <tr> <td>D - Ringworm</td> <td>4 Protozoan</td> </tr> </tbody> </table> (a) A-4, B-3, C-2, D-1 (b) A-4, B-3, C-1, D-2 (c) A-3, B-4, C-1, D-2 (d) D-3, B-4, C-2, D-1	List-1	List-2	A - Malaria	1 Fungi	B - Polio	2 Bacteria	C - TB	3 Virus	D - Ringworm	4 Protozoan
List-1	List-2										
A - Malaria	1 Fungi										
B - Polio	2 Bacteria										
C - TB	3 Virus										
D - Ringworm	4 Protozoan										
9	Haemophilia is a genetic disorder which leads to: [1998] A. Decrease in haemoglobin level B. Rheumatic Heart Disease C. Decrease in WBC D. Non-clotting of blood										

10	<p>Assertion (A): Unsaturated fats are more reactive compared to saturated fats  Reason (R): Unsaturated fats have only single bonds in their structure</p> <p>(A) Both A and R are true and R is the correct explanation of A  (B) Both A and R are individually true but R is not the correct explanation of A  (C) A is true but R is false  (D) A is false but R is true</p>
11	<p>Consider the following statements about probiotic food: [2008]</p> <ol style="list-style-type: none"> <li>1. Probiotic food contains live bacteria which are considered beneficial to health</li> <li>2. Probiotic food help in maintaining gut flora</li> </ol> <p>Which of the statements given above is/are correct?</p> <ol style="list-style-type: none"> <li>A. 1 only</li> <li>B. 2 only</li> <li>C. Both 1 and 2</li> <li>D. Neither 1 nor 2</li> </ol>
12	<p>Regular intake of fresh fruits and vegetables is recommended in the diet since they are good source of anti-oxidants. How do antioxidants help a person maintain health and promote longevity? [Prelims 2011]</p> <ol style="list-style-type: none"> <li>A. They activate the enzymes necessary for vitamin synthesis in the body and help prevent vitamin deficiency</li> <li>B. They prevent excessive oxidation of Carbohydrates, fats and proteins in the body and avoid unnecessary wastage of energy</li> <li>C. They neutralize the free radicals produced in the body during metabolism</li> <li>D. They activate certain genes in the cells of the body and help delay the ageing process</li> </ol>
13	<p>Which of the following is/are correct? [2013]</p> <ol style="list-style-type: none"> <li>1. Viruses lack enzymes necessary for the generation of energy</li> <li>2. Viruses can be cultured in the synthetic medium</li> <li>3. Viruses are transmitted from one organism to another by biological vectors only</li> </ol> <p>Select the correct answer using the codes given below:</p> <ol style="list-style-type: none"> <li>A. 1 only</li> <li>B. 2 and 3 only</li> <li>C. 1 and 3 only</li> <li>D. 1, 2 and 3</li> </ol>
14	<p>Consider the following minerals [Prelims 2013]</p> <ol style="list-style-type: none"> <li>1. Calcium</li> <li>2. Iron</li> <li>3. Sodium</li> </ol>

	<p>Which of the minerals given above is/are required by human body for the contraction of muscles?</p> <ol style="list-style-type: none"> <li>1 only</li> <li>2 and 3 only</li> <li>1 and 3 only</li> <li>1, 2 and 3</li> </ol>
15	<p>Which of the following diseases can be transmitted from one person to another through tattooing? [Prelims 2013]</p> <ol style="list-style-type: none"> <li>Chikungunya</li> <li>Hepatitis B</li> <li>HIV-AIDS</li> </ol> <p>Select the correct answer using the codes given below:</p> <ol style="list-style-type: none"> <li>1 only</li> <li>2 and 3 only</li> <li>1 and 3 only</li> <li>1, 2 and 3</li> </ol>
16	<p>Consider the following diseases: [Prelims 2014]</p> <ol style="list-style-type: none"> <li>Diphtheria</li> <li>Chickenpox</li> <li>Smallpox</li> </ol> <p>Which of the above diseases has/have been eradicated in India?</p> <ol style="list-style-type: none"> <li>1 and 2 only</li> <li>3 only</li> <li>1, 2 and 3</li> <li>None</li> </ol>
17	<p>H1N1 virus is sometimes mentioned in news with reference to which one of the following diseases? [Prelims 2015]</p> <ol style="list-style-type: none"> <li>AIDS</li> <li>Bird Flu</li> <li>Dengue</li> <li>Swine Flu</li> </ol>
18	<p>Which of the following statements is/are correct? (2016 Pre)</p> <p>Viruses can infect</p> <ol style="list-style-type: none"> <li>bacteria</li> <li>fungi</li> <li>plants</li> </ol> <p>Select the correct answer using the code given below.</p> <ol style="list-style-type: none"> <li>1 and 2 only</li> <li>3 only</li> <li>1 and 3 only</li> <li>1, 2 and 3</li> </ol>

19	<p>'Mission Indradhanush' launched by the Government of India pertains to (Pre 2016)</p> <ul style="list-style-type: none"> <li>(a) immunization of children and pregnant women</li> <li>(b) construction of smart cities across the country</li> <li>(c) India's own search for the Earth-like planets in outer space</li> <li>(d) New Educational Policy</li> </ul>
20	<p>Consider the following statements: (Pre 2017)</p> <ol style="list-style-type: none"> <li>1. In tropical regions, Zika virus disease is transmitted by the same mosquito that transmits dengue.</li> <li>2. Sexual transmission of Zika virus disease is possible.</li> </ol> <p>Which of the statements given above is/are correct?</p> <ul style="list-style-type: none"> <li>(a) 1 only</li> <li>(b) 2 only</li> <li>(c) Both 1 and 2</li> <li>(d) Neither 1 nor 2</li> </ul>
21	<p>Which of the following statements is not correct? (Pre 2019)</p> <ul style="list-style-type: none"> <li>(a) Hepatitis B virus is transmitted much like HIV.</li> <li>(b) Hepatitis B, unlike Hepatitis C, does not have a vaccine.</li> <li>(c) Globally, the number of people infected with Hepatitis B and C viruses are several times more than those infected with HIV.</li> <li>(d) Some of those infected with Hepatitis B and C viruses do not show the symptoms for many years.</li> </ul>
22	<p>Which of the followings are the reasons for the occurrence of multi-drug resistance in microbial pathogens in India? [Prelims 2019]</p> <ol style="list-style-type: none"> <li>1. Genetic predisposition of some people.</li> <li>2. Taking incorrect doses of antibiotics to cure diseases.</li> <li>3. Using antibiotics in livestock farming.</li> <li>4. Multiple chronic diseases in some people.</li> </ol> <p>Select the correct answer using the code given below.</p> <ul style="list-style-type: none"> <li>(a) 1 and 2</li> <li>(b) 2 and 3 only</li> <li>(c) 1,3 and 4</li> <li>(d) 2,3 and 4</li> </ul>
23	<p>A company market food products advertises that its items don't contain trans-fats. What does this campaign signify to customers? [Prelims 2021]</p> <ol style="list-style-type: none"> <li>1. The food products are not made out of hydrogenated oils</li> <li>2. The food products are not made out of animal fats</li> <li>3. The oil used are not likely to damage the cardiovascular health of consumers</li> </ol> <p>Which of the statements given above is/are correct?</p> <ul style="list-style-type: none"> <li>A. 1 only</li> <li>B. 2 and 3 only</li> <li>C. 1 and 3 only</li> <li>D. 1, 2 and 3</li> </ul>
24	<p>The term ACE2 is talked about in the context of (Prelims 2021):</p> <ul style="list-style-type: none"> <li>A. genes introduced in the genetically modified plants</li> <li>B. development of India's own satellite navigation system</li> </ul>

	<p>C. radio collars for wildlife tracking D. spread of viral diseases</p>
25	<p>In the context of hereditary diseases, consider the following statements: [Prelims 2021]</p> <ol style="list-style-type: none"> <li>1. Passing on mitochondrial diseases, from parent to child can be prevented by mitochondrial replacement therapy either before or after in vitro fertilization of egg</li> <li>2. A child inherits mitochondrial diseases entirely from mother and not from father</li> </ol> <p>Which of the statements given above is/are correct?</p> <ol style="list-style-type: none"> <li>A. 1 only</li> <li>B. 2 only</li> <li>C. Both 1 and 2</li> <li>D. Neither 1 nor 2</li> </ol>
26	<p>Consider the following statements in respect of probiotics: [Prelims 2022]</p> <ol style="list-style-type: none"> <li>1. Probiotics are made of both bacteria and yeast.</li> <li>2. The organisms in probiotics are found in foods we ingest but they do not naturally occur in our gut.</li> <li>3. Probiotics help in the digestion of milk sugars.</li> </ol> <p>Which of the statements given above is/are correct?</p> <ol style="list-style-type: none"> <li>A. 1 only</li> <li>B. 2 only</li> <li>C. 1 and 3</li> <li>D. 2 and 3</li> </ol>
27	<p>'Wolbachia method' is sometimes talked about with reference to which one of the following?</p> <ol style="list-style-type: none"> <li>(a) Controlling the viral disease spread by mosquitoes</li> <li>(b) Converting crop residues into packing material</li> <li>(c) Producing biodegradable plastics</li> <li>(d) Producing biochar from thermochemical conversion of biomass</li> </ol>



# TARGET PRELIMS 2024

## BOOKLET-11; EB&CC-1

# ENVIRONMENTAL ECOLOGY - BASICS

### 1. TABLE OF CONTENTS

1. <i>Table of Contents</i> .....	0
2. <i>Some Basic Facts</i> .....	2
1) Ramdeo Misra .....	2
3. <i>Organisms, Population, Ecosystem and Ecology</i> .....	2
1) Organism and Its Environment; Ecology and Ecosystem .....	2
2) Level of Organisations in Ecosystem .....	3
3) Ecosystem and various components of AN Ecosystem .....	4
A) Abiotic Components .....	4
B) Biotic Component .....	4
4) Ecotone .....	5
2) Ecological Niche .....	6
3) Biomes .....	7
C) Various Types of Terrestrial Biomes and Key Features:.....	8
D) Various types of Aquatic Biomes and their key features:.....	9
4) Biosphere .....	10
5) habitat and how organisms have evolved to adapt to optimize its survival and reproduction in its habitat .....	10
A) Major Abiotic Factors/ Abiotic Components.....	10
B) Responses to Abiotic Factor.....	12
C) Adaptation .....	14
5) Populations .....	16
A) Population Growth.....	16
B) Life History Variation .....	16
C) Population INteraction:.....	17
4. <i>Functions of an Ecosystem</i> .....	21
1) Energy FFlow through an Ecosystem.....	22
A) TROPHIC LEVEL: .....	22

B)	FOOD CHAIN: .....	22
C)	FOOD WEB: .....	25
D)	ECOLOGICAL PYRAMIDS.....	25
E)	Pollutants and Trophic Levels .....	28
<b>2)</b>	<b>BIO-GEO-CHEMICAL CYCLING OR NUTRIENT CYCLING.....</b>	<b>30</b>
A)	Water Cycle (Hydrologic Cycle).....	31
B)	CARBON CYCLE.....	31
C)	NITROGEN CYCLE .....	32
D)	PHOSPHOROUS CYCLE .....	33
F)	Sulphur Cycle: .....	33
<b>3)</b>	<b>ECOLOGICAL SUCCESSION: .....</b>	<b>34</b>
A)	Types of Ecological Succession: .....	35

## 2. SOME BASIC FACTS

### 1) RAMDEO MISRA

- He is considered the **father of ecology in India**. He was born in 1908 and obtained **Ph.D. in Ecology (1937)**, from LEEDS University in UK.
- He **established teaching and research in ecology at the Department of Botany of the Banaras Hindu University (BHU)**.
- His research laid the **foundations for understanding of tropical communities and their succession**, environmental responses of plant populations and productivity and nutrient cycling in tropical forest and grassland ecosystems.
- He **formulated first post graduate course in ecology in India**.
- Due to his efforts, the GoI established the **National Committee for Environmental Planning and Coordination (1972)** which, in later years, paved the way for the **establishment of the Ministry of Environment and Forest (1984)**.

## 3. ORGANISMS, POPULATION, ECOSYSTEM AND ECOLOGY

- **Ecology** is the study of the **relationships of living organisms with the abiotic (physical-chemical factors) and biotic components (other species) of their environment**. It is concerned with **four levels of biological organization – Organisms, Populations, Communities and Biomes**.

### 1) ORGANISM AND ITS ENVIRONMENT; ECOLOGY AND ECOSYSTEM

- **Environment:** Everything that surrounds an organism is its environment.
  - » In simple terms, **environment of an organism refers to the physical, chemical, and biological conditions and factors** that surround and influence the life of an organism. It includes **all the living (biotic components)** and non-living things (**abiotic components**) that an organism interacts with, such as the air, water, soil, light, temperature, **other organisms**, and the physical structure in its surroundings.
  - » The environment of an organism is critical for its survival and protection as it affects many aspects of its life including metabolism, behaviour, growth and development.
  - » **Understanding Environment of organism** is very important because:
    - Environment is **critical for the survival and protection**.
    - Different organisms have **different environmental requirements** and adaptations. Some may be **more tolerant or adaptable to change in their environment than others**.

- By studying environment of an organism, scientists can gain insights into how it has evolved and adapted to its surroundings and how it may respond to future changes in environment.
- **Ecology** is the study of relationship between living organisms, including humans and their environment. It seeks to understand the vital connections between plants and animals and the world around them. It seeks to understand how organisms interact with each other and with their physical environment, and how these interactions affect the sustainability of the entire system.

## 2) LEVEL OF ORGANISATIONS IN ECOSYSTEM

Ecosystems are complex and dynamic systems that can be studied at different levels of organization each provide a different perspective on the ecosystem. The level of organizations in ecosystem include:

- 1) **Individual Organisms:** The smallest unit of an ecosystem is the individual organism, such as a single plant, animal or microbe.
- 2) **Population:** A population is a group of individuals usually of the same species living in the same area and interacting with each other.
- 3) **Community:** It is a group of populations of different species living in the same area and interacting with each other. It consists of all the biotic factors of an area.
  - Communities in most cases are named after the dominant plant from (species). E.g. Grassland community is dominated by grasses. Though it may contain herbs, shrubs, some trees, and other animals. It is named after grasses.
  - **Communities can be classified into – Major Community vs Minor Communities**

Features:	Major Community	Minor Community
<b>Definition:</b>	These are <u>large sized, well organized, and relatively independent</u> ( <u>self-sustaining</u> ) and depend on only sun's energy and is independent of inputs and outputs from adjacent community. E.g. <u>Grasslands; Deserts; Evergreen rain forests etc.</u>	These are <u>smaller</u> and are <u>dependent on neighbouring communities</u> . These are <b>secondary congregation within a major community</b> and are <u>not therefore completely independent units</u> as far as energy and nutrient dynamics are concerned. E.g. ( <u>stream within a forest; mat of lichen on a cow dung pad</u> )
<b>Size</b>	Large	Small; localized area
<b>Self-sustainability</b>	Yes	No; depends on resources from other neighbouring communities
<b>Impact of disturbance</b>	More resilient due to larger size and diversity	More vulnerable to disturbance due to smaller size and dependence on other community.

- 4) **Ecosystem:** It includes all the biotic and abiotic components in the given area and the interactions between them.

- 5) **Biome:** A biome is a large geographical area characterized by a specific set of climatic conditions and plant and animal communities.
- 6) **Biosphere:** The biosphere is the portion of the Earth that supports life, including all of the ecosystems on the planet

Each level of organization in an ecosystem is interconnected and interdependent, and changes at one level can have cascading effects on the other levels. Understanding the different levels of organization in an ecosystem can help us better understand how ecosystem function, how they respond to disturbance, and how we can manage them for sustainability.

### 3) ECOSYSTEM AND VARIOUS COMPONENTS OF AN ECOSYSTEM

- An ecosystem is a community of living organisms (plants, animals, and microorganisms) that interact with each other and with the non-living components (such as air, water, and soil).
- Ecosystem can vary in size, from a small pond to a vast forest. Each ecosystem is a functioning unit of nature.
  - Every organism in an ecosystem is dependent on the other component of the ecosystem. Therefore, if some part of the ecosystem is damaged, it has an impact on other organisms living in that ecosystem.
- **Components of Ecosystem:**

#### A) ABIOTIC COMPONENTS

- Energy
- Water/Rainfall
- Temperature
- Atmosphere
- Substratum (soil and minerals)
- Latitude and Longitude

#### B) BIOTIC COMPONENT

- It consists of living organisms and are classified as per their functional attributes into **producers** and **consumers**:
  - a) **Primary Producers (Autotrophs):** These are organisms which are capable of making their own food using sunlight (photosynthesis) or inorganic compounds (chemosynthesis).
    - Examples include plants, algae, and some bacteria.
  - b) **Consumers (Heterotrophs or phagotrophs)**
    - They don't produce their own food and depend on food derived from other plants, animals and other species.
    - They can be divided into macro-consumers and micro-consumers.
      - **Macroconsumers:** They feed on both plants and animals and can be classified into **herbivores/primary consumers** (e.g. Deer) (feed mainly on plants);

- carnivores/secondary consumers** (e.g. wolves) (feed on primary consumers); **carnivores/tertiary consumers** (e.g. lion) (feed on secondary consumers) and **Omnivores** (e.g. humans, monkeys etc.) (feed on both plants and animals).
- **Micro consumers – Saprotrophs** (decomposers or osmotrophs): These are bacterias and fungi which derive their energy and nutrients by decomposing dead organic substances (detritus) of plant and animal origin. They release inorganic nutrients into environment which are used by primary producers and thus are recycled. Earthworms, and some soil organisms (such as nematodes and arthropods) are detritus feeders and help in decomposition of organic matter and are called detrivores.

#### 4) ECOTONE

**Ecotone** refers to the transitional zone or boundary where two different ecosystems or biomes meet and integrate with each other. It is characterized by a mix of vegetation, soil and animal species from both ecosystems, creating a unique habitat with its own set of ecological dynamics.

It can be found in various terrestrial and aquatic environments, such as where a forest meets a grassland, or where a river meets a lake.

**Important Characteristics of ecotones:**

- 1) **Transitional zone**
- 2) **High Species Diversity** compared to either of the adjacent ecosystem, as they contain species from both ecosystems and may offer greater range of resources for organisms.
  - a. **Edge Effect:** Sometimes number of species, and the population density of some of the species is much greater in this zone than either ecosystem. This is called edge effect.
  - b. **Edge Species:** Edge dwelling or ecotone dependent species are those that are particularly adapted to living in the transitional zone or boundary between two different ecosystems or biomes. These organisms occur primarily or most abundantly in the ecotone zone. In terrestrial ecosystem the edge effect is most applicable on birds. Density of birds is greater in the mixed habitat of ecotone between the forest and desert.
    - E.g., of edge species: Indian Spotted eagle; Indian rock python; Golden jackal etc.
- 3) **Unique Species Composition:** Ecotones may contain unique species that are specialized to the transitional habitat and not found in either adjacent ecosystem.
- 4) **Abiotic Gradient:** Ecotones may be characterized by abiotic gradient, such as changes in soil, water, temperature, or light conditions, which create different microhabitats and ecological niches for species.
  - a. This brings a linearity -> progressive increase in composition of one in coming community and a simultaneous decrease in species of the other outgoing adjoining community.

**Significance of ecotone:**

- **Support high level of biodiversity** due to greater range of resources (higher species richness and ecological resilience)

- Act as **important corridors for movement of species** between different ecosystems, allowing for a genetic exchange and maintaining population viability.
- **Important indicator of ecosystem health:** They can also be particularly sensitive to environmental changes and disturbances. Thus, they can inform conservationists about the required management efforts.

**Overall**, ecotones play a crucial role in maintaining the health and functioning of ecosystems, as well as providing important ecosystem services and biodiversity.

## 2) ECOLOGICAL NICHE

**Ecological Niche** refers to the role or position of a species within an ecosystem. It includes its interaction with biotic and abiotic factors of the ecosystem. It encompasses the species habitat requirements, food and water requirements, reproductive strategy and its relationship with other species in the ecosystem.

**Niche Differentiation:** Each species in an ecosystem occupies a unique ecological niche to minimize competition for resources. This allows different species to co-exist and allows for a greater biodiversity within an ecosystem.

- For example, some species may occupy a niche as primary producers, converting sunlight and inorganic nutrients into organic matter, while others may occupy a niche as herbivores or carnivores, feeding on the primary producers or other consumers in the ecosystem

**Competitive Exclusion Principle:** The two species competing for same limited resources cannot coexist in the same niche at a constant population level. If the needs are identical and resources limited than one will outcompete other leading to extinction or niche differentiation.

- **E.g.-1: Darwin Finches** (Galapagos Finches): On Galapagos island, different finch species have evolved different beak types so that they can depend on different kind of food sources. This allowed them to co-exist even within limited resources.
- **E.g.-1: Competitive Dominance:** An invasive species which has some competitive advantage can lead to extinction of native species.

### Fundamental vs Realized Niche:

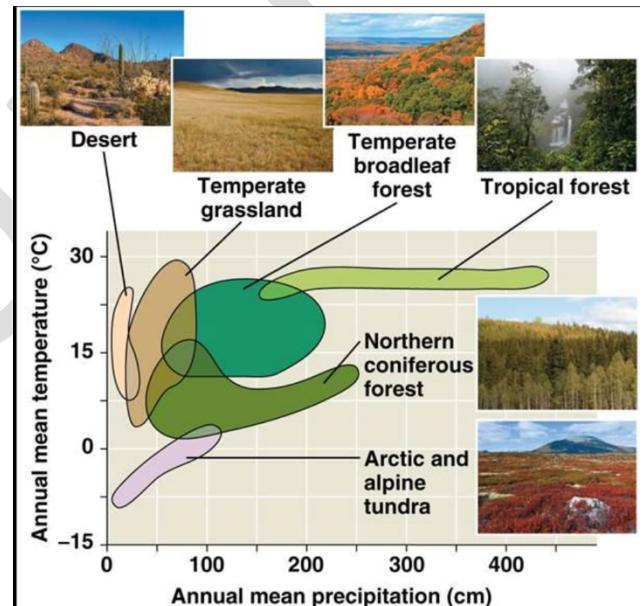
- **Fundamental niche** refers to range of environmental conditions which will allow a species to reproduce and survive successfully, if there was no competition or predators. It reflects species full ecological capabilities and adaptations, assuming ideal conditions.
- **Realized Niche:** It refers to actual set of conditions and resources a species utilizes in the presence of competition from other species. Competition, Predation, and limited resources restrict the species' access to some parts of its fundamental niche. The realized niche is always smaller than or equal to fundamental niche. The same species can have different realized niche in different locations, depending on the local community and environment.

The ecological niche of a species is not fixed, but rather can change over time due to changes in the environment, competition with other species, and other factors. In some cases, two or more species may occupy similar ecological niches, leading to competition for resources and potential changes in the niche of one or both species.

Understanding the ecological niche of a species is important for conservation and management efforts, as it can help to identify the key resources and environmental conditions that are necessary for the survival of the species. By protecting the ecological niche of a species, conservationists can help to maintain the biodiversity and functioning of the ecosystem as a whole.

### 3) BIOMES

- A biome is a large geographical area characterized by a specific set of climatic conditions and plant and animal communities. Variation in temperature, precipitation (both rain and snow) account for the formation of biomes.
- It can also be defined as a major life zone, that includes communities of plants and animals that have a common adaptation to that particular environment.
- **Biomes of the World:** For general understanding purpose we have divided the terrestrial biome into following types (based on NCERT). Please note that some other sources may make this division in many different ways, some going to the extent of 20 different biomes.



## C) VARIOUS TYPES OF TERRESTRIAL BIOMES AND KEY FEATURES:

### 1) Arctic and Alpine Tundra:

- It is characterized by cold, dry and windy conditions.
- Most of the region is under permafrost (a thick layer of ice lying just below the shallow soil). Because of this tree cant penetrate to anchor their roots.
- **Flora:** Lichens, Mosses, grasses, shrubs etc.
- **Fauna:** Polar bears, arctic foxes, migratory birds, reindeer etc. Here reptiles and amphibians are almost absent.



### 2) Taiga/ Northern Coniferous Forests/ Boreal Forests:

- Boreal forests are full of life that are adapted to withstand frigid temperatures year around (or very long cold winters). They are made up of conical evergreen trees with needle like trees. These trees are called conifers because their seeds are clumped into cones. They include spruce, fir, pine etc.
- **Fauna** includes birds, hawks, fur bearing carnivores, little mink, elks, puma etc.
  - During cold winters mammals hibernate and birds migrate. Some animals have evolved to grow dense feathers or fur to survive the winters.
- **Taiga** is the largest land (terrestrial) biome in the world.



### 3) Temperate Deciduous Forest:

- Characterized by moderate temperatures and rainfall
- Deciduous trees, shrubs, grasses
- Fauna: Deer, bears, squirrels, birds etc.

### 4) Tropical Rain Forests:

- High temperatures and rainfall, little seasonal change,
- **Fauna:** Broad leaf evergreen trees, lianas, epiphytes, orchids. Multiple storey of broad-leaved evergreen trees are in abundance.
- **Floras:** Most animals and epiphytes are concentrated in the canopy or tree top zones. They include monkeys, sloths, jaguars, snakes etc.

**Why tropical rain forests are not suitable for agriculture-> very less fertility:**

- Surface soil is heavier leached (nutrients washed away) by running water. Here, the inferior surface soil is the limiting factor that limits the germination of seeds.
- Germinated saplings may not survive due to lack of light because of the dense canopy. Here, the absence of light (shade of the forest) is the limiting factor.

## 5) Savannah Grasslands/ Tropical Grasslands:

- Most extensive in Africa
- Warm and hot conditions with distinct wet and dry seasons
- **Flora:** Grasses are the dominant vegetation in Savannah grasslands, with trees and shrubs scattered throughout the landscape.
  - **Acacia tree** is commonly found in African Savannahs and eucalyptus trees are found in Australian Savannahs.
  - **Enough seasonal rainfall** so that trees can grow in open groups or singly throughout.
- **Fauna:** Large herbivores like zebra, giraffes, antelopes, as well as predators like Lions, Cheetahs, and hyenas.
- **Fire:** It is a common characteristic of Savannah which help to maintain grassy landscapes by clearing away excess vegetation and promoting new growth.
- **Soil:** Soil is typically nutrient poor and shallow and thus it finds difficulty in supporting trees.



## 6) Temperate Grasslands:

- They are popularly known as prairies, steppes or pampas.
- **Climate:** Continent climate with hot summers cold winters. They receive moderate rainfalls.
- **Fauna:** Large herbivores such as bison, pronghorn, and deer as well as predators such as foxes, coyotes, wolves etc.
- **Fire:** they are also characterized by frequent forest fires.  
(The region is dry enough to cause fires and trees can't survive).
- **Soil:** Nutrient rich due to accumulation of organic matter from the grasses. The soil is often deep, and fertilize making it suitable for agriculture.



## 7) Desert:

- **Climate:** Low precipitation; extreme temperature fluctuations
- **Flora:** Cacti, Succulents scrubby bushes
- **Fauna:** Lizards, snakes, scorpions, coyotes, kangaroo rats etc.

---

## D) VARIOUS TYPES OF AQUATIC BIOMES AND THEIR KEY FEATURES:

The aquatic biomes are divided into fresh water and marine regions.

### 1) Fresh Water Biomes:

- a. **Rivers and Lakes:** Fast moving, flowing water that originates from mountains and has high oxygen levels.
- b. **Lakes and Ponds:** Standing bodies of water with varying depths, temperatures, and oxygen level
- c. **Wetlands:** Low lying area with standing water, such as marshes, swamps.

### 2) Marine Biomes:

- a. **Oceans:** The largest biome on earth, oceans are divided into zones based on depth and receive varying amount of sunlight, affecting the types of organisms that can survive in each zone
- b. **Coral Reefs:** Warm, shallow waters where diverse species of corals thrive
- c. **Estuaries:** Areas where freshwater meets saltwater, creating unique habitats for species adapted to changing salinity levels.

**Please note:** This is not an exhaustive list of terrestrial and aquatic biomes.

#### 4) BIOSPHERE

- The biosphere is the part of the earth where life exists, which includes all living organisms and their interactions with the environment. It extends from the deepest ocean depths to the highest altitudes in the atmosphere and includes all terrestrial and aquatic ecosystems.
- The biosphere is composed of various biomes.
- The biosphere is a complex system, with numerous ecological interactions and feedback loops. It consists of various food chains and food webs.

#### 5) HABITAT AND HOW ORGANISMS HAVE EVOLVED TO ADAPT TO OPTIMIZE ITS SURVIVAL AND REPRODUCTION IN ITS HABITAT

- **Regional and local variations** with each biome leads to formation of habitat.
  - » Over a period of time, the organism had evolved to adapt to optimize its survival and reproduction in its habitat.

##### A) MAJOR ABIOTIC FACTORS/ ABIOTIC COMPONENTS

- **Temperature:** It is the most important ecologically relevant environmental factor. It affects the kinetics of enzymes and through it the metabolic activity and other physiological functions of the organism. The levels of thermal tolerance of different species determine to a large extent their geographical distribution.
  - » A few organisms can tolerate and thrive in wide range of temperatures (they are called euthermal). (e.g., Humans, Cows, Monkeys, Sheep, Goats etc.)
  - » A vast majority of organism are restricted to a narrow range of temperatures (they are called stenothealthal). (e.g. penguins, crustaceans etc.)

- **Water:** Life on earth originated in water and can't sustain without water. In limited water conditions like deserts, special adaptations techniques are needed for organisms to live there. The productivity and distribution of plants are also dependent on water. Even aquatic organisms face water related issues as sometimes the quality, pH etc. becomes problematic. The salt concentration of water is also an important factor. Many freshwater species can't survive in ocean water for long because of the osmotic pressure that they face.
  - » Some organisms may tolerate a wide range of salinities (euryhaline), but others are restricted to narrow range (stenohaline).
- **Light:** Autotrophs who form the first level of any food chain depend on light for generating food. Thus, light is important for all living organisms.
  - » **Some organisms** survive in less light conditions (e.g., herbs and shrubs growing in tropical rain forests have adapted to do photosynthesis optimally under very low light conditions because they are constantly overshadowed by tall, canopied trees).
  - » **Many plants** are dependent on sunlight to meet their photoperiodic requirement for flowering.
    - Most angiosperms (flowering plants) use photoperiodism to determine when to flower. To do that they use one of the photoreceptor protein present in their body such as cryptochrome or photochrome.
  - » **For many animals too, light is important** in that they use diurnal and seasonal variation in light intensity as cues for timing their foraging, reproductive and migratory activities.
  - » **Note:** How do deep sea organisms get their energy (since light doesn't reach there)?
    - **Three major methods** – Marine Snow; Whale Falls; Chemosynthesis.
    - **Marine Snow:** It refers to biological debris that originate from the top layers of the ocean and drift to the seafloor, providing primary source of energy for animals in the deep ocean. It primarily consists of phytoplankton produced through photosynthesis and as they sink, it collects other floating debris, including fecal material, dead or decaying animals, suspended sediments etc.
    - **Whale Fall:** When whales die and sink, the whale carcasses, or whale falls provide a sudden concentrated food source and a bonanza for organisms in the deep sea. Useful video: [https://youtu.be/LUFKzP8ql\\_A?si=aSWIQtOw2u1xeAsi](https://youtu.be/LUFKzP8ql_A?si=aSWIQtOw2u1xeAsi)
  - » **Among the red, green and brown algae** that inhabits the sea, which is likely to be found deepest in water?
    - **How sunlight penetration varies with depth of ocean? Short wavelength/high frequency** light can penetrate sea water more easily. Thus, as depth increases, blue light reaches, green reaches less, Yellow further lesser and Red reaches the least.

- Red algae at the depth of the ocean thus absorbs blue green wavelength and survive at deeper layer. They have more quantity of the pigment **phycoerythrin**. It absorbs the blue-green spectrum of the visible light.
- **Soil:** Characteristics of soil such as soil composition, grain size, and aggregation determine the percolation and water holding capacity of the soils. These characteristics along with other parameters like pH, mineral composition, and topography determine to a large extent the vegetation in any area. This in turn dictates the type of animals that can be supported. Similarly, the aquatic environment, the sediment-characteristics often determine the type of benthic animals that can thrive in the soil.

## B) RESPONSES TO ABIOTIC FACTOR

- **Abiotic components** of a habitat may vary drastically with time.
  - » But most species have evolved to have a relatively constant internal (within the body) environment. This constant environment provides maximal efficiency for all biochemical and physiological functions and thus enhances the overall fitness of the organisms. This may be in terms of optimal temperature and osmotic concentration of the body fluid.
  - » **Ideally then**, the organism should try to maintain the constancy of its internal environment (a state called homeostasis) despite varying external conditions that tends to upset its homeostasis.
    - **Note:** Homeostasis is the state of steady internal, physical, and chemical conditions maintained by living environment.
- How do organisms living in such habitats cope or manage with such stressful conditions?
  - » **Regulate:** Some organisms are able to maintain homeostasis by physiological means (sometimes behavioral means also).
    - All birds and mammals, and a very few lower vertebrates and invertebrates are capable of such regulation (thermoregulation and osmoregulation).
    - Evolutionary biologists believe that success of Mammals is largely due to their ability to maintain a constant body temperature and thrive weather they live in Antarctica or Sahara Desert
      - **For e.g.: Human** maintain the body temperature at 37-degree C. In summers, we sweat to produce evaporating cooling and in winters, we shiver to produce heat and raise the body temperature.
    - **Regulation is energetically expensive.** This is particularly true for small animals like shrews and hummingbirds. Small animals have large surface area relative to their volume, they tend to lose their body heat very fast when it's cold outside; and they would need a lot of energy to maintain the body temperature. This is the reason why very small animals are rarely found in Polar region.
  - » **Conform:** Conformers are organisms that lack the ability to regulate their internal body temperature (endothermy) and instead rely on their environment to dictate their internal

temperature (ectothermy). This means that they experience significant changes in their body temperature along with the fluctuations in their surrounding environment.

- In aquatic animals, the osmotic concentration of body fluids changes with that of the ambient air, water osmotic concentration. These animals and plants are conformers.
- **E.g. of conformers:**
  - » **Fish:** Many fish are conformers, meaning that their body temperature matches to their surrounding water. They adjust metabolic rates and activity levels based on the outside temperature. Some fish species like trots which prefer colder waters will migrate to deeper or cooler oceans during warmer seasons.
  - » **Reptiles** are classic examples of conformers. They rely on external source of heat such as sunlight to regulate their body temperature. Basking in the sun helps them warm up, while seeking shade or burrowing underground helps them cool down.
  - » **Amphibians** – most are conformers. Basking in sun, shelter in cooler areas to avoid overheating etc.
  - » **Ectothermic Plants** – The metabolic activities and growth of plants are influenced by ambient temperature. For e.g., the rate of photosynthesis in plants increase at higher temperature and decreases with low temperature.
- **Why didn't these animals and plants become regulators?**
  - » Thermoregulation is energetically expensive for many organisms.
  - » During evolution, the cost and benefit of maintaining a constant internal environment are taken into consideration. Some species have evolved the ability to regulate, but only over a limited range of environment, beyond which they simply conform.
- » **Migrate:** If the stressful external condition is localized or remain only for short duration, the organisms have two other alternatives for survival Migration or Suspension.
  - **Migration:** In migration, organism move temporarily from the stressful habitat to a more hospital area and return when stressful period is over. (E.g., Siberian crane coming to Rajasthan in winters)
  - **Suspension:**
    - In bacteria, fungi and lower plants, various kinds of thick-walled spores are formed which help them to survive unfavorable conditions – these germinate on availability of suitable environment.
    - In higher plants, seeds and some other vegetative reproductive structures serve as means to tide over periods of stress besides dispersal – they germinate to form new plants under favorable moisture and temperature condition. They do so by reducing their metabolic activity and going into a state of 'dormancy'.

- **Animals** which are unable to migrate, may escape in time (i.e., **hibernate** during winters). Some animals go into **deep sleep** for extended period of time, while **others will just slow down** but **remain active**. Some will go into a combination of both, known as **Torpor**.
  - » Animals like bats, Squirrels, Marmot, Lemurs, Hedgehog, Earthworms, Toads, Bees, bears etc. **hibernate in a warm place during winters**.
  - » **Bears** living in cold climate hibernate during winters – when the food is scarce, but the bear in warmer climate can find plenty of food all year long so they don't have any reason to hibernate. **Bears** are **true hibernators** and sleep heavily never to wake up again till the spring arrives. Only the Mama Bear wakes up in Jan/Feb to give birth to the new cubs, and the babies will be happy nestling with Mamma until she can take them out on their first adventure.
  - » **Bats also hibernate** (again the once in warmer areas don't).
  - » **Some snakes** also hibernate.
- **Some snails and fish** go into aestivation to avoid summer-related problems-heat and desiccation.
  - » **Note:** Aestivation or estivation is a state of dormancy that some animals enter during hot and dry periods. It is similar to hibernation, which is a state of dormancy during cold and harsh conditions.
- Under unfavorable conditions, many zooplankton's species in lakes and ponds are known to enter diapause, a stage of suspended development.
- **Dieback:** It refers to the progressive dying, usually backwards from the tip of any portion of the plant. This is one of the adaptive mechanisms to avoid adverse conditions like droughts. In this mechanism, the root remains alive for years together, but the shoots die. E.g., Sal, Red Sanders, Silk-Cotton etc.

### C) ADAPTATION

- Adaptation is any attribute of the organism (morphological, physiological, behavioral) that enable the organism to survive and reproduce in its habitat.

Many adaptations have evolved over long evolutionary time and are genetically fixed. In the absence of external source of water, the **Kangaroo rat**, in North American deserts is capable of meeting all its water requirements through its internal fat oxidation (in which water is a byproduct). It also has the ability to concentrate its urine so that less water is lost



- **Desert plants** have adapted to following features to survive in water scarce conditions:

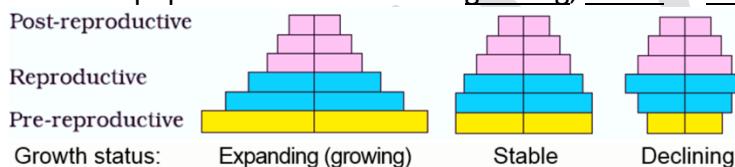
- » **Reduced Leaf Size:** Smaller leaves minimize water loss through transpiration.
  - » **Thick Cuticles:** Desert plants have a thick waxy layer on the surface of their leaves and steps to reduce water loss.
  - » **CAM Photosynthesis:** Some desert plants, such as cacti and succulents, use a special type of photosynthesis called Crassulacean Acid Metabolism (CAM), which allows them to conserve water during photosynthesis.
    - In this system, CO<sub>2</sub> is fixed at night when temperature is cooler, and stomata (pores in leaves) can remain open without excessive water loss. Here CO<sub>2</sub> is converted into malate (a four carbon acid) which will be used during day time for photosynthesis.
    - E.g. of CAM mechanisms: Succulents like aloe-vera and Jade plant; some orchids; Crassula, a genus of flowering plants giving CAM its name.
  - » **Deep Roots:** To access water from deep underground.
  - » **Efficient Water Use:** Desert plants have adapted to use water efficiently by closing their stomata during the day and opening them at night to reduce water loss.
  - » **Succulent Tissues:** Some desert plants have fleshy, water storing tissues that allow them to survive for long periods without water.
  - » **Spines or Thorns:** To deter herbivores and to reduce water loss from leaf surface.
- **Allen's Rule:** Mammals from colder climate, generally have shorter ears and limbs to minimize heat loss (This is called Allen's Rule).
- In the **polar seas**, aquatic mammals like **seals**, have a thick layer of fat (blubber) below their skin that acts as insulator and reduces loss of body heat.
- **Tribes living in high altitude region**, normally have higher RBC count (or total hemoglobin) than people living in plains. Why?
- **Some microbes** (archaeabacteria) flourish in hot springs and deep-sea hydrothermal vents where temperature far exceeds 100-degree C.
  - » Microbes which can live at such high temperature are called **thermophiles**. They are able to survive in such high temperatures because their bodies have adapted to such environmental conditions. They contain specialized thermo resistant enzymes, which carry out metabolic functions that don't get destroyed at such high temperatures.
- **How do fish in Antarctic water prevent their body fluids from freezing?**
  - They have developed proteins that act as **anti-freeze**. These anti-freeze proteins are a group of unique macromolecules that help some polar and subpolar marine bony fishes avoid freezing in their icy habitat. These **proteins bind to and inhibit growth of ice crystals** within body fluids through an absorption-inhibition process. These proteins attach to small ice crystals stemming their growth.
- **How do deep sea organisms live under high pressure?**
  - Most living things in the deep sea are largely water and water is incompressible. **Without gas filled spaces** like lungs or bladders, organisms in the great deep are less affected by pressure than we imagine. Further, they have "**piezolytes**" – small, organic molecules which have only recently been discovered. These piezolytes stop the other molecules in the creatures' bodies, such as membranes and proteins, from being crushed by the pressure.

## 5) POPULATIONS

- Majority of organisms live in groups in a well-defined geographical area, share or compete for similar resource, **potentially interbreed (same species)**, and thus constitute a **population**.
- Although the term interbreeding may imply **sexual production**, a group of individuals resulting from **even asexual reproduction** is also generally considered a population.
  - » E.g.: Rats in an abandoned dwelling; bacteria in a culture plate, lotus plants in a pond etc.
- So far, we had studied that Individual organism is the one that has to cope with a changed environment, it is at population level that **natural selection operates to evolve the desired traits**. Population ecology is, therefore, an important area because it links ecology to population genetics and evolution.

Individual	Population
Individuals don't show attributes	Population has certain attributes
Individual may have <u>births and deaths</u>	Population has <u>birth rates and death rates</u>
Individual may be male/female etc.	Population can have <u>sex ratio</u> .

- **Age distribution of a population** forms what is called **Age Pyramid**. The shape of the pyramid reflects the growth status of population. Whether it is growing, stable or declining.



- The size of the population tells us a lot about the habitat.

### A) POPULATION GROWTH

- The density of a population in a given habitat during a given period, fluctuates due to changes in four basic processes: **Natality and Immigration** contribute to an increase in population. **And Mortality and Emigration** contribute to decrease in population.

### B) LIFE HISTORY VARIATION

- Populations evolves to maximize their reproductive fitness, also called **Darwinian fitness** (high r value), in the habitat in which they live. Life history traits of organisms have evolved in relation to the constraints imposed by the abiotic and biotic components of the habitat in which they live. They develop the most efficient reproductive strategy.

For e.g. – Some organisms breed only once (for e.g., Pacific Salmon fish, Bamboo); while others breed many times during their lifetime (most birds and mammals)

### C) POPULATION INTERACTION:

- In nature, animals, plants and microbes don't and cannot live in isolation but interact in various ways to form a biological community. Even in minimal communities, many interactive linkages exist, although all may not be readily apparent.
- Interspecific interactions arise from the interaction of population of two different species. This interaction could be beneficial (+), neutral (0) or detrimental (-) to one of the species or both. All possibilities are given below:

Species A	Species B	Name of Interaction
+	+	Mutualism
-	-	Competition
+	-	Predation
+	-	Parasitism
+	0	Commensalism
-	0	Amensalism

- In parasitism and predation only one species benefits (parasite and predator, respectively) and the interaction are detrimental to other species (host and prey, respectively).
- Mutualism, Predation, Parasitism, and Commensalism share a common characteristic, the interacting species live closely together.

#### MUTUALISM

- The interaction confers benefits to both the interacting species.
- E.g.
  - » Lichens (intimate mutualistic relationship between fungus and photosynthesizing algae or cyanobacteria)
  - » Mycorrhizae are associations between fungi and the roots of higher plants. The fungi help the plant in the absorption of essential nutrients from the soil, while the plant in turn provides the fungi with energy yielding carbohydrates.
  - » Plant Animal Relationship: Plants need animals for pollinating their flowers and dispersing the seeds, whereas plants given them in return, honey fruits etc.
  - » Now you can see why plant-animal interactions often involve co-evolution of the mutualists, that is, the evolutions of the flower and its pollinator species are tightly linked with one another.
  - » In many species of fig trees, there is a tight one-to-one relationship with the pollinator species of wasp. It means that a given fig species can be pollinated only by its 'partner' wasp species and no other species. The female wasp uses the fruit not only as an oviposition (egg-laying) site but uses the developing seeds within the fruit for nourishing its larvae. The wasp pollinates the fig inflorescence while searching for suitable egg-laying sites. In return for the favour of pollination the fig offers the wasp some of its developing seeds, as food for the developing wasp larvae

#### COMPETITION

- Competition occurs when closely related species compete for the same resources that are limiting.
  - » But totally unrelated species may also compete (for e.g., visiting flamingoes and resident fishes compete for their common food, the zooplanktons in a lake).
  - » Even in case of abundant resources, competition may occur, in **interference competition**, the feeding efficiency of one species might be reduced due to interfering and inhibitory presence of the other species.
- Therefore, competition is best defined as “a process in which **fitness of one species**, is significantly lower in the presence of another species”.
- E.g., **Abingdon tortoise in Galapagos Islands** became extinct within decade after goats were introduced on the island, apparently due to the greater browsing efficiency of the goats.
- Species facing competition might also evolve mechanisms that promote co-existence rather than exclusion. One such mechanism is “**resource partitioning**”. Here species avoid competition by choosing for instance, different time for feeding on different foraging patterns.

#### PREDATION:

- » **Significance:** Transferring the energy to higher trophic levels; Keeping prey population under control and contribute to ecosystem stability; they also help in promoting species biodiversity in a community, by reducing the intensity of competition among competing prey species.
  - In the absence of predator, a prey may become invasive and damage the ecosystem. E.g., when prickly pear cactus was introduced in Australia in the early 1920s, they caused havoc by spreading rapidly to millions of hectares. It was only when a cactus feeding predator (a moth) was introduced, the population could be controlled and damaged could be reduced.
  - **Predators by nature are prudent.** Because if the overexploit and prey population reduces drastically, predators would also suffer.
  - **Prey species** have also evolved various mechanisms to protect themselves from predators – e.g., insects and frogs are cryptically colored (camouflaged) to avoid being detected easily by predator. Some are poisonous and thus are avoided by Prey. **Monarch Butterfly** is highly distasteful to its predators (birds) because of a special chemical present in its body.
  - **For Plants**, herbivores and predators, so plants also develop various mechanisms to protect themselves.
    - » **Thorns** (Acacia, Cactus) are the most common morphological means of defence.
    - » Many plants produce **chemicals that make herbivore sick** when they are eaten, inhibit feeding or digestion, disrupt its reproduction or even kill it.
      - i. **E.g., Calotropis** (they grow in abandoned fields, and they produce highly poisonous cardiac glycosides and that is why you never see any cattle or goats browsing on this plant.



- ii. **A wide variety of chemical substances** that we extract from plants on a commercial scale (nicotine, caffeine, quinine, strychnine, opium, etc.) are produced by them actually as defences against grazers and browsers.

---

## PARASITISM

- **Majority of the parasites harm the host.** They may reduce the survival, growth and reproduction of the host and reduce its population density. They may also render the host more vulnerable to predation by making it physically weak.
- **Ectoparasites:** Parasites feeding on the external surface of the host organisms.
  - » E.g., lice on humans, ticks on dogs.
  - » Many fish species are infested by ectoparasitic copepods.
  - » Cuscuta, a parasitic plant, has lost its chlorophyll and leaves in the course of evolution. It derives its nutrition from the host plant that it parasites.
  - » **Note:** The female mosquito is not considered a parasite, although it needs our blood for reproduction. Why?
    - Because it needs blood for reproduction not for nutrition. Human blood is required for nourishment of the offspring. A parasite depends for its entire lifespan or at least for a considerable period within a host body and completely depends on the host for nutrition and habitat.
- **Endoparasites:** Parasites that live inside the host body at different sites (liver, kidney, lungs, red blood cells, etc.)
  - » The lifecycle of endoparasites is more complex because of their extreme specialization. Their morphological and anatomical features are greatly simplified while emphasizing their reproductive potential.
- **Brood Parasitism:** Here parasitic bird lays its eggs in the nest of its host and lets the host incubate them. During the course of evolution, the eggs of the parasite bird has evolved to resemble the host's eggs in size and color to reduce the chances of the host bird detecting the foreign egg and ejecting them from the nest.
  - » Asian Koel, like many of its related cuckoo kin is a brood parasite that lays its eggs in the nests of crows and other hosts, who raise it young.

---

## COMMENSALISM

- Interaction in which one species benefit, the other is neither harmed nor benefited.
- E.g.
  - » Orchid growing as an epiphyte on mango branch.
  - » Barnacles growing on the back of a whale. They don't harm whales or feed on them. They don't serve any obvious advantage to whale, but they give helpful lice a place to hang onto the whale without getting washed away in water.

- » The **cattle egret** and the grazing cattle is a classic example of commensalism. The egrets always forage close to where the cattle is grazing because the cattle, as they move, stir up and flush out insects from the vegetation that otherwise may be difficult for egrets to find.

## 4. FUNCTIONS OF AN ECOSYSTEM

**Ecosystems** perform some basic functions which are essential for supporting life on earth and maintaining ecological balance. These functions can be categorized under the following heads:

- 1) **Primary Production:** This refers to the production of food by autotrophs through the process of photosynthesis (plants, algae, bacteria etc.) and chemosynthesis (in some bacteria). Primary production provides energy and nutrients for all other organisms within the ecosystem.
- 2) **Energy Flow:** This refers to one-way transfer of energy from producers to consumers and eventually to decomposers through food chain. At each level some energy is lost as heat.
- 3) **Nutrient Cycling:** Essential nutrients, like nitrogen, phosphorus, carbon etc. are constantly recycled in the ecosystem. This continuous cycle ensures the availability of these vital elements for all organisms.
- 4) **Water Cycle/Water Regulation :** Ecosystems regulate the water cycle, which is essential for the survival of living organisms.
- 5) **Habitat Provisions:** Ecosystem provides diverse habitats for various species. Each habitat, with its particular set of features support unique set of species.
- 6) **Environmental Provisions:** Regulation of climate, air quality and water quality.
  - Absorbing Carbon, reducing global warming and mitigating effects of climate change
  - Plants also filter air pollutants and release oxygen through photosynthesis.
  - Wetlands and forests act as natural filters and help in removing sediments and pollutants from water as it flows through them. This helps in maintaining of clean water for humans and other organisms.
- 6) **Ecological Succession:** Ecological succession is the process by which natural communities replace (or succeed) one another over time.
- 7) **Soil Formation**
- 8) **Cultural and Recreational Services**

In this chapter, we will primarily focus on three important functions of ecosystem – **Energy Flow; Nutrient Cycling and Biogeochemical Cycles:**

## 1) ENERGY FLOW THROUGH AN ECOSYSTEM

Energy flow through an ecosystem refers to transfer of energy from one organism to another within a food chain or food web. The sun is the primary source of energy in most ecosystems, and it's captured by plants through photosynthesis. This energy flows through the ecosystem as one organism consume other organism for food.

### A) TROPHIC LEVEL:

- Trophic level refers to different levels of food chain where organisms obtain energy and nutrients. There are primarily four main trophic levels – Producers; Primary Consumers; Secondary Consumers; Tertiary Consumers. The energy flow through the trophic levels from producers to subsequent trophic levels is unidirectional.
- Each trophic level represents a transfer of energy and nutrients from one group of organisms to another. As organisms consume other organisms, they extract energy and nutrients from their food, and some of this energy is lost as heat. This means that there is typically less energy available at higher trophic levels, which is why food chain tend to be relatively short.
- The trophic level interaction involves three concepts viz. Food Chain, Food Web and Ecological Pyramids.

### B) FOOD CHAIN:

- Transfer of food energy from green plants (producers) through a series of organisms with repeated eating and being eaten link is called a food chain. A food chain starts with producers and ends with top carnivores. The trophic level of an organism is the position it occupies in a food chain.
  - E.g., Grassland Ecosystem:
    - Grasses-Grasshopper-Frog-Snake-Hawk/Eagle.
  - E.g., Aquatic Ecosystem:
    - Algae -> Zooplankton (smaller animals and immature stages of large animals) -> Small fish -> large fish -> Shark

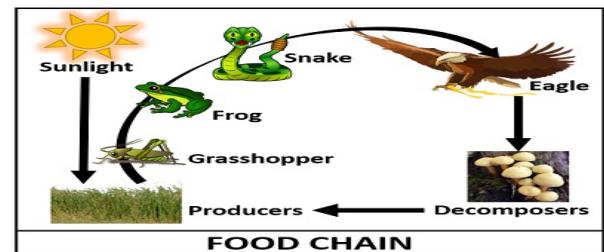
- **Diatom** (microscopic algae) -> **Crustaceans** -> **Herring** -> **Shark**
  - **Note:** Crustaceans such as copepods are typically herbivores that feed on phytoplankton, including diatoms. Herring are small fish that feed on zooplanktons, including Crustaceans.
- **E.g., Forest Ecosystem**
  - **Trees** – Caterpillar – Blue Jay (small bird) – Hawk
- **E.g., Desert Ecosystem**
  - **Cactus** -> Grasshopper -> Lizard -> Snake -> Eagle
- **E.g., Arctic Ecosystem**
  - Phytoplankton's -> Krill (crustacean)-> Arctic Cod (fish) -> Seal (mammal) -> Polar Bear (Mammal)

#### Types of Food Chains:

1. Grazing Food Chain
2. Detritus Food Chain

#### Grazing Food Chain:

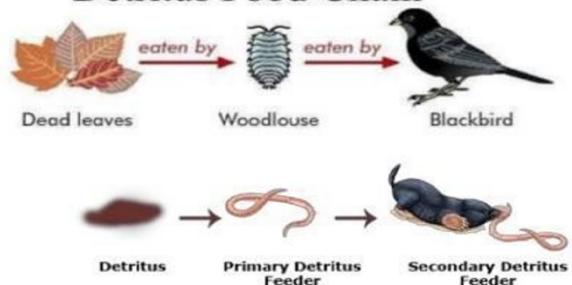
- The consumers which start the food chain, utilizing the plant or plant part as their food, constitute grazing food chain.



#### Detritus Food Chain:

- Starts from **organic matter of dead and decaying animals and plant bodies** from the grazing food chain.

#### Detritus Food Chain



E.g.: Forest Floor Detritus food chain: Leaf litter

→ Fungi → Mites → Beetles → Salamanders

E.g.: Aquatic Detritus Food chain: Dead algae and other organic matter → Bacteria → Zooplankton  
→ Small fish → Larger fish

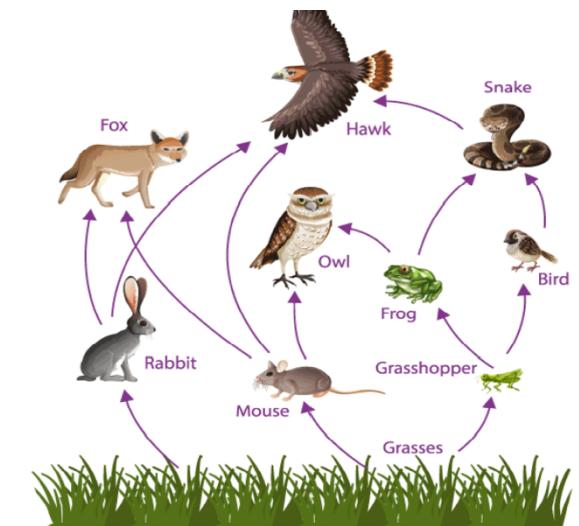
- In aquatic ecosystems, the grazing food chain is the major conduit for energy flow.
- In terrestrial ecosystem, a much larger fraction of energy flows through the detritus food chain than through the grazing food chain.

**NOTE:**

- 1) **Detritus Food Chain is important** because it increases the soil process/fertility by the process of 'Humification'.
  - a. **Humus:** It is a dark, organic rich substance that forms as a result of decomposition of plant and animals and animal material in soil. It is a complex mixture of organic compounds, including carbon, nitrogen, phosphorus, and sulfur, as well as minerals such as calcium, magnesium and potassium. It is key to healthy soil and can help to improve soil structure, retain moisture, and provide a source of nutrients for plants. In addition, it can help restore carbon in soil.
- 2) **Catabolism:** It is a set of metabolic processes that involve the breakdown of complex molecules into simpler ones, releasing energy in the process. The term catabolism is often used in contrast to **anabolism**, which refers to the set of metabolic activities that involve the synthesis of complex molecules from simpler ones, using energy.
- 3) **Humification and mineralization** occur during decomposition in the soil. Humification leads to accumulation of a dark-colored amorphous (formless) substance called humus viz. highly resistant to microbial action and undergoes decomposition at an extremely slow rate. The humus is further degraded by some microbes and release of inorganic nutrients occur by the process known as **mineralization**.

### C) FOOD WEB:

- Multiple interlinked food chains make a food web. Food web represents all the possible paths of energy flow in an ecosystem.
- If any of the intermediate food chains is removed, the succeeding links of the chain will be affected largely.
- The food web provides more than one alternative for food to most of the organisms in an ecosystem and therefore increases their chance of survival.



### D) ECOLOGICAL PYRAMIDS

The pyramidal representation of trophic levels of different organisms based on their ecological position (producer to final consumer) is called as Ecological Pyramid.

The ecological pyramids are of three categories:

1. Pyramid of Numbers
2. Pyramid of Biomass, and
3. Pyramid of Energy or Productivity

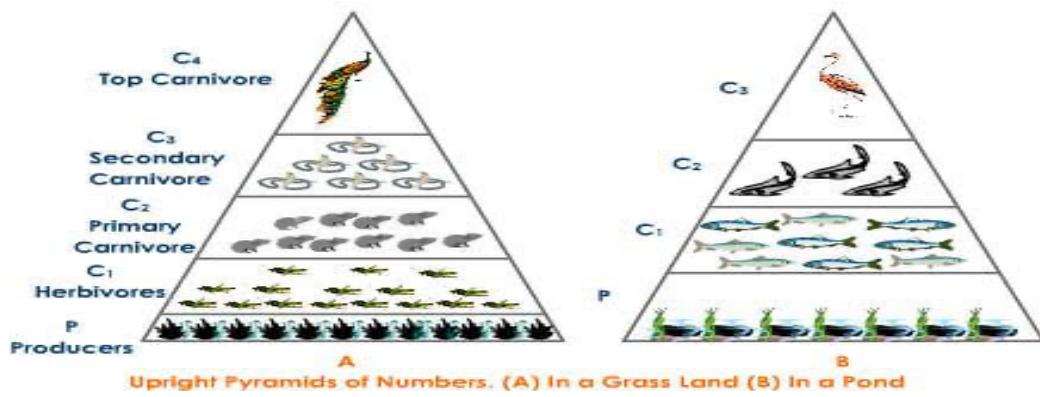
#### PYRAMID OF NUMBERS:

- It represents the total number of individuals of different species (population) at each trophic level.
- Depending upon the size, the pyramid of numbers may not always be upright, and may even be completely inverted.

##### (a) Upright:

In this pyramid, the number of individuals is decreased from lower level to higher trophic level.

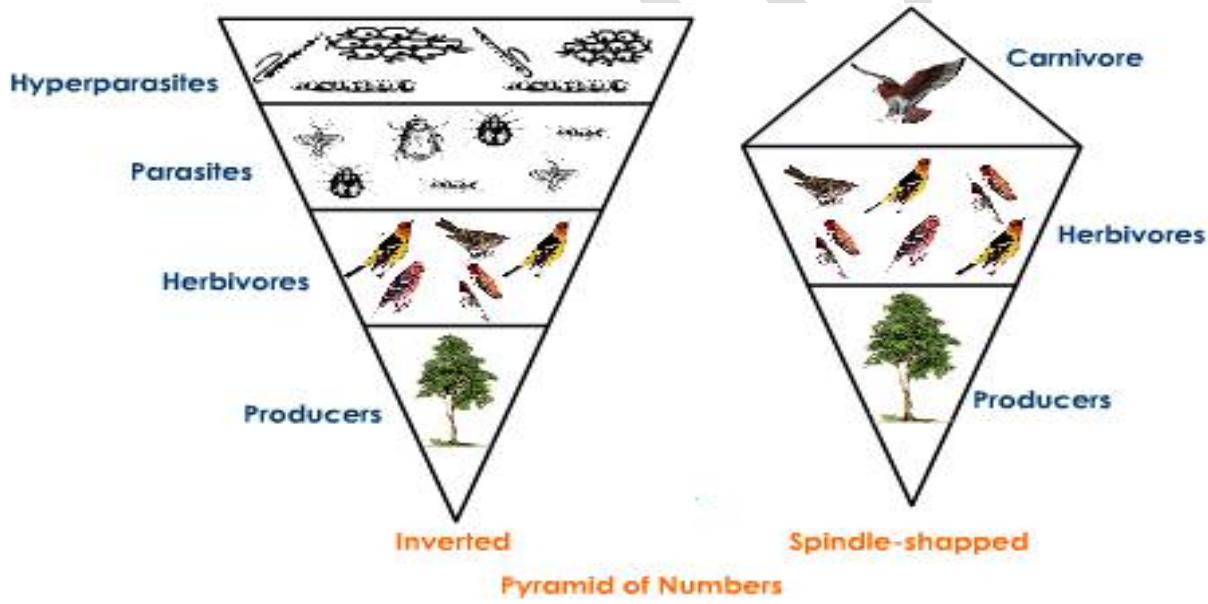
This type of pyramid can be seen in the Grassland Ecosystem and Pond Ecosystem.



### (b) Inverted:

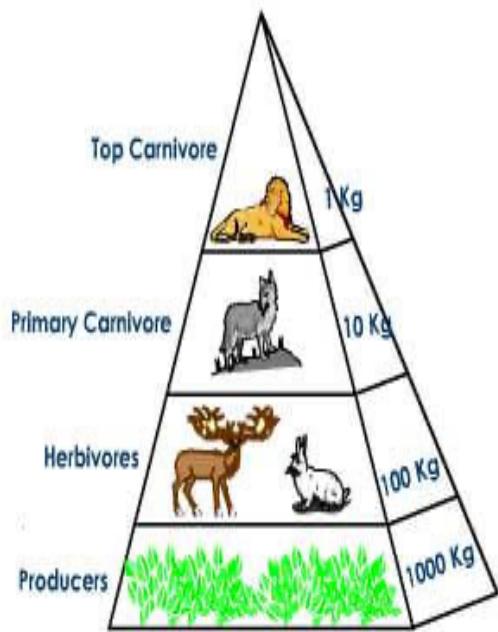
In this pyramid, the number of individuals is increased from lower level to higher trophic level. E.g., Tree Ecosystem

**NOTE: Pyramid of Number is ALWAYS Upright in Aquatic Ecosystem, but it may be Upright as well as Inverted in Terrestrial Ecosystem.**

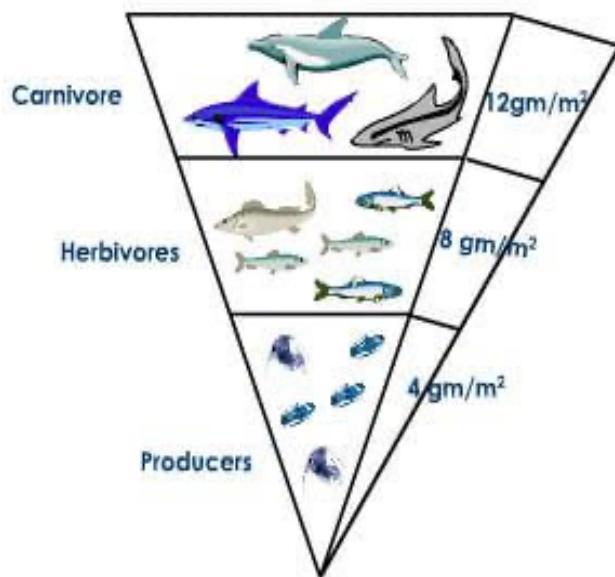


### PYRAMID OF BIOMASS:

- Biomass means the weight of an organism in a given area and volume. To calculate the biomass of pyramid, we consider the 'dry weight'.
- NOTE:** Pyramid of Biomass is ALWAYS Upright in Terrestrial Ecosystem, but in Aquatic Ecosystem, as Producers are microscopic, small phytoplankton's, they do not have much weight. Hence, pyramid of biomass is Inverted.



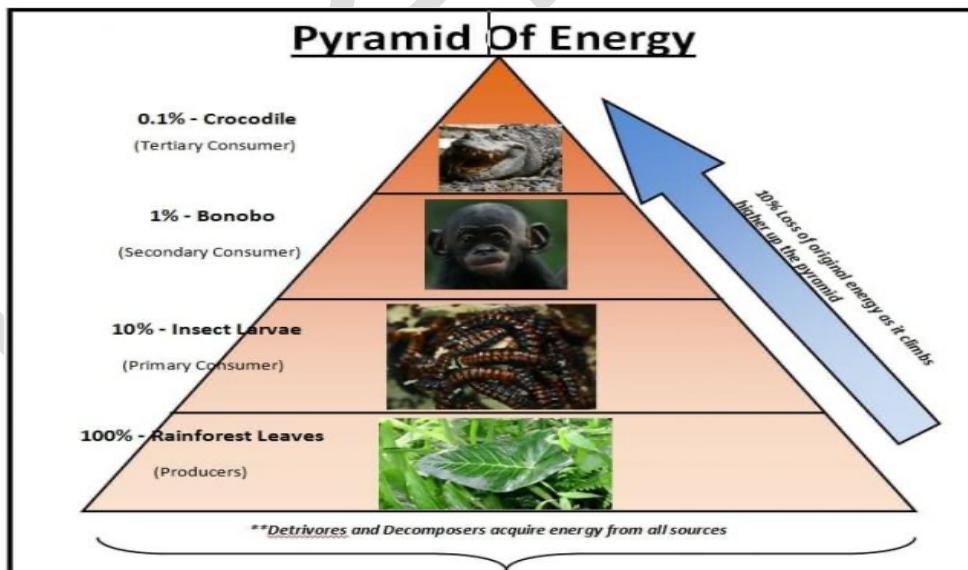
Upright Pyramid of biomass in a Terrestrial Ecosystem



Inverted Pyramid in an Aquatic Ecosystem

#### PYRAMID OF ENERGY:

- It is **most important pyramid** because it represents the amount of energy at each trophic level.
- As per Lindeman's law, **only 10 % of Energy** is transferred from lower to higher trophic level.
- At each trophic level, energy lost in respiration or in metabolism or in locomotion. **Therefore, pyramid of energy is ALWAYS uni-directional & Upright.**



**NOTE:** As ecological efficiency is LOW, therefore, organisms higher in food chains are LESSER in Number than they require more food.

As they require more food, Higher Organism in food chains, then there is GREATER chance of Biomagnification & Bioaccumulation.

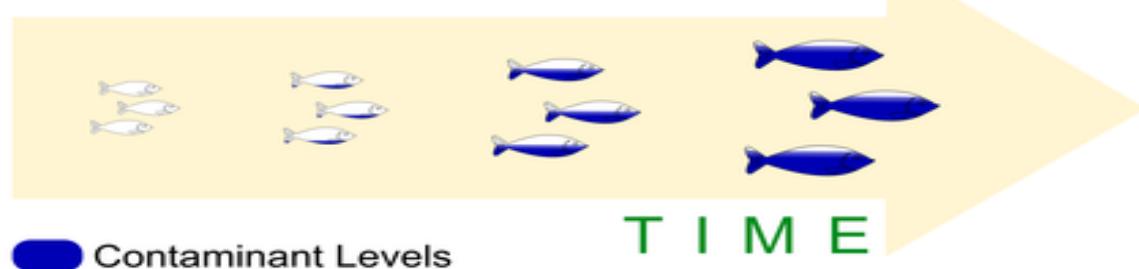
## E) POLLUTANTS AND TROPHIC LEVELS

- Pollutants, especially the non-degradable ones move through various trophic levels in an ecosystem.
- Because of the mechanisms of bioaccumulation and biomagnification even small concentrations of chemicals in the environment find their way into organisms in high enough dosages to cause problems.

### BIO-ACCUMULATION

- It refers to entry of a pollutant or toxic substance in the food chain. It actually is gradual accumulation of substances like pesticides or other chemicals, in an organism's body over time.
- It will take place when rate of absorption of pollutant is more than the rate of elimination (metabolism or excretion).
- Bioaccumulation typically occurs within individual organism, particularly those at lower trophic levels of a food chain. The concentration of pollutants in the organism may increase with repeated exposures or with prolonged exposures to contaminated environments.
- **Note:** Bioaccumulation doesn't necessary mean higher concentration of pollutant at higher trophic levels.
- **Source of pollutant** may be food, soil, water, air etc.
- **Substances which are likely to bioaccumulate:** Long lives (doesn't easily break/destroy); Mobile; fat soluble and biologically active (thus causes damage)
- **E.g.: Mercury in Fish** (Mercury is absorbed by algae and plankton, which are then consumed by small fish. Here mercury accumulate in the tissue of the fish.

## Bioaccumulation

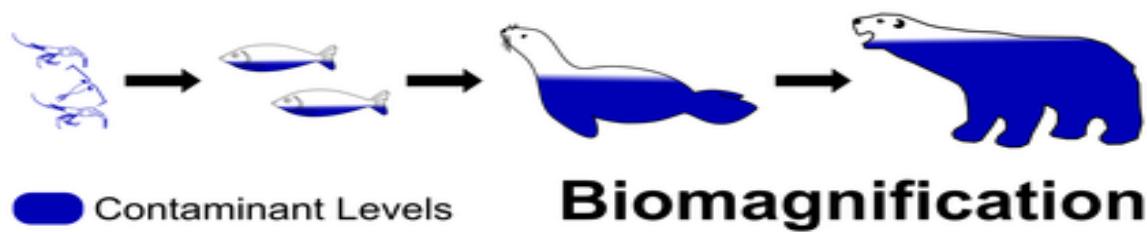


### BIO-MAGNIFICATION

**Bio-Magnification:** The tendency of pollutant to increase in concentration as it moves from lower to higher trophic level, is known as Bio-magnification. This usually occurs across the entire food chain and affects all the organisms in the food chain. The animals at the higher trophic levels are affected more.

E.g.: **DDT**: it is a pesticide which is non-biodegradable. It gets incorporated in the food chain and gets deposited in the tissues of the organisms. When DDT enters water bodies, it gets accumulated in the body of fish (bioaccumulation) and when these fish are eaten by bigger fish, the concentration of DDT increase at each successive step (biomagnification).

**Note:** Biological magnification specifically refers increasing concentration of material in each higher connecting link in the food chain. However, bioaccumulation examines the increased presence of particular substance in a single organism.



#### Causes of Bio-accumulation & Bio-magnification:

1. **Agricultural Products:** Highly toxic substances such as herbicides, pesticides, fungicides etc. and these substances can also penetrate into the soil.
2. **Organic Contaminants:** Bio-solids used in agriculture farms are treated using toxic chemicals that may contain heavy metals.
3. **Plastic Pollution:** Disposal of plastic waste near or in water bodies. It is caused by 'Ghost Nets' for fishing nets. For instance, Bisphenol A is one of the major contaminants released into the water bodies.
4. **Mining:** Zinc, Copper, Lead and other chemicals may be released into the aquatic and farm environment.
5. **Toxic Gases and Air Pollution:** Exhaust gases from vehicles, refineries industries can be dissolved by the rainwater and fall as acidic rain. These chemicals are absorbed by soil and water bodies.

#### Effects of Bio-accumulation and Bio-magnification:

- On Human Health:** Accumulation of mercury and Polycyclic Aromatic Hydrocarbons affect the tissues of marine organisms. Therefore, in recent years, the consumption of seafood has been linked to certain types of cancer, kidney failure, brain damage etc.
- On aquatic animals-** Toxic chemicals such as selenium and mercury include effects on reproductive process of fish.

### Some Important Bio-accumulators:

- DDT:** It is pesticide and insecticide, generally used for control the malaria population (i.e., mosquito population).
  - (a) DDT has been banned under Stockholm Convention, but it is used in tropical countries like India to control the spread of growth of malaria, dengue etc.
  - (b) Effects: Headache, Noroviral disorder, thinning of egg-shells & loss of fertility which ultimately result to Cancer.
- Endosulfan:** It is an insecticide which is used in Cashew, Rubber & Plantation agriculture (tea plantation).
  - (a) It is cheap but dangerous bioaccumulate because it is associated with birth defects including cryptorchidism (absence of testis in male), neurological disorder including autism (mental retardness), cancer etc.
  - (b) Endosulphane was added to the list of POPs in the year 2011. Government of India has banned the use of endosulphane, but the matter is in sub-judice.

## 2) BIO-GEO-CHEMICAL CYCLING OR NUTRIENT CYCLING

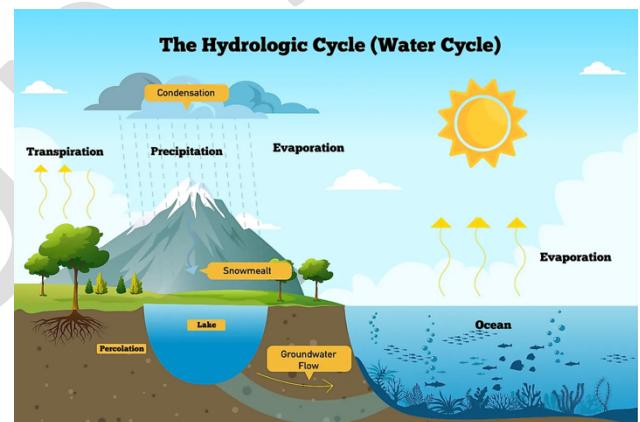
- “Nutrient Cycle” or “Biogeochemical cycle” refers to the movement or exchange of nutrients among the living and non-living constituent of an ecosystem. Nutrient Cycling is the process through which components change into different forms and then return to their original state.
- Based on the nature of reservoir, a nutrient cycle is divided into two types of cycles viz. Gaseous cycle; and Sedimentary Cycle.
  - o **Gaseous Cycle:** In Gaseous cycle, atmosphere or hydrosphere acts as the primary reservoir and elements primarily cycle through the atmosphere and living organisms, with minimal

involvement of soil or sediments. It includes, water cycle (hydrologic); carbon cycle; nitrogen cycle etc.

- **Sedimentary Cycle:** In this cycle, earth's crust act as the primary reservoir. It includes phosphorus cycle; sulphur cycle etc.
  
- **Biogeochemical Cycle (Nutrient Cycle)** can also be divided into perfect nutrient cycle and imperfect nutrient cycle.
  - **Perfect Nutrient Cycle** is one in which nutrients are replaced as fast as they are utilized. Most of the gaseous cycles are generally perfect cycles.
  - **Imperfect Nutrient Cycle** sees loss of some nutrients from cycle and the nutrients get locked into sediments and so become unavailable for immediate cycling.

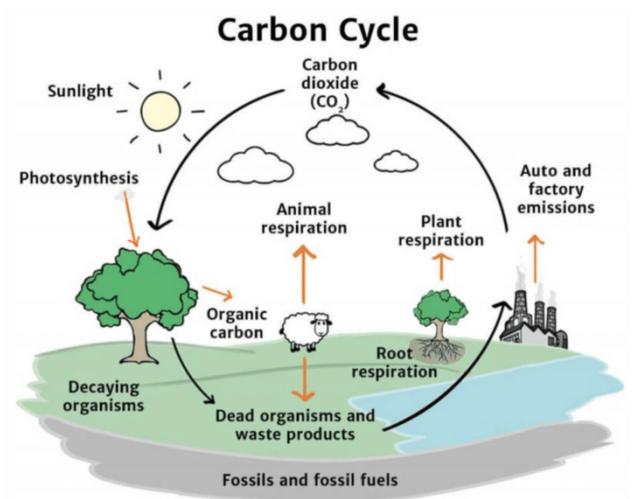
#### A) WATER CYCLE (HYDROLOGIC CYCLE)

- Water Cycle is the continuous circulation of water in the Earth-Atmosphere system which is driven by solar energy. There are various reservoirs of water on earth including ocean, atmosphere, lakes, rivers, soils, glaciers, snowfields, and groundwater. Water moves from one reservoir to another through the process of evaporation, transpiration, condensation, precipitation, percolation, ground water flow, deposition etc.



#### B) CARBON CYCLE

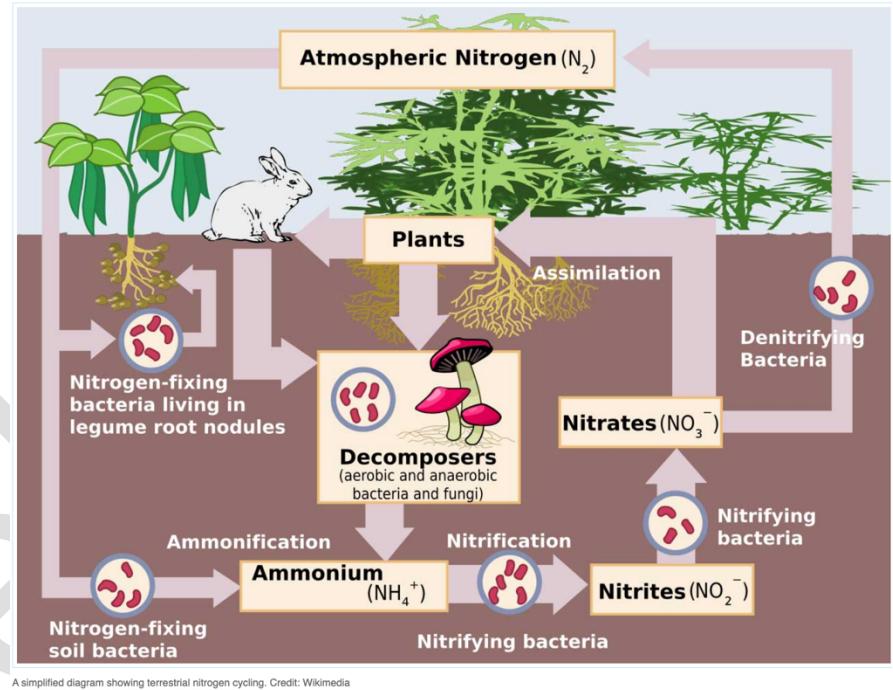
- The carbon cycle is the process that circulates the carbon between plants, animals, and microbes; minerals on earth; and the atmosphere.
- **Photosynthesis** leads to carbon from atmosphere moving to green plants and then to animals. **Respiration and decomposition** of dead organic matter leads to return of carbon back to atmosphere. This is usually a short-term cycle.
- Some carbon also enters a long-term cycle. It accumulates an undecomposed carbon in the peaty layers and as insoluble carbonates in the bottom sediments of aquatic systems. In the deep ocean, carbon can remain buried for millions of years.



years until geological movement uplifts the rocks and erosion releases carbonates and bicarbonates. Fossils also trap carbon for millions of years.

### C) NITROGEN CYCLE

- Nitrogen is the key component of the bodies of living organisms. Nitrogen atoms are found in all proteins and DNA.
- Though, Nitrogen is the most abundant element in the atmosphere (N<sub>2</sub> is 78% of atmosphere), it is still a limiting nutrient in nature and agriculture. It is because it is not available in atmosphere in usable form.
  - Note: A limiting nutrient is the nutrient that's in the shortest supply and limits growth.
- **Nitrogen Fixation:** It is the process by which bacterial and other single celled prokaryotes convert atmospheric nitrogen (N<sub>2</sub>) into biologically usable form i.e. ammonium ion (NH<sub>4</sub><sup>+</sup>).
  - Some species of nitrogen fixing bacteria are free living in soil or water (aerobic Azotobacter and anaerobic Clostridium), while others are symbiotic nitrifying bacteria (living in association with leguminous plants) and symbiotic bacteria living in non-leguminous root nodule plants (e.g. Rhizobium) as well as blue green algae (e.g. Anabaena, Spirulina).
  - Ammonium ion can directly be taken up as a source of nitrogen by some plants, or are oxidized to nitrites or nitrates by two groups of specialized bacterial:
    - Nitrosomonas bacteria promote transformation of ammonia into nitrite.
    - Nitrobacter bacteria convert nitrite into nitrate.



- Nitrates synthesized by bacteria in the soil are taken up by plants and converted into amino acids, which are the building blocks of proteins. This can further go to higher trophic levels.
- Organic Nitrogen will again be converted into N<sub>2</sub> gas by bacterial. Nitrogenous compounds from dead organisms or wastes are converted into ammonia-NH<sub>3</sub> – by bacteria, and the ammonia is converted into nitrite and nitrates. In the end, the nitrates are made into N<sub>2</sub> gas by denitrifying prokaryotes (e.g. Pseudomonas). This nitrogen escape into atmosphere, thus completing the cycle.

**Note:** Nitrogen fixation also happens by other mechanisms:

- 1) Industrial Process (fertilizer factories)

- 2) **Atmospheric phenomenon** (thunder and lightning): The periodic thunderstorms convert the gaseous nitrogen into the atmosphere to ammonia and nitrates which eventually reach the earth's surface through precipitation and then into the soil to be utilized by plants.

**Note1:** Water Cycle, Carbon Cycle and Nitrogen Cycle were Gaseous Cycle.

**Note2:** Phosphorus, Calcium, Magnesium and sulphur circulate using sedimentary cycle. The elements involved in sedimentary cycle generally follow a pattern of Erosion -> Sedimentation -> Mountain Building -> Volcanic Activity and biological transport through the excreta of marine birds.

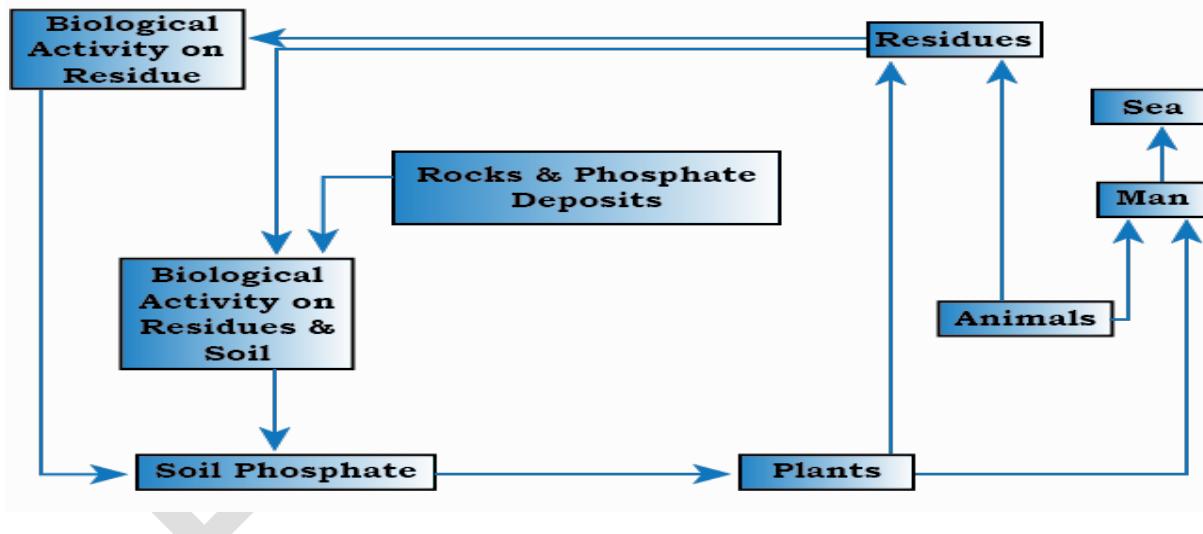
#### D) PHOSPHOROUS CYCLE

Unlike carbon and nitrogen, phosphorus occurs in large amounts as a mineral in phosphate rocks and enters the cycle from erosion and mining activities.

By the process of weathering and erosion, phosphate enter rivers and streams that transport them to ocean.

In Ocean, phosphorus will accumulate on continental shelves in the form of insoluble deposits. After millions of years, the crustal plates rise from the sea floor and expose the phosphates on land. After more time, weathering will release them from rock and the cycle's geochemical phase begins again.

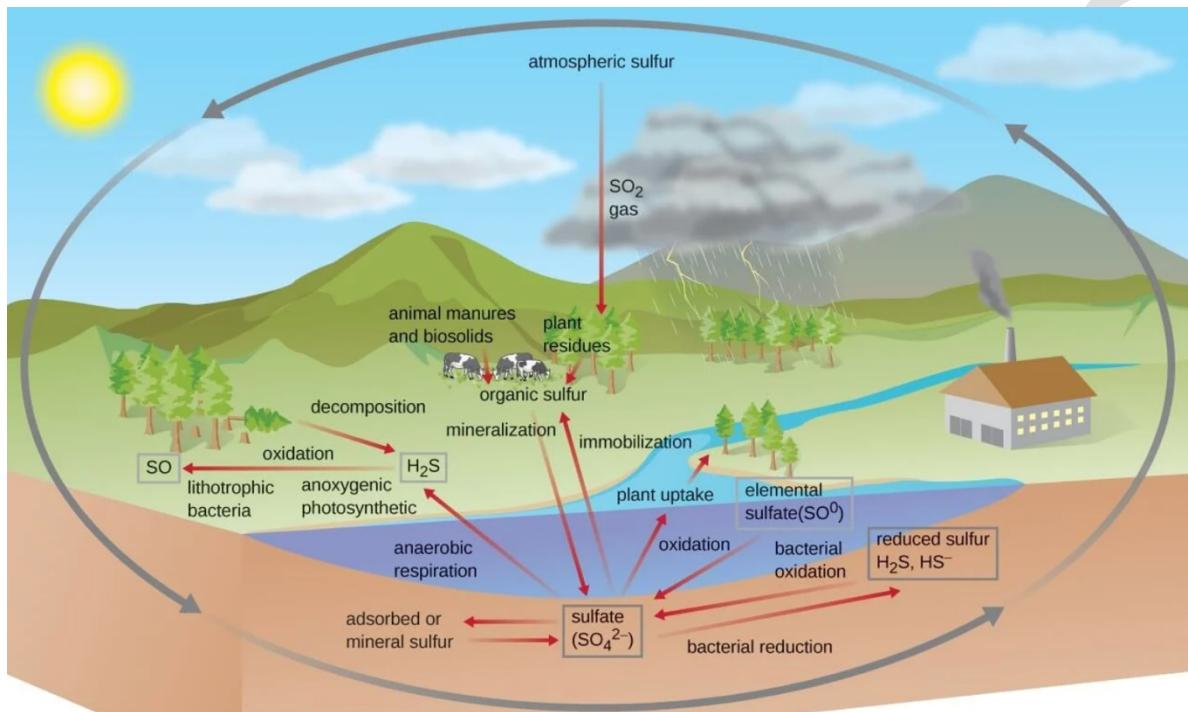
**Note:** Phosphorus is a primary nutrient that causes eutrophication in lakes causing algal blooms.



#### F) SULPHUR CYCLE:

- **Sulphur Reservoir** is in the soil and sediments where it is locked in organic (coal, oil and peat) and inorganic deposits (pyrite rock and sulphur rock) in the form of sulphates, sulphides and organic sulphur.
- **Release:** Weathering of rocks; Erosional runoff and decomposition of organic matter. It is carried to terrestrial and aquatic ecosystem in salt solutions.

- **Note:** The sulphur cycle is mostly sedimentary except two of its compounds Sulphur dioxide ( $\text{SO}_2$ ) and Hydrogen Sulphide ( $\text{H}_2\text{S}$ ) which add gaseous component to its sedimentary cycle.
- **Various ways in which Sulphur enters atmosphere:** Volcanic eruption, burning of fossil fuels, from surface of ocean and from gases released by decomposition. Atmospheric hydrogen Sulphide ( $\text{H}_2\text{S}$ ) also gets oxidized to sulphur dioxide and is carried back to earth as Acid Rain.



### 3) ECOLOGICAL SUCCESSION:

- The process by which communities of plant and animal species in an area are replaced or changed into another over a period of time is known as ecological succession. Succession is a universal process of directional change in vegetation, on an ecological time scale. The process involves a progressive series of changes with one community replacing another until a stable, mature, climax community develops.

#### (A). Stages in Ecological Succession:

- 1. Pioneer Species:** The first plant to colonize an area. Pioneer Species will occupy the bare rocks. E.g., Bacteria, Fungus, Weeds, Moss, Lichens and in Tundra region, Rhododendrons.
- 2. Climax Community:** The final stage of succession is called climax community. A climax community is stable, mature, more complex and long-lasting.
  - E.g.: Temperature Deciduous forests; Tropical Rain forests etc.

**3. Seral Community:** A seral community is temporary and transitional stage in ecological succession, leading to the development of a stable and self-sustaining climax community. During ecological succession, a seral community represents a stage where a specific set of plant and animal species are dominant, but **they are not the final or permanent community.**

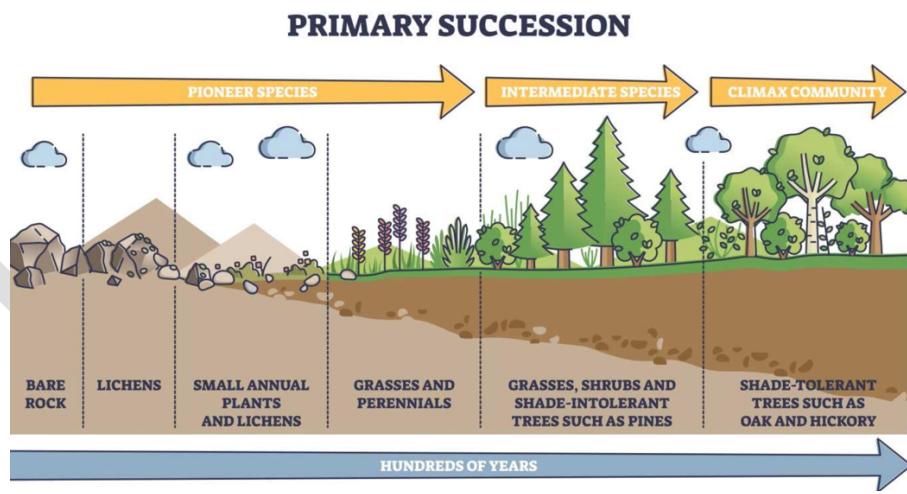
**NOTE:** Each ecological succession is characterized by **the increased productivity**, the shift of nutrients from the reservoirs, increased diversity of organisms, and a gradual increase in the complexity of food webs.

#### A) TYPES OF ECOLOGICAL SUCCESSION:

1. Primary Succession
2. Secondary Succession

#### PRIMARY SUCCESSION:

- Primary succession takes place an over where no community has existed previously. Such areas include rock outcrop, newly formed deltas and sand dunes, emerging volcano islands and lava flows, glacial moraines etc.
- In primary succession on a terrestrial site, the new site is first colonized by a few hardy pioneer species that are often microbes, lichens and mosses.



#### SECONDARY SUCCESSION:

- Secondary succession is the sequential development of biotic communities after the complete or partial destruction of the existing community.

- A mature or intermediate community may be destroyed by natural events such as floods, droughts, forest fires etc. or anthropogenic activities such as deforestation, agriculture, overgrazing etc.
- This abandoned land is first invaded by hardy species of grasses that can survive in bare, sunbaked soil.
- These grasses may be soon joined by tall grasses and herbaceous plants. These dominate the ecosystem for some years along with mice, rabbits, insects etc. Eventually some trees come up in this area, seeds of which may be brought by wind or animals.
- And over the years, a forest community develops. Thus, an abandoned land over a period becomes dominated by trees and is transformed into a forest.

#### **ECOLOGICAL SUCCESSION IN WATER/AQUATIC:**

- In primary succession in water, the pioneers are the small phytoplankton, and they are replaced with time by free-floating angiosperms, then by rooted hydrophytes (aquatic plants), grasses and the finally, trees.
- The climax again would be a forest. As the time passes, the water body is converted into land.

#### **NOTE:**

1. All the succession whether taking place in water or on land, proceeds to a similar climax community-the mesic.
2. Secondary Succession is faster process than the primary succession because the secondary succession starts on a well-developed soil already formed at the site.
3. Succession would happen faster in the area existing in the middle of the large continent. Here seeds related to various species would reach much faster, establishing and ultimately resulting in climax community.
4. In Savanna or Grasslands, Succession do not take place due to water and fire limits.
5. In Tropical Evergreen forests, original dense forest/vegetation does not re-grow once it is cleared because the soil is deficient in nutrients due to intense leaching.
6. In Tundra region, natural vegetation consists of Moss, Lichens & Rhododendrons, because in such tough conditions, only pioneer species can survive.

7. **Human beings affect 'secondary succession'** by causing 'soil erosion, global warming, loss of biodiversity, introduction of invasive alien species etc.' E.g., Due to introduction of invasive alien species such as pine, wattle, eucalyptus in Shola Forests of Western Ghats, forest fires (canopy fires occurs in Western Ghats) are increasing.
8. **Autogenic and Allogenic Succession:**
  - a. **Autogenic:** Succession brought about by living inhabitants of the community itself, the process is called autogenic succession.
  - b. **Allogenic:** Succession brought by outside forces.
9. **Autotrophic and Heterotrophic Succession:** Succession in which, initially the green plants are much greater in quantity is known as autotrophic succession; and the ones in which the heterotrophs are greater in quantity is known as heterotrophic succession.



# TARGET PRELIMS 2024

## BOOKLET-12; EB&CC-2

### AIR POLLUTION

#### 1. TABLE OF CONTENTS

1. <i>Table of Contents</i> .....	0
2. <i>Pollution and Pollutants</i> .....	2
3. <i>Air Pollution</i> .....	2
1) CO <sub>2</sub> .....	3
2) Suspended Particulate Matter (SPM).....	3
A) PM2.5.....	3
B) PM10.....	3
3) Carbon monoxide.....	4
4) Ozone .....	4
5) Nitrogen dioxide .....	5
6) SO <sub>2</sub> .....	6
7) Benzene .....	7
8) Ammonia .....	7
9) Smog.....	9
10) Aerosol Pollution.....	10
11) Fly Ash.....	11
12) Indoor Air Pollution .....	13
A) Radon (Rn <sup>222</sup> ) .....	14
13) Pet Coke (Petroleum Coke) and Associated Issues .....	14
14) Fuel Oil/ Heavy Oil/ Furnace Oil -> Issues Concerning Them .....	15
15) Agri-Subsidy and Air Pollution .....	15
16) WHO's Air Quality Guidelines .....	16
4. <i>Institutions, Initiatives, Schemes, Programs etc.</i> .....	16
1) Central Pollution Control Board (CPCB) .....	16

2)	Air (Prevention and Control of Pollution) Act, 1981 .....	17
3)	Environment Pollution (Prevention and Control) Authority (EPCA) [1998 - 2020].....	17
4)	The Commission for Air Quality Management in National Capital Region and Adjoining Areas ..	17
5)	Graded Response Action Plan (GRAP).....	18
6)	National Clean air Program .....	21
7)	Bharat Stage Emission Standards (BS Norms) .....	22
8)	Petrol Vs Diesel Comparison.....	23
9)	Natural Gas .....	24
5.	<i>Recent Air Pollution Issues</i> .....	25
1)	Delhi's Air pollution Problem .....	25
2)	Ban on Coal and Other Unapproved Fuel in Delhi (Jan 2023) .....	26
3)	Stubble Burning – CClass discussion.....	27
A)	Pusa Decomposer .....	27
4)	Fire crackers.....	27
5)	NGT Bans Fire Crakers (Nov 2020) .....	28
6)	Petroleum and Explosive Safety Organization (PESO) .....	28
7)	Green Crackers.....	29
8)	Smelting Industry and Pollution .....	29
9)	Odour Pollution.....	30
6.	<i>Various Air QUality measuring Initiatives in India</i> .....	31
1)	National Air Quality Monitoring Programmes (NAMP) .....	31
2)	NAAQS (National Ambient Air Quality Standards) by CPCB.....	31
3)	Air QUality Index (AQI).....	31

## 2. POLLUTION AND POLLUTANTS

- Pollution refers to introduction of harmful materials (pollutants) into environment.
- Many things which are useful to people produce pollution.
  - » **Vehicles, Electricity production, Fertilizers, Pesticides, Plastic etc.**
- **There** are various types of pollution - Air Pollution, Water Pollution, Soil/Land pollution, plastic pollution, noise pollution, light pollution etc.
- There are various ways of classifying pollutants:
  - i. **Primary vs Secondary**
    - **Primary Pollutants:** It is an air pollutant emitted directly from the source.
      - Examples of primary pollutants: (Particulates, CO, NO<sub>2</sub>, SO<sub>2</sub> etc.)
    - **Secondary Pollutant:** It is not directly emitted from the source as such, but forms when other pollutants (primary pollutants) react in the atmosphere.
      - Examples of secondary Pollutants: (Ozone, NO<sub>2</sub>, Acid Rain, Haze (Organic Aerosol))
  - ii. **Quantitative Pollutants vs Qualitative Pollutants**
    - **Quantitative Pollutant:** These substances are naturally present in environment. They become problematic only when their quantity increase.
    - **Qualitative Pollutant:** These are not naturally present in environment and are introduced in environment by human activities. E.g., Fungicide, herbicide etc.
  - iii. **Persistent Pollutant vs Non-Persistent Pollutant**
    - **Persistent Pollutants** are those pollutants which remain consistent in the environment for a long period of time without any change in its original form. (For e.g., nuclear wastes, pesticides, plastics etc.)
    - **Non-Persistent Pollutants** are the opposite of persistent pollutants and breakdown in the simple form.
  - iv. **Biodegradable vs non-Biodegradable**
    - Biodegradable pollutants are the pollutants which can be decomposed by micro-organisms.
    - **Non-biodegradable pollutants** are those which are not decomposed by microbial action (e.g., plastics, glass, DDT, salts of heavy metals etc.)
  - v. **Natural vs Anthropogenic**

## 3. AIR POLLUTION

- Air pollution is contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere: WHO.

- **Sources** of Air pollution:
  - Vehicular emissions, industrial fuel burning, energy production, forest fires, household combustion etc. are important sources of air pollution.
- **Pollutants** of major public health concern include PM, CO, Ozone, NO<sub>2</sub>, SO<sub>2</sub>, Smog, Hydrocarbon, CFCs etc.

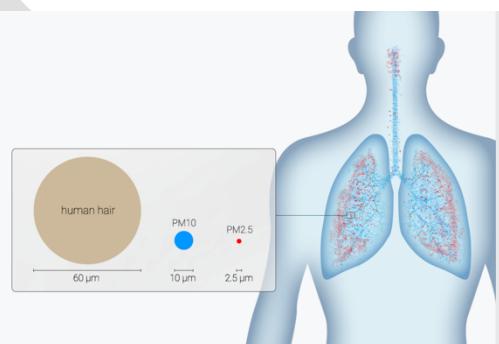
## 1) CO<sub>2</sub>

It is a greenhouse gas which results into global warming.

## 2) SUSPENDED PARTICULATE MATTER (SPM)

### A) PM2.5

- PM2.5 is defined as ambient airborne particulates (including dust, soot, dirt, smoke, and liquid droplets) that measure upto 2.5 microns in size. These particles include a range of chemical makeups and come from a range of source.
- **Main sources** include fossil fuel powered vehicles, power generation, Industries, Agriculture and biomass burning etc.
  - **Chemical reaction between gases** can also be a source of PM2.5 This include reactions between: SO<sub>2</sub>, NO<sub>2</sub>, Ammonia, Black carbon, Mineral dust, water, volatile organic carbon.
- Among criteria pollutants commonly measured in real time, fine particulate matter (PM2.5) is currently understood to be the most harmful to human health. Due to very small size, they can remain suspended in air for long periods and the microscopic size allows these particles to be absorbed deep into the bloodstream upon inhalation.
- **Exposure to PM2.5** have been linked to negative health effects like cardiovascular diseases, respiratory illness, premature mortality, low birth weight, and stroke.
- **PM2.5 can also cause negative environmental impact:** Damage to materials and buildings; Acid Deposition; increase ozone levels.



### B) PM10

- **PM10** are suspended coarse particles, either solid or liquid, with a diameter of 10 micrometers or less. For comparison, a human hair is, on average, 50 to 70 micrometers in diameter. They are also sometimes referred to as floating dust or aerosols.
- **Difference between PM2.5 and PM10**
  - **Size:** PM2.5 is very fine, and PM 10 is larger and coarser.
  - **Less Harmful:** PM10 is less likely to cross from lungs to the bloodstream. Though they can penetrate deep into lungs.
- **Various sources:**
  - Smoke, Dust, and dirt from unsealed road, construction, landfill and agriculture

- Pollen
- Mold
- Smoke
- Industrial sources
- Fossil fuel burning
- Sea Salt

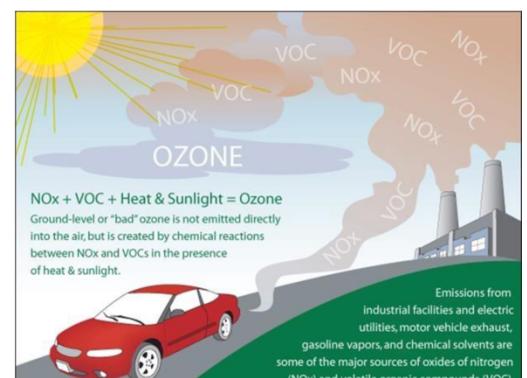
- **Health Impact:**
  - **Short term** - Difficulty breathing; coughing; eye, nose and throat irritation; Chest tightness and pain; Fatigue; General respiratory discomfort.
  - **Long term impact:** Heart failure, asthma, heart failure, cancer, adverse birth outcomes etc.
- **Environmental Impact:** Can corrode organic and inorganic material from vegetation to buildings. Painted surfaces, stone, fabrics, metal, and wood can become damaged and discolored.

### 3) CARBON MONOOXIDE

- CO is an odorless, colorless, and tasteless gas produced by the incomplete combustion of carbon in fossil fuels such as wood, propane, charcoal, oil, coal or other fuel.
- **Carbon monoxide Poisoning:** It occurs when carbon monoxide builds up in your bloodstream. When too much CO is in the air you're breathing, your body replaces the oxygen in your RBCs with carbon monoxide. This prevents oxygen from reaching your tissues and organs.
  - **Science behind this:**
    - Hemoglobin binds carbon monoxide (CO) 200 to 300 times more with oxygen, resulting in the formation of carboxyhemoglobin and preventing the binding of oxygen to hemoglobin due to competition of the same binding sites.
  - **Signs and symptoms** of CO Poisoning: Dull headache, weakness, dizziness, nausea or vomiting, shortness of breath, confusion, blurred vision, loss of consciousness etc.
  - It can particularly be dangerous for people who are sleeping or intoxicated. People may have a irreversible brain damage or even die before they realize the problem.

### 4) OZONE

- **Ozone ( $O_3$ )**
  - Ozone is a gas composed of three atoms of oxygen ( $O_3$ ).
    - » **Key Properties:** It is a bluish gas. It is also a major oxidant.
  - It occurs in both earth's upper atmosphere and at ground level.
  - Ozone can be "good" or "bad" for health and the environment depending on where it's found in atmosphere.
- **What is Ground Level Ozone Pollution?**
  - Ozone pollution is a **secondary pollution** and is not emitted by source directly. It is created by chemical reactions between oxides of Nitrogen (NOx) and Volatile Organic Compounds that are



emitted from combustion sources like vehicles, industry, power plants etc. in **the presence of sunlight and heat.**

- It is most likely to reach unhealthy levels on hot sunny days in urban environment. It may also reach high level during colder winter months because of high pollution and sunlight.
- Since it can also be transported for long distances by wind, it may also impact rural areas.

- **Unprecedented Ozone Levels have made Delhi Air More Toxic: CSE analysis (June 2022)**
- **Why increasing in Delhi**
  - High level of pollution, with high sunshine and high ambient temperatures.
- **Negative Impact of Ozone Pollution**
  - **Health Impacts** -> Breathing problems, chest pain, cough, throat irritation; Further people with certain genetic conditions, and people who have lower intake of Vitamin C and Vitamin E are at greater risk of Ozone exposure.
  - **Environmental Impact** -> impact sensitive vegetation during growing season
- **Monitoring of Ozone**
  - **NAAQS (National Ambient Air Quality Standards)** by CPCB measures Ozone
  - AQI and SAFAR measurements also has listed ozone as a pollutant which is regularly measured.
- **Increase in Ozone levels even during lockdown: CSE Study (June 2020): Class Discussion**

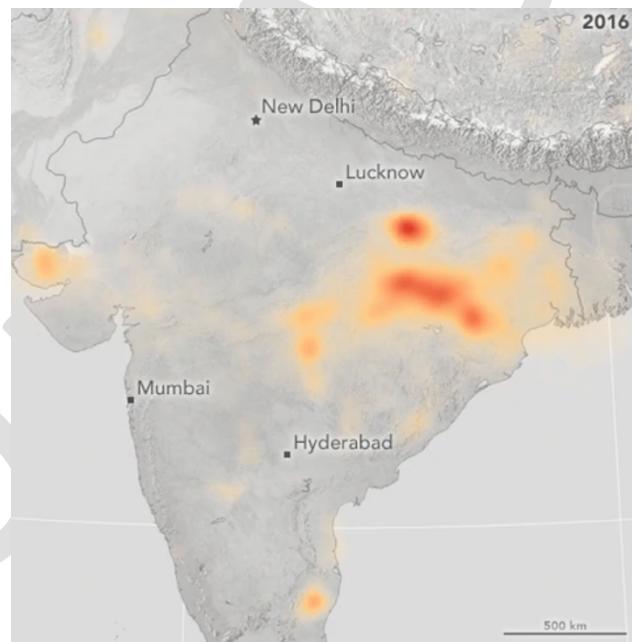
## 5) NITROGEN DIOXIDE

- **Details**
  - **Physical features:** It is a deep red-orange gas and when released into the air, it is seen as a reddish-brown haze. It has a pungent and acrid odour.
  - NO<sub>2</sub> is a major contributor in the formation of Smog and a precursor to many harmful secondary pollutants, including ozone and particulate matter. It is highly reactive with other chemicals and is strong oxidizing agent.
  - **Sources of NO<sub>2</sub>**
    - **Natural Sources:**
      - Lightning Strikes
      - Volcanoes
      - Oceans
      - Biological decay
    - **Manmade sources:**
      - **Combustion** creates oxides of nitrogen, a major portion of which is nitrogen dioxide. When vehicles emit oxides of nitrogen, 90-95% of the emissions are nitric oxide (NO). However, nitric oxide quickly oxidizes in outdoor air when reacting to oxygen, ozone, and volatile organic carbons (VOCs) to form nitrogen dioxide.
  - **It is both a primary and secondary pollutant.**
    - As primary pollutant, NO<sub>2</sub> is emitted in limited amounts through vehicles.

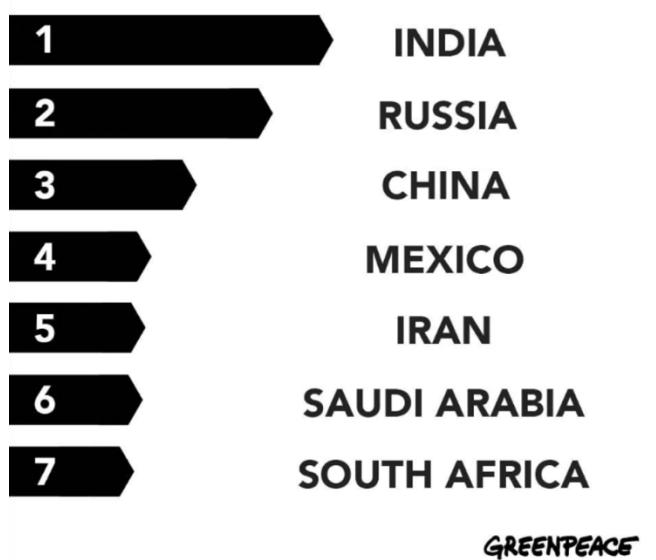
- It is also a secondary pollutant as it can be formed through oxidation. Nitrogen dioxide further oxidizes into **Nitric Acid (HNO<sub>3</sub>)**, which can enter the environment through the ground as droplets or nitrate containing particles.

## 6) SO<sub>2</sub>

- **Basics**
  - SO<sub>2</sub> is a colorless gas which has a nasty, sharp smell. It reacts with other substances to form harmful compounds, such as sulfuric acid, sulfurous acid, and sulfate particles.
- **Main Sources** - Burning of Fossil fuels and ships, locomotives using furnace oil/ heavy oil; Other small sources are - **industrial processes** like extracting metal from ore; nature sources such as volcanoes.
- **Why Sulphur dioxide pollution is problematic?**
  - **Health Issues:** Respiratory diseases; contribute to PM pollution.
  - **Environmental Issues ->**
    - **Harm trees and plants** -> Damaging foliage and decrease growth of trees and plants.
    - **ACID Rain** -> harms sensitive ecosystem
  - **Damage Cultural Heritage**
    - Deposition of sulfur particles may cause discoloration and damage of monuments, statues etc.
    - The fine particles may reduce visibility (Haze)
- **India has emerged as the largest SO<sub>2</sub> emitter in the world: NASA data.**
  - India has **highest number (more than 15%) of all anthropogenic SO<sub>2</sub> hotspots** in the world detected by the **Ozone Monitoring Instrument (OMI)** satellite. These include Singaruli, Nevyeli & Chennai, Talcher & Jharsuguda, Korba, Kutch etc.
- **Key reasons for High Sulphur pollution in India**
  - Nearly all the SO<sub>2</sub> emission in India comes from coal burning power plants which are the major source of energy for India.
  - The vast majority of power plants in India lack flue-gas desulfurization technology to reduce their air pollution.



Worst emitters of SO<sub>2</sub> pollution in the world



- **Note: Flue Gas Desulfurization (FGD)** is a set of technologies used to remove SO<sub>2</sub> from exhaust gas of fossil fuel based power plants.

## 7) BENZENE

- **Details**
  - Benzene (C<sub>6</sub>H<sub>6</sub>) is an aromatic, organic compound with a single six-member unsaturated carbon ring. It is clear, colorless, volatile, highly inflammable liquid with a characteristic order and a density of 874/m<sup>3</sup>.
  - Benzene in air mostly occurs in vapor phase, with residence times varying between 1 day to two weeks, depending on the environment, the climate and the concentration of other pollutants.
  - It is an **air pollutant** emitted from gasoline stations, motor vehicle exhausts and fuel evaporation, the burning of coal and oil, and various other sources. Urban areas generally have higher ambient air concentration of benzene than other areas.
  - **Indoor sources** of benzene pollution are material used in construction, remodeling, and decorating. Benzene is also present in particle board, furniture, plywood, fiberglass, flooring adhesives, paints, wood paneling, paint removers etc. Therefore, new buildings or recently decorated indoor environments have been associated with high concentration of benzene from materials and furnitures. Use of **fuel for space heating** like coal, wood, gas, Kerosene, LPG etc. also produce benzene.
  - **Negative Health Impacts of Benzene**
    - » Cancer, damage to immune system, neurological, reproductive or developmental issues.
  - In addition of being an air pollutant, it may also pollute water.
- **Joint Committee by NGT**
  - The joint committee consisted of officials from MoEF&CC, CPCB, SPCBs, NEERI etc. The committee was directed to assess the ambient air quality levels in the state, especially in major cities of Kerala.
  - **Key findings**
    - » Petrol refueling stations were a major source of benzene emissions, volatile organic compounds, and particulate matter 2.5 concentration.
  - **Key recommendations**
    - » Installation of vapor recovery systems at the fueling stations
    - » Retrofitting of diesel vehicles with particulate filters to improve air quality.
    - » Stringent action against industrial units that don't comply with emission norms.
    - » Retrofitting of emission control devices of generators and replacing diesel generators with gas-based ones.
    - » Promoting battery operated vehicles and banning old diesel vehicles in a phased manner, greening of open areas, and creation of green buffers along traffic corridors.

## 8) AMMONIA

- **About Ammonia**
  - Ammonia is a colorless gas with characteristics pungent odor.
  - **Natural sources** include decaying organic matter and animal waste.

- **Manmade sources** include fertilizer manufacturing, waste disposal sites, industrial processes etc.
- It doesn't last long in environment and thus doesn't bio-accumulate.

#### - Applications

- 80-90% of ammonia all over the world is used for **making fertilizer** (ammonium nitrate is an important nitrogen fertilizer)
- It is a precursor of various nitrogenous compounds. Virtually, all synthetic nitrogen compounds are derived from ammonia.
- It is also used in making household cleaners, plastics, dyes, pharmaceuticals etc.
- It is an anti-septic and is used in food preservation industry.
- Scientists are also experimenting with using ammonia as a storage of renewable energy. (Nitrogen gas and water use energy to convert into Ammonia). Later Ammonia can be used a fuel in the fuel cell.

#### - Ammonia Pollution

- Majority of airborne ammonia comes from fertilizers.
- Ammonia can also contribute to formation of PM<sub>2.5</sub> (ammonia combines with VOC, NO<sub>x</sub>, SO<sub>2</sub> etc. to form PM<sub>2.5</sub>)



#### - Health Impacts:

- At higher concentration ammonia is toxic, caustic, and hazardous. Exposures at high levels of ammonia can be irritating to a person's skin, eyes, throat, lungs, and cause coughing and burns.
- **Long term health concerns** associated with Ammonia exposure include – severe cardiovascular and respiratory effects, decreased lung function, asthma aggravation, premature death etc.

#### - Environmental Impacts -> Eutrophication, Soil Acidification; biodiversity loss -> promote species which prefer nutrient fueled growth to outcompete other species.

#### - Indo-Gangetic Plain Global Hotspot of atmospheric Ammonia: Study by IIT KGP (Dec 2020)

- The study titled “**Record high levels of atmospheric ammonia over India: Spatial and temporal analysis**” has been published in the international Elsevier journal “*Science of the Total Environment*”. In this study, the seasonal and inter-annual variability of atmospheric ammonia emitted by the agricultural sector was analyzed and the key highlights have raised certain concerns:
  - » The general trend in atmospheric ammonia over India is negative in most seasons. But, in USA, China and Europe, this trend is positive.
  - » For the period 2008-2016, the atmospheric ammonia during the month of June to Aug have grown rapidly at a rate of 0.08% annually.
  - » The Indo-Gangetic Plain is a global hotspot of atmospheric ammonia.
    - **Reason:** Intense agri activity and a lot of fertilizer use and production
  - » Atmospheric Ammonia has a positive correlation with Fertilizer use, hot weather (high temperature supports volatilization) and fires.

- » It has a negative correlation with total precipitation as wet deposits helps in the removal of ammonia.

#### - Water Pollution

- An ammonia concentration of upto 0.5 ppm (BIS) is maximum limit for drinking water. But, if the ammonia concentration is more than 1 ppm, it would negatively impact our health in long run. Similarly, ammonia concentration of more than 1 ppm in water bodies is dangerous for fish population.
- **High Ammonia Concentration in Yamuna River** is regularly disrupting water supply in Delhi.
  - For e.g., in July 2020, the ammonia concentration in Yamuna River reached 3 ppm. This led to reduction of water supply from Yamuna for Delhi, as Delhi Jal Board doesn't have technology to treat this high concentration of water.
- **Why ammonia pollution is so high?**
  - Industrial units of Sonipat and other drains joining the river along the way may be contributing to this.
- **Way Forward – Precision agriculture; Regulation of discharge; Reducing Nitrogen feed to animals; Improving water treatment technology; maintaining ecological flow of water.**

## 9) SMOG

#### - Smog

- Smog is a kind of air pollution, originally named for the mixture of smoke and fog in the air.
  - » **Classical smog** results from the large amount of coal burning in the area and is caused by mixture of Sulphur dioxide and smoke.
  - » Today, **most of the smog** that we see is **Photochemical Smog** (or ground level Ozone). It is produced when Nitrogen oxides in presence of sunlight react with **Volatile Organic Compounds (VOCs)** in the atmosphere.
    - **Nitrogen oxides** come from car exhaust, coal power plants, and factory emissions.
    - **VOCs** are released from petrol, paints, and many cleaning solvents.
    - When sunlight hits these chemicals, they form airborne particles and ground-level Ozone or Smog.

#### - Harmful impacts of SMOG

- **Health Impacts:** Ground level ozone, SO<sub>2</sub>, NO<sub>2</sub>, CO are especially harmful for senior citizens, children, and people with heart and lung conditions such as bronchitis and Asthma.
  - It may inflame breathing passage, impacting the functioning of lungs thus causing breathlessness, wheezing and coughing. It can also cause irritation to eyes and nose. It also dries out the protective membrane of the nose and throat and interfere with the body's



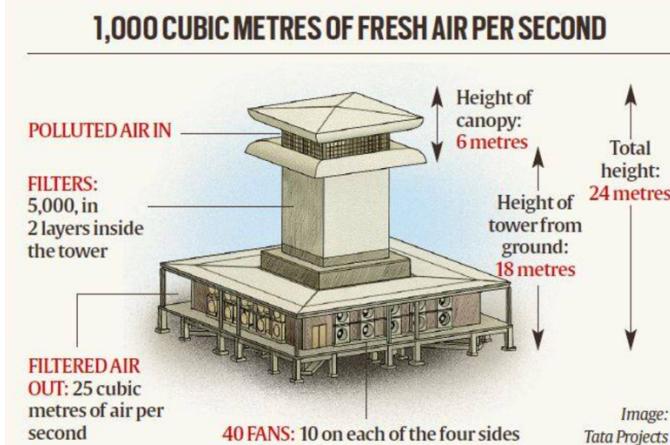
ability to fight infection, increasing susceptibility to illness.

- **By decreasing visibility**, it slows down traffic and increases the chance of accidents.
- Smog also negatively affects the **aesthetics** of the city by making sky brown and gray.

- **Supreme Court verdict:**

- **The Supreme Court** in Nov 2019 asked the CPCB and the Delhi government to come up with a road map on installing smog towers in the NCR to combat air pollution. In Jan 2020, the SC directed that the two towers should be installed by April as a pilot project.

- **Components of Delhi's first Smog tower by Government of Delhi:**



- The tower uses a '**down draft air cleaning system**' developed by University of Minnesota.
  - Polluted air is sucked in at a height of 24 meters, and filtered air is released at the bottom of the tower, at a height of about 10 meters from the ground.
  - When the fan at the bottom layer operates, the negative pressure created sucks in the air from the top. The 'macro layer' in the filter traps particles of 10 microns and larger, while the 'micro layer' filters smaller particles of around 0.3 microns.
  - This method is **different from the 'Updraft system'** - in which air is sucked in from the ground and is propelled upwards by heating and convection. Filter air is released at the top of the tower.
- **Expected Impacts**
  - Computational fluid dynamics modelling by IIT Bombay suggest that towers could have an impact on air quality of upto 1 KM.
- **Criticism**
  - Experts say that there isn't enough evidence to show that Smog towers work.

## 10) AEROSOL POLLUTION

- **What is aerosol?**

- » An aerosol is a **mixture of tiny particles suspended in a gas**, typically air. This particle can be solid, liquid, or a combination of both. These particles can range in size from a few nanometers to several tens of micrometers and can be produced naturally or by human activities.
  - » **Examples of natural aerosols** include dust, pollen, sea salt, and volcanic ash.

- » Examples of Human made aerosols include smoke, soot, exhaust fumes from vehicles, and particles generated by industrial processes like mining and manufacturing. They include PM2.5 and PM10.
- Impacts that aerosols can have:
  - » On Human Health: they may cause respiratory problems and exacerbating heart disease.
    - A study published in Science Advances showed that excess infant deaths in India were estimated to be three million - the highest among the eight regions evaluated in the study.
  - » On Environment: They can contribute to climate change by altering the balance of radiation in the atmosphere and affecting cloud formation.
- Aerosol Optical Depth (AOD):
  - » It is a measure of how much atmospheric aerosols, such as smoke, dust, and pollution, are scattering and absorbing sunlight.
    - It is typically measured using specialized instruments that detect the amount of light that is scattered or absorbed by aerosols in the atmosphere.
    - It is the quantitative estimate of the aerosol present in the atmosphere and it can be proxy measurement of PM2.5.
  - » The value of AOD range from 0 and 1. 0 indicating crystal-clear sky with maximum visibility whereas a value of 1 indicates very hazy conditions.
  - » AOD value less than 0.3 falls under green zone (safe), 0.3-0.4 is the blue zone (less vulnerable), 0.4-0.5 is orange zone (vulnerable) while over 0.5 is the red zone (highly vulnerable)
- Aerosol Pollution in West Bengal and Bihar (Nov 2022)
  - A study by Bose Institute in Kolkata as revealed that aerosol pollution in WB is anticipated to rise by 8% and continue to remain in the "highly vulnerable" red zone for aerosol pollution. This is the second highest forecasted aerosol pollution level in the country after Bihar.
  - India's regional weather patterns and topography makes the country highly vulnerable to aerosol pollution.
- Why?
  - West Bengal receives Indo-Gangetic Plain air pollution outflows and its local emissions have put WB in the highly vulnerable zone.

## 11) FLY ASH

- Introduction
  - Fly ash is a coal combustion byproduct produced in coal based thermal power plants. It refers to ash that is driven out of coal fired boilers together with the flue gases.
  - In modern coal fired power plants, fly ash is captured by electrostatic precipitators or other particle filtration equipment before the flue gas reaches the chimney.
  - The composition of fly ash varies considerably, but all fly ash includes substantial amount of Silicon di oxide (SiO<sub>2</sub>), Aluminium oxide (Al<sub>2</sub>O<sub>3</sub>) and Calcium oxide(CaO), the main mineral compounds in coal-bearing rock strata.
  - **Note:** The ash that falls to the bottom of the boiler is called bottom ash.

- **Key characteristics of fly ash**
  - **Harmful for human health:** Fly ash contains toxic constituents like lead, cadmium, chromium, arsenic which can be very dangerous for human health. They contribute heavily to particulate matters in air and cause lung problems.
  - **Bad for environment**
    - Toxic content results in both soil pollution and water pollution (toxic leaching)
  - **Affects large land area.**
    - If fly ash is not captured at the power plant itself, it spreads easily through air and affects large land area.
  - **It is a pozzolan, a substance containing aluminous and siliceous material that forms cement in the presence of water.** Hence it can be used in construction process.
- **Reducing Fly Ash pollution**
  - Washing the coal at its place of origin is an important step which ultimately reduces the amount of ash being produced.
  - Increasing R&D, for enhancing the efficiency of power plants, would also help in reducing the ash content.
  - Capturing fly ash before it is released in air by Chimney using various types of precipitators.
- **Where can the captured fly Ash be used?**
  - Cement industry uses Fly Ash in the manufacturing of Portland Pozzolana Cement.
    - Recently, scientists at IIT-Hyderabad have found ways to turn fly ash into products like paints, textile coatings etc.
  - It can also be used fly ash bricks/blocks/ and tiles manufacturing, road embankments construction etc.
  - Fly ash may also be utilized in agriculture as soil conditioners.
  - It is also used as a substitute of soil/sand for reclamation of low lying areas.
  - In mining it can be used for backfilling of mines.
- **Steps taken to promote the use of Fly Ash?**
  - i. **Various notification for fly ash utilization** since 1999
    - The **2016 notification** calls for every agency engaged in construction activity within a radius of 300 km of coal-based thermal power plant to use ash based products for construction.
    - It also mandates the use of ash-based bricks or products in all government schemes and programs.
  - ii. **Maharashtra** is the first state to have a Fly Ash Utilization Policy. It is also looking to export fly ash to countries like Singapore and Dubai where it is in demand.
  - iii. **GST rates** on fly ash and its products have been reduced to **5%**.
  - iv. Launching of **ASHTtrack Mobile App** for better management of fly ash produced by thermal power plant in Feb 2018.
    - It will act as an interface between fly ash producers (thermal power plants) and potential ash users such as road contractors, cement plants etc and thus will help in increasing the utilization of fly ash being produced at coal based thermal power plants.
  - v. **Various awareness campaigns**

- Through workshops and other programs.
- **Draft Fly Ash Notification (2021)** - it is the proposed 5th amendment to the 1999 fly ash notification.
  - It introduces a concept of 3-5 years compliance cycle to achieve a target of 100 percent fly ash utilization by the end of cycle.
  - It also gives an extension of 10 years to power plants to progressively utilize their legacy ash.

## 12) INDOOR AIR POLLUTION

- Indoor Air Pollution or Household Pollution is the air pollution whose source lies within the household. Various recent studies have found that indoor PM2.5 level in most Indian households is much higher than the outdoor PM2.5 concentration of the respective geographic area.
 
- **Causes:**
  - Use of **the traditional biomass** (Cow dung cake, firewood, coal etc.) for cooking is the leading cause of air pollution.
  - Burning fuels such as dung, wood, coal in inefficient open hearth produce a variety of health-damaging pollutants, including particulate matter, methane, CO, polycyclic aromatic hydrocarbon and VOCs.
  - These pollutants may **further accumulate** in the indoor environment if the indoor air is not well ventilated.
  - **Tobacco** consumption
  - **Building Materials** (Deteriorating asbestos containing insulation, paints, varnishes, wood flooring, etc.)
  - Products for household cleaning and maintenance, personal care, or hobbies.
  - Broken CFLs, Tubelights etc.
  - **Increased penetration of closed ventilation** due to Air-conditioners etc. makes situation worst.
  - **Outdoor sources** such as Radon, Pesticides, outdoor air pollution.
- **Health Impacts**
  - Household air pollution is responsible for 3.2 million deaths per year in 2020.
  - Household air pollution leads to non-communicable diseases including stroke, ischaemic heart disease, chronic obstructive pulmonary disease (COPD) and lung cancer.
  - The most common effect of IAP is called **sick building syndrome**, in which people experience uncomfortable or acute health effects such as irritation of nose, eyes and throats, skin ailments, allergies and so on.
- **Key steps being taken by government.**
  - **RAISE initiative**.
  - **Unnat Chulha Abhiyan** – By Ministry of New and Renewable Energy for providing a clean cooking energy solution with a view to reduce consumption of fuel wood with higher efficiency and low emissions.
  - **PM Ujjwala Yojna**

## A) RADON ( $Rn^{222}$ )

- It is an odorless, invisible, radioactive gas, naturally released from rocks, soil, and water.
  - It is a noble gas and thus doesn't react chemically with other substances.
- It is formed by decay of uranium and thorium in the earth's crust.
- It can seep into buildings and accumulate to dangerous levels, especially in areas with poor ventilation.
- **Harmful Impacts:**
  - Carcinogen: It can cause lung cancer.
    - In USA, radon is the leading cause of lung cancer after smoking.
- **The risk of developing lung cancer** from radon exposure depends on the level of radon in air, the duration of exposure, and whether or not the person is smoker.
  - **Note:** For smokers the risk is higher as smoking can damage the lungs and make them more susceptible to the harmful effects of radon.
- **Detection of Radon:**
  - Since, radon is colorless, odorless gas, the only way to know if the building has higher levels of radon is to test for it.
    - The test is relatively easy and inexpensive, and it can be done by homeowners and professionals.
- **Some Steps that can be taken are:**
  - Sealing cracks in the foundation
  - Installing a ventilation system
  - Relocating to different house

## 13) PET COKE (PETROLEUM COKE) AND ASSOCIATED ISSUES

- **Introduction: What is Pet Coke**
  - » It is a type of coke derived from oil refining process. It is the final carbon-rich solid material from the bottom of the barrel after refining of heavy oils.
    - **Coking Process:** In petroleum coker units, residual oils from other distillation processes used in petroleum refining are treated at high temperature and pressure leaving petcock after driving off gases and volatiles, and separating off remaining light and heavy oils.
  - » **Properties**
    - Petcoke is 90% carbon and emits 5-10% more carbon dioxide (CO<sub>2</sub>) than coal on a per-unit-energy basis when it is burned.
      - As they have higher energy content, they emit between 30-80% more CO<sub>2</sub> than coal per unit weight.
    - It also contains higher sulfur content which makes it burning more polluting.
    - It is cheaper and burns hotter than coal.
  - » **Used less in western countries.**
    - Its higher sulfur content makes it a less attractive fuel in US and thus power hungry India becomes an easy export destination.
  - » **Impact of use of petcock in India**
    - **India is the largest user** of the Pet coke.
    - It is making a bad situation worse in India due to its higher CO<sub>2</sub> and Sulfur emissions.

- **Ban on Pet Coke Import as fuel (Aug 2018)**
  - DGFT has banned import of Pet-Coke as fuel.
  - Import is allowed for only Cement, Lime Kiln, Calcium carbide and gasification industries, when used as feedstock or in the manufacturing process of actual condition.

#### 14) FUEL OIL/ HEAVY OIL/ FURNACE OIL -> ISSUES CONCERNING THEM

- **Introduction**
  - » Fuel oil/ Heavy Oil/ Furnace Oil is the heavier fraction obtained from petroleum distillation.
  - **Note: Fractional Distillation**
    - Crude oil is separated into fractions by fractional distillation. The fractions at the top have lower boiling points than the fractions at the bottom.
    - » All the fractions are processed further in refining units.
    - » **Bunker Fuel** is the fuel used aboard vessels (heavy ships). Generally the heaviest variety of oil i.e. fuel oil is used there. It is also known as marine fuel oil.
- **Some features of heavy fuel oil:**
  - » Heavy fuel combustion products remain high in NO<sub>x</sub>, So<sub>x</sub>, Particulate matter and CO<sub>2</sub>.
  - » It has high viscosity when compared to Diesel, Kerosene and Petrol. To be used as fuel it's viscosity should be less and therefore it needs to be kept at higher temperature. It is also mixed with lighter fuel (e.g. diesel) to reduce its viscosity.
- **In case of oil spills heavy oil is more aggravating in nature because:**
  - i. Marine fuel is hazardous and very toxic to marine life.
    - The incombustible material that remains after the combustion mainly consists of the metals vanadium, silicon, aluminium, nickel, sodium, and iron that are present in the original heavy fuel oil supply
    - Marine organisms are very susceptible to these heavy metals.
  - ii. It evaporates at a slower pace when compared to other fuel (petrol, Kerosene, diesel etc) and thus remain in water for longer period impacting marine diversity more.
- Despite the above limitations the use continues because of the cheap price and large availability (as it keeps getting produced in oil refineries)

#### 15) AGRI-SUBSIDY AND AIR POLLUTION

- High MSP for Rice -> Rice grown in Haryana, Punjab etc. -> Stubble burning.

- Power subsidy -> more use of water -> paddy cultivation -> stubble burning
- Fertilizer subsidy -> Overuse -> Indo-Gangetic plains emerging as atmospheric ammonia hotspots

## 16) WHO'S AIR QUALITY GUIDELINES

- In Sep 2021, WHO revised the air quality guidelines. This was the first major update to the standards in 15 years.
- **Why was there a need of update?**
  - New studies have found that even smaller quantity of pollutants were harmful for human beings.
- Therefore, WHO has strengthened nearly all pollutant standards in comparison to the quality guidelines established in 2005 (published in 2006)
  - **Expected Impact:** If the target levels are implemented and achieved by governments, it would lead to saving of lakhs of lives.
- **The new guidelines recommend air quality levels for 6 pollutants**, where evidence has advanced the most on health effects from exposure.

**Recommended 2021 AQG levels compared to 2005 air quality guidelines**

Pollutant	Averaging Time	2005 AQGs	2021 AQGs
PM <sub>2.5</sub> , µg/m <sup>3</sup>	Annual	10	5
	24-hour <sup>a</sup>	25	15
PM <sub>10</sub> , µg/m <sup>3</sup>	Annual	20	15
	24-hour <sup>a</sup>	50	45
O <sub>3</sub> , µg/m <sup>3</sup>	Peak season <sup>b</sup>	-	60
	8-hour <sup>a</sup>	100	100
NO <sub>2</sub> , µg/m <sup>3</sup>	Annual	40	10
	24-hour <sup>a</sup>	-	25
SO <sub>2</sub> , µg/m <sup>3</sup>	24-hour <sup>a</sup>	20	40
CO, mg/m <sup>3</sup>	24-hour <sup>a</sup>	-	4

- **Expected impact of the new guidelines:**
  - » Spur greater global reactions in pollution emissions.
  - » Contribute to fight against climate.
- **Note:** These guidelines are not legally binding on any country. But, countries and legislative bodies regularly refer to WHO guidelines when setting airborne pollutant control legal policy.
- **Implications for India**
  - » As per the new WHO guidelines, almost the entire India, specially the Urban areas would now be considered polluted for entire year.

## 4. INSTITUTIONS, INITIATIVES, SCHEMES, PROGRAMS ETC.

### 1) CENTRAL POLLUTION CONTROL BOARD (CPCB)