

- **Control Rods:** These are made of neutron absorbing material such as Cadmium, Hafnium or Boron, and are inserted or withdrawn from the core to control the rate of reaction.
- **Coolant:** A fluid circulating through the core so as to transfer the heat from it. In light water reactors, the water moderator functions also as primary coolant. Except in BWRs, there is secondary coolant circuit where the water becomes steam.
- **Steam Generator:** Part of the cooling system of pressurized water reactors (PWRs and PHWRs) where the high-pressure primary coolant bringing heat from the reactor is used to make steam for the turbine, in a secondary circuit.

5) TYPES OF REACTORS

A) BOILING WATER REACTOR

B) PRESSURIZED WATER REACTOR

C) PRESSURIZED HEAVY WATER REACTOR

D) ADVANCED GAS COOLED REACTORS

E) FAST NEUTRON REACTOR (FAST BREEDER REACTOR)

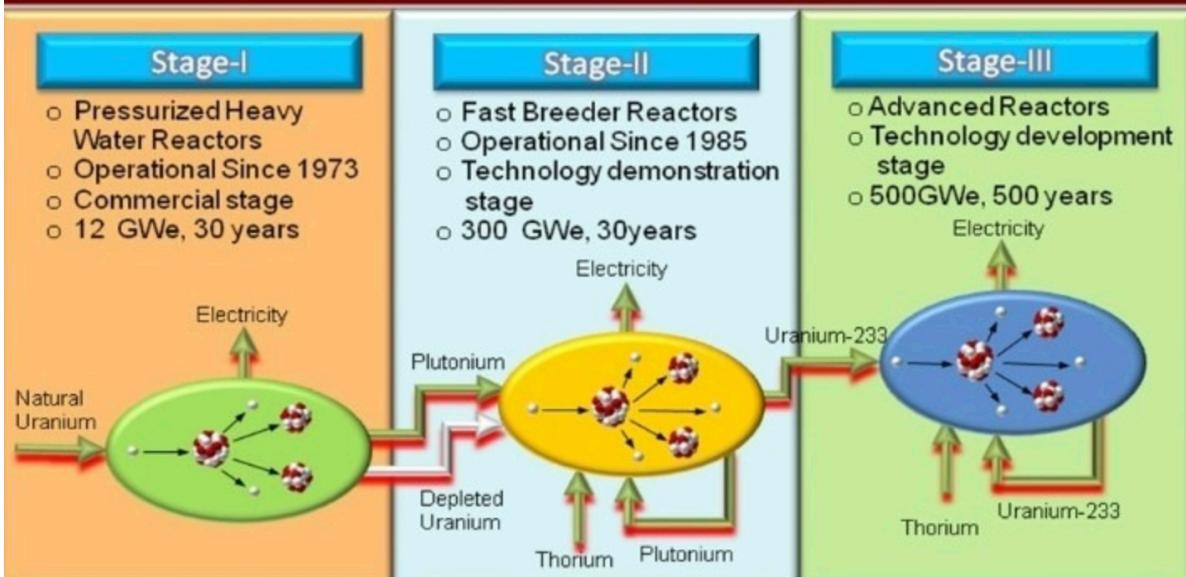
- Some reactors (**only one in commercial service**) do not have a moderator (they use a coolant that is not effective moderator, like liquid sodium). Although these fast neutrons are not good at causing fission, they are readily captured by uranium (U_{238}), which then becomes plutonium (Pu_{239}). This Plutonium isotope can be reprocessed and can be used as more reactor fuel or in the production of nuclear weapons.

- **Advantages:**
 - They get more than 60 times as much energy from the original Uranium compared with normal reactors.
 - Reduction in radioactive waste.
 - Safety -> closed fuel cycle would ensure safety
 - Energy security for India -> India plans third phase of its nuclear energy program on the success of FBR
- **Disadvantage:** Expensive and complicated to build and operate
- **Fast Breeder Reactors** - If FNRs are configured to produce more fissile material (plutonium) than they consume they are called Fast Breeder Reactors (FBR).
 - Breeder reactors are possible because of the proportion of uranium isotopes that exist in nature.
- **Problems associated with fast Breeder reactors / Fast Neutron Reactors**
 - Plutonium produced can be removed and used in nuclear weapons
 - To extract Plutonium the fuel must be reprocessed, creating radioactive waste and potentially high radiation exposure.
- **Use scenario globally**
 - US, UK, France and Germany have effectively shut down their fast breeder reactor plants
 - **India, Russia, Japan and China** currently have operational fast breeder reactor program.

6) INDIA'S 3-STAGE NUCLEAR POWER PROGRAM

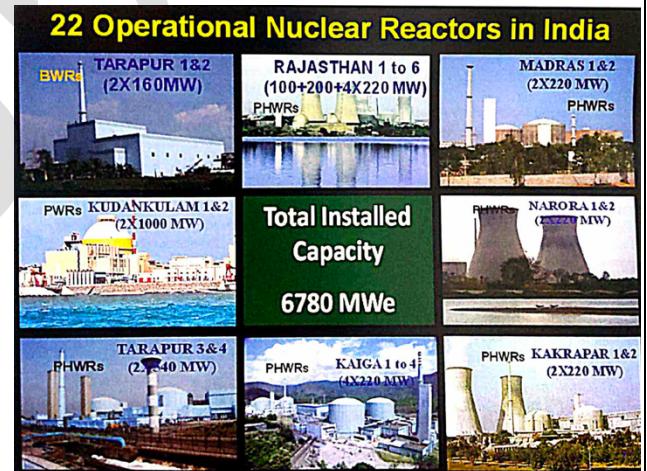
- The three-stage nuclear power production program of India had been conceived by the 'father of Indian Nuclear Power Program' Dr Homi J Bhabha, with the ultimate objective of utilizing the country's vast reserves of thorium-232.
 1. The first stage comprises setting up of **Heavy Water Reactors/Pressurized Heavy Water Reactors (PHWRs)** and associated fuel cycle facilities.
 2. The second stage envisages setting up of **Fast Breeder Reactors (FBRs)** backed by reprocessing plants and plutonium based fuels fabrication plants. Plutonium is produced by irradiation of U-238.
 3. The third stage is based on the thorium-232 -> Uranium 233 Cycle, Uranium-233 is obtained by irradiation of Thorium.

Indian Three Stage Nuclear Power Programme



Progress of the 3 Stages

- The first stage of Nuclear Power Programme is already in commercial domain. The Nuclear Power Corporation of India Ltd. (NPCIL), a public sector undertaking of DAE, is responsible for the design, construction and operation of nuclear reactors. The company presently operates 23 reactors with a capacity of 7.8 GW. In addition, the company is also engaged in construction of many other nuclear power reactors. In addition, 10 nuclear power reactors with a total of 8000 MW capacity are under construction. This include a 500 MW PFBR of the second stage nuclear power program. Further, government has accorded administrative approval and financial sanction of 10 indigenous PHWRs of 700 MW capacity each, to be set up in fleet mode. With completion of these projects, India's nuclear energy capacity is expected to go to 22.4 GW by 2031.



Nuclear power plant	State	Reactor
Tarapur atomic power station	Mha	Taps-1; taps-2 2*160 mw (BWR) Taps-3 and taps-4 (2*540) (phwr)
Rajasthan atomic power station	Rajasthan	Raps-1 to 6 (100 + 200 + 4*220)
Madras atomic power station	Tn	Maps-1; maps-2 (2*220) (phwrs)
Kaiga atomic power station	Karnataka	Kaps-1 to 4

		(4*220) (phwrs)
Kakrapara atomic power station	Gujarat	Kaps-1, kaps 2 (2*220) (phwrs) Kaps-3 (generating electricity from 30th Aug 2023) (700MW) Kaps-4 (attained criticality in Dec 2023)
Kudankulam nuclear power plant	Tn	Kknpp-1; kknpp-2 (2*1000 mw) pwrs
Naora atomic power stations	Uttar pradesh	Naps-1; naps-2 (2*220 mw) (phwrs)

- **Karappar-3** has been generating commercial electricity from 30th Aug 2023.
 - o The 700 MWe units are the largest indigenous nuclear power reactors to be built by the Nuclear Power Cooperation of India (NPCIL), a public sector undertaking of the Department of Atomic Energy (DAE)
- **Kakrapar-4 (KAPP-4)**, with 700 MWe capacity, started controlled chain reaction and thus became critical in Dec 2023.
- Both these reactors are PHWRs, which use natural Uranium as fuel and heavy water as coolant.

- **The Second Stage** of Nuclear power generation programme is geared towards setting up the Fast Breeder Reactors. These reactors produce more fuel than they consume. The fast breeder program is in technology demonstration stage.

▪ **Features of the Prototype Fast Breeder Reactor (PFBR)**

- **Fuel:** Plutonium Uranium Oxide (PuO_2 and UO_2)
- **Coolant:** Liquid Sodium
- **Liquid Sodium additional safety requirements**
 - o Since sodium explodes if it comes in contact with water and burns when in contacts with air, additional safety requirements are needed to isolate the coolant from the environment.
 - o Sodium also absorbs neutron to form Radioactive Na²⁴ isotope.

- **Advantages of FBR:**

- They can ensure upto 60 times as much energy from the original Uranium compared with normal reactors.
- Reduction in radioactive waste.
- Safety -> closed fuel cycle would ensure safety
- Energy security for India -> India plans third phase of its nuclear energy program on the success of FBR

- **The Third Stage:** of the Nuclear Power Programme is in **technology development stage**.
 - The ongoing development of 300 MWe Advanced Heavy Water Reactor (AHWR) at BARC aims at developing expertise for thorium utilization and demonstrating advanced safety concepts.
 - Thorium-based systems such as AHWR can be set up on commercial scale only after a large capacity based on fast breeder reactors, is built up.
 - Why Thorium based reactors are important for us
 - i. **Abundance:** India has the world's third largest reserve of thorium.
 - ii. **Less Enrichment requirement:** Thorium mining produces a single pure isotope, whereas the mixture of natural uranium isotope must be enriched to function.
 - iii. **Superior Nuclear Properties:** Superior physical and nuclear properties
 - iv. **Better Nuclear weapon resistant:** Better resistance to nuclear weapon proliferation
 - Weapon grade fissionable material (U-233) is harder to retrieve safely from a thorium reactor. It contains U-232, a strong source of gamma radiation that makes it difficult to work with. Further, its daughter product, thallium-208, is equally difficult to handle and easy to detect.
 - v. Reduced plutonium and actinide production. They have minuscule long lived radioactive waste.

7) THORIUM RESERVES IN INDIA

- As per the Department of Atomic Energy, India has reserves of thorium in sufficient quantity as compared to other parts of the world.
- As of 2014, the Atomic Mineral Directorate for Exploration and Research (AMD), a constituent unit of Department of Atomic Energy (DAE), has so far established 11.93 million tonnes of in situ resource Monazite (Thorium bearing mineral) in the country which contains about 1.07 million tonnes of thorium.
- **The state-wise details of the Monazite resources** (as of March 2021, as per Department of Atomic Energy):
 - » **Total: 12.73 million tonnes of Monazite** (More than 1 million tonnes of thorium in it)

State	No of Deposits	Resource (million tonne)	
		Monazite	Total Heavy Minerals
Odisha	12	3.16	332.44
Andhra Pradesh	24	3.78	333.45
Tamil Nadu	50	2.47	298.42
Kerala	35	1.84	242.88
Maharashtra	5	0.004	5.64
Gujarat	2	0.07	12.53
West Bengal	1	1.20	5.45
Jharkhand	1	0.21	1.12
Total	130	12.73	1,231.93

8) OTHER IMPORTANT ASPECTS

- Why most of the nuclear power plants are situated near the coast?

- India's n-facilities under IAEA's umbrella (Dec, 2014)
 - Paving the way for import of fuels for its nuclear reactors, India has completed the process of placing its civilian reactors under IAEA safeguards.
 - The reactors under the IAEA's umbrella are eligible to use imported uranium.
 - **Need of placing reactors under IAEA safeguards**
 - Enable India to use international fuel for civilian reactors.
 - A deal was signed under which India was to sign and ratify the Additional Protocol of the IAEA. A separation plan was chalked out after the deal, segregating the military and civilian reactors.

9) NUCLEAR WASTE MANAGEMENT

- Global Endeavours for Nuclear Waste Management:
 - » **On Site Storing:** Some nations go for onsite storing. But it carries the risk of radioactive leakage.
 - » In USA, for e.g., spent fuel is stored in a concrete and steel container called a dry cask.
 - » **India and a few other countries,** reprocess about 97-98% of spent fuel to recover plutonium and uranium. India also recovers materials like caesium, strontium, and ruthenium, which finds application as blood irradiators to screen transfusions, cancer treatment, and eye cancer therapeutics, respectively. The remaining 1-3% end up in storage facilities. India also immobilizes the wastes by mixing them with glass, which is kept under surveillance in storage facilities.
 - » **Deep geological Repositories:** Nations like Finland, Canada, France and Sweden are looking at deep geological repositories to tackle spent nuclear fuel wastes.
 - In Jan 2022, the Swedish government greenlit an underground repository for nuclear waste. Construction in Sweden will take at least 10 years.
 - » **About Onkalo Spent Nuclear Fuel Repository:** It is a deep geological repository for the final disposal of spent nuclear fuel. It will be world's first long-term disposal facility for spent fuel.
 - **Is geological repository safe?**
 - Experts associated with the project said that 40 years of theoretical and lab-based studies suggest that the geological repository is safe.
 - The bedrock provides a natural barrier to protect from radioactive release to the environment, such as water bodies and air.
 - The use of copper and clay provides a protective layer to ensure no release due to extreme conditions like earthquakes.

A) FUKUSHIMA AND THE ISSUE OF ITS WASTE DISPOSAL

- Why in news?
 - » In Aug 2023, in spite of backlash from public and neighbouring countries, Japan began the release of contaminated water from the Fukushima nuclear plant into the sea (Aug 2023)

- **Project to decommission the facility:**
 - » The decommissioning project got cabinet's approval in 2021 and could take three decades to complete. It will cost \$76 billion. Under this Japan plans to start flushing 1.2 million tonnes of water from the embattled nuclear power plant into the Pacific Ocean.
- » **Issue of water disposal into the Pacific Ocean:**
 - The water that the Japanese government wants to flush from the plant was used to cool the reactor, plus rainwater and groundwater. It contains radioactive isotope from the damaged reactor and is thus itself radioactive. Japan has said that it will release this water into Pacific over the next 30 years.
 - **Why release water in ocean?**
 - TEPCO is running out of room for the water tanks and that nuclear plants around the world regularly release water containing trace number of radionuclides into large water bodies.
 - **How was the water treated?**
 - The Tokyo Electric Power Cooperation (TEPCO) has treated the water using multiple techniques, notably the Advanced Liquid Processing System (ALPS), which removes 62 types of radioactive material.
- » **CONCERNS:**
 - ALPS technique doesn't remove Tritium which can be easily absorbed by the bodies of living creatures and rapidly distributed via blood. Removing tritium is quite impossible as it is chemically similar to Hydrogen. Since tritiated water can pass through the placenta, it could lead to developmental effects in babies when ingested by pregnant women.
 - Though Japanese government argue that the concentration of tritium doesn't exceed international standards, in particular, those of IAEA. It is six times less than the limit of tritium in drinking water.
 - As per TEPCO, the radiation emitted by Tritium is "extremely weak, and can be blocked with a single sheet of paper".
 - There is no safe limit of radionuclide and any number of radionuclides in water will increase the risk of cancer.
 - **Neighbouring countries** like China, South Korea and Taiwan have also expressed concerns over Japan's Plan

10) CLND, 2010

- This act has been deemed responsible for Nuclear energy deadlock within the country. The two most contentious have been **Section 17(b) and Section (46)**

- **Section 17(b)** : It contains provisions on **recourse liability on suppliers**. This allows a liable operator to recover compensation from a supplier in case the accident was caused by provisions of sub-standard services or defective or faulty equipment.
- **Section 46:** **Potentially unlimited liability** under this section. Section 46 provides that *nothing would prevent proceedings other than those which can be brought under the act, to be brought against the operator*. This is not uncommon as it allows criminal liability to be pursued where applicable.

11) NUCLEAR BOMB:

Basic Raw material for atomic bomb

- An atomic bomb can be made from two types of radioactive materials: Uranium and Plutonium. In both cases, the manufacturing starts with Uranium ore.
- **Highly enriched U-235** (more than 90%) and no control rod to extract neutrons.
 - **Uranium** mined from earth is less than 1% U-235, the isotope that can be used to fuel reactors and make bombs. Centrifuges are needed to separate the U-235 from the rest of the Uranium, in a process called **Enrichment**. **Bomb grade Uranium 90% U-235**.
 - The Other fuel that can be used to make a bomb, **plutonium**, is made by irradiating uranium in a nuclear reactor. The process transforms some of the Uranium into Plutonium.

A) UNDERESTIMATED FALLOUT OF THE TRINITY NUCLEAR TEST: NEW STUDY (JULY 2023)

- On 16th July 1945, in a nuclear test code named “**Trinity**”, a plutonium-based implosion device was set off a 100-foot metal tower. The irradiated mushroom cloud also went many times higher into the atmosphere than expected – Some 50,000 to 70,000 feet.
- **New Findings:** Using state of art modelling software and recently uncovered historical weather data, the study found that radioactive fallout from the Trinity test reached 46 states, Canada and Mexico within 10 days of detonation. How much of the fallout still remains is difficult to calculate.

B) J ROBERT OPPENHEIMER: FATHER OF ATOM BOMB

- **Why in news?**
 - » Christopher Nolan’s new film on the American Physicist who built most destructive weapon known to man was released on 21st July 2023.
- **J Robert Oppenheimer** (1904-1967) was an American physicist and one of the most prominent scientists of 20th century. He is best known for his role as the scientific director of the Manhattan Project, the top-secret US government program during WW-II that led to the development of the first atomic bomb.
- **Education:** He was born in 1904, in New York City. He attended Harvard University and studied Physics there. He completed his PhD in theoretical physics at University of Gottingen in Germany under the supervision of Max Born in 1927. Later he returned to USA, and taught in University of California,

Berkely, and the California Institute of Technology (Caltech). He made significant contribution to physics, especially in the area of quantum mechanics and quantum field theory, earning him the recognition as one of the leading theoretical physicists of his time.

- In 1942, he was appointed as the scientific director of the Manhattan Project. He played a crucial role in organizing and coordinating the efforts of various scientists and engineers to develop an atomic bomb. The project resulted in successful detonation of the first atomic bomb on 16th July 1945, in the New Mexico desert, in an area known as the Trinity Test Site.
- The use of Atomic Bomb over Hiroshima and Nagasaki in Aug 1945 led to the end of WW-II and raised profound ethical and moral questions about the use of nuclear weapons. Oppenheimer was deeply affected by the destruction caused by the bombs and became an advocate for arms control and international cooperation in the peaceful use of atomic energy.
- His political views and opposition to nuclear weapons led to him coming under scrutiny during the era of McCarthyism and the Red Scare. In 1954, his security clearances were removed, and he was also ostracized from the scientific community.
- Inspite of these controversies, he continued serving at Princeton from 1947 – 1966. In 1963, he received the Enrico Fermi Award, one of the highest honors in the field of nuclear science.
- He passed away in 1967, leaving behind a complex legacy of a brilliant physicist and a controversial figure in American History.

It was only in 2022, that the US government nullified its 1954 decisions, and affirmed his loyalty. President Joe Biden's Energy Secretary, Jennifer M Granholm, said the decision to revoke Oppenheimer's clearance was the result of a "flawed process", and that with time more evidence of his loyalty and love of country have only been further affirmed.

12) NUCLEAR ENERGY AND ENERGY SECURITY

- **Introduction:**
 - » Energy security means consistent availability of sufficient energy in various forms at affordable prices. When a country moves ahead on the path of development, it is necessary to utilize every energy resource available in the country.
 - » Currently, nuclear energy makes up about 3% of India's energy sources
- **Advantages of Nuclear Energy:**
 - a) Least carbon footprint (lesser than renewable energy)
 - b) Cost of nuclear power
 - c) Quantity of waste generated is also very less
 - d) Potential of self sufficiency
 - e) Depleting fossil fuels and import dependency: India is currently drawing around 63% of its total energy from thermal sources. A significant part of this is imported.

f) Limitations of Renewable Energy

- Renewable energy are subject to vagaries of weather; they are land intensive; dependence on import technology; energy storage handicaps;
- Renewable energy is inevitable and nuclear option should be retained as insurance.

» Limitations

- a) Safety concerns in light of recent disasters
- b) Nuclear waste disposal is a big concern
- c) Potential of developing nuclear weapons
- d) Security concerns
- e) India is dependent on other countries both for raw material and technology
- f) Ecological concerns
- g) Long gestation period
- h) More safeguards -> more costly

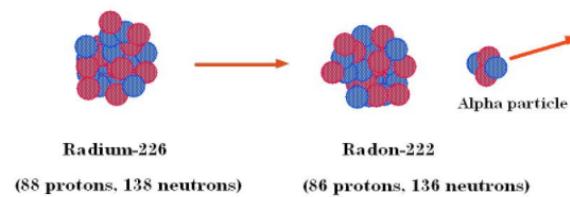
13) RADIOACTIVITY BASICS

▪ Introduction

- Radioactivity is the tendency of unstable nuclei to emit particles in order to bring it closer to stability. There are four main types of radioactivity.

1. Alpha Radiation: The emission of a He nucleus.

Alpha radiation is common when the nuclides of high atomic mass have a lower neutron to proton ratio than stable nuclide and ejects an alpha particle.

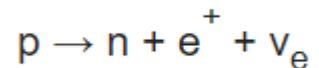


2. Beta Minus (plus) radiation: the emission of a high energy electron (or positron) from the nucleus.

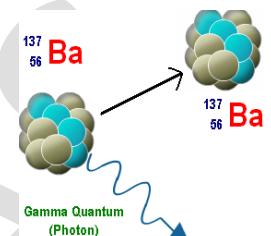
- Generally, an unstable atomic nucleus with an excess neutron undergo Beta (-) decay, where a neutron is converted into a proton, an electron and an electron anti-neutrino (the antiparticle of the neutrino).

$$n \rightarrow p + e^- + \bar{\nu}_e$$

- An unstable atomic nucleus with an excess of protons may undergo beta (+) decay, also called **positron decay**, where a proton is converted into a neutron, a positron, and an electron neutrino.



- Gamma Radiation:** These are penetrating electromagnetic radiation of a kind arising from radioactive decay of atomic nuclei.



- The decay of an atomic nucleus from a high energy state to a lower energy state, a process called gamma decay, produces gamma radiation.
- Gamma rays ionize atoms, and are thus biologically hazardous.

- Neutron Radiation:** It is a kind of ionizing radiation that consists of free neutrons.

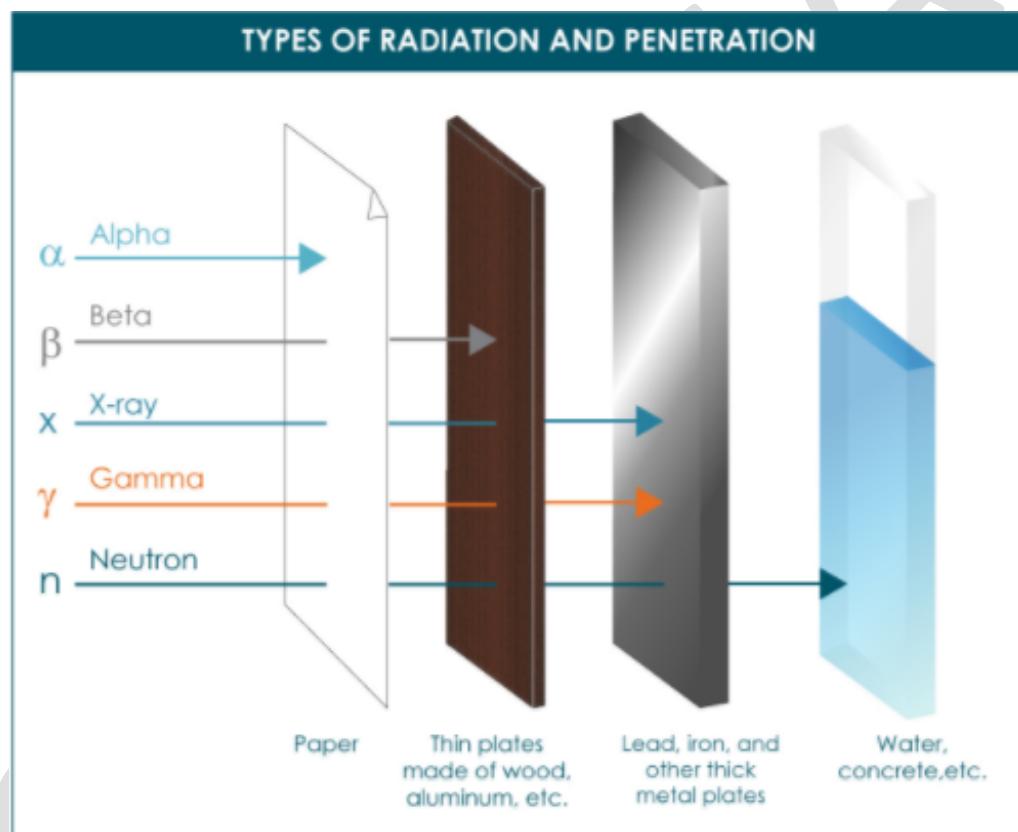
- This is generally a result of nuclear fusion and nuclear fission reaction.

- These particles (Alpha, Beta and Gamma) are available at an extremely low level in nature. Moderate to high rates of exposure to these particles can be severely detrimental to organic tissues and the life threatening to humans and rest of the ecosystem.

- Radiation can be ionizing or non-ionizing**, depending on how it affects matter.

- **Non-ionizing radiation** includes visible light, heat, radar, microwaves, and radio waves. This type of radiation deposits energy in the material through which it passes, but it doesn't have sufficient energy to break molecular bonds or remove electrons from atoms.
- **Ionizing Radiation** (such as x-rays and cosmic rays) is more energetic than non-ionizing radiation.
 - When ionizing radiation passes through material, it deposits enough energy to break molecular bonds and displace (or remove) electrons from atoms. This electron displacement creates two electrically charged particles (ions), which may cause changes in the cells of plants, animals, and people.
 - Ionizing radiation can be used for a number of beneficial purposes.

- For e.g. ionizing radiations are used in smoke detectors, medical purposes, etc.
- **Level of penetration of various ionizing radiations** (see the adjacent figure)
- **Sources of Radioactivity**
 - Minerals containing naturally radioactive elements (potassium, radium, uranium, thorium...)
 - Background cosmic rays
 - Solar Flux



- Nuclear power plants and nuclear fuel cycle plants
- Old Equipment (e.g. watches and clocks having radio luminescent paints) (radium, tritium)
- Nuclear labs
- Radioactive waste
- Nuclear Medicines
- Nuclear Bomb testing
- Radon gas

14) RADIOACTIVE DECAY

- Radioactive decay is the process through which radioisotopes lose their radioactivity over time. This gradual loss of radioactivity is measured in half-lives.
- **Law of Radioactive Decay:**
 - In any radioactive sample, which undergoes α , β or γ -decay, it is found that the number of nuclei undergoing the decay per unit time is proportional to the total number of nuclei in the sample. If N is the number of nuclei in the sample and ΔN undergo decay in time Δt then
 - $\Delta N / \Delta t \propto N$
or, $\Delta N / \Delta t = \lambda N$
- The **activity of a radioactive nucleus** (the rate of decay with time) can be described by the following equation:

$$A = \frac{dN}{dt} = -\lambda N$$

where λ is the 'decay' constant of the process in the equation.

- The **half-life** of a radioactive material is the time it takes one-half of the atoms of a radioisotope to decay by emitting radiation.
 $T_{1/2} = \frac{\ln 2}{\lambda}$ (note: $\ln 2=0.6931$)
 - The half-life of different elements can range from fractions of a second (for radon-220) to millions of years (for thorium 232).
 - **Note:** Half Life of Carbon-14 is **5,730** years.

15) RADIO-CARBON DATING

- Radiocarbon dating is a method by which age of an object is determined using radiocarbon, a name for the isotope Carbon-14.
- **How is Carbon-14 formed?**
 - It is created in the earth's atmosphere when cosmic rays – energetic streams of charged particles coming from sources in outer-space – slam into the atoms of the gases and release neutrons. When these neutrons interact with the nitrogen-14 nitrogen isotope, they can produce carbon-14. Since cosmic rays are constantly passing through earth's atmosphere, the carbon-14 is getting constantly created.
 - Carbon-14 readily combines with atmospheric oxygen to form radioactive CO₂ which enter the bodies of plants (during photosynthesis), animals (when they consume plants), and other biomass through the carbon cycle.
 - **Two key things which makes carbon-14 dating accurate:**

- The concentration of carbon-14 in the earth's atmosphere doesn't change across thousands of years. (if this wasn't true than radiocarbon dating – which dates organic materials by measuring the amount of carbon-14 they contain-wouldn't work).
- Carbon-14, in the form of carbondioxide and other carbon compounds, would have to be able to diffuse into the earth's various ecosystems such that the concentration of carbon-14 in the atmosphere was comparable to the concentration of carbon-14 in the planet's other biospheres.

- How does radiocarbon dating work?

- When an organism is alive, it constantly exchanges carbon with its surrounding by breathing, consuming food, defecating, shedding skin etc. Through these activities, carbon-14 is both lost and replenished in the body, so its concentration in the body is nearly constant and in equilibrium with its surrounding.
 - When the living organism dies, the C-14 is not replenished and it begins to reduce due to radioactive decay.
 - Radiocarbon dating dates an object by measuring amount of C-14 left, which scientists can use to calculate how long ago the body expired.
- Note: Since carbon-14 decays with a half-life of around 5,730 years, its presence can be used to date samples that are around 60 millennia old (i.e. 60,000 years old). Beyond that, the concentration of carbon-14 in the sample would have declined by more than 99%.

- Tools of Radiocarbon dating:

- Geiger Counter was used in 1940s when radiocarbon dating began. It consists of a Geiger-Muller tube connected to some electronics that interpret and display signals.
 - The Geiger-Muller tube contains a noble gas, such as helium or neon, and a rod passing through the centre. A high voltage is maintained between the tube's inner surface and the rod. The gas is insulating, so no current can pass between the two. But when energetic particles (including gamma radiation), such as those emitted during radioactive decay, pass through the gas, they can energize electrons in the gas's atoms and produce an electric discharge. The persistent voltage could also encourage these electrons to knock off electrons in more atoms, producing a bigger discharge (called the Townsend discharge). This electric signal is relayed to the electronics, where, say, a light may come on in response, indicating that radioactive decay is happening nearby.
- Today, more sophisticated devices are used. For e.g., one of the most sensitive dating setups uses accelerator mass spectrometry (AMS), which can work with organic samples as little as 50 mg.
 - Mass spectrometry is used to isolate ions that have the same mass-to-charge ratio. They begin with a sample – for e.g. a piece of bone – bombard it with electrons to ionize the atoms. Then they subject ions to different physical conditions that cause them to separate according to their mass-to-charge ratio.
 - For e.g. when deflected by electric or magnetic fields – Ions with different mass-to-charge ratios are deflected to different extents.

- **Impact of Radio-carbon dating on science and technology:** It was the first objective dating method to give numerical date to organic matter. Its impact on the field of archaeology and geology have come to be known as “**radiocarbon revolution**”

16) USE OF NUCLEAR RADIATION TECHNOLOGY FOR PROVIDING BETTER QUALITY OF LIFE TO ITS CITIZENS

1. Health: Care to Cure

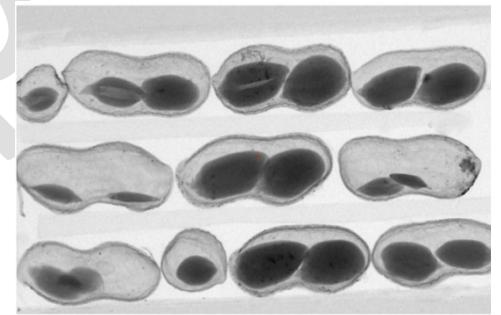
- Healthcare has grown into one of the most important peaceful uses of nuclear energy.
- **Nuclear Medicine - Diagnosis**
 - Radio pharmaceuticals can be administered by injection, inhalation, or orally and selectively localized and retained at sites of diseases. And thus, allow an image to be obtained of the loci using gamma scintigraphy or to deliver cytotoxic dose of radiation to specific disease sites without adversely affecting the surrounding normal tissues.
 - They help in identification of abnormalities in organ function even in early stages of a disease.
- **Radiation Therapy**
 - A treatment that involve use of high-energy radiation either by using special machines or from radioactive substance. The aim is to impart specific amount of radiation at tumours or parts of the body to destroy the malignant cells.
 - 1. **External Beam Radiation Therapy / teletherapy**
 - Radiation is delivered by using a machine outside the body.
 - A machine, either a ^{60}Co -teletherapy unit or linear accelerator is used
 - It can be used to treat Breast Cancer, Bowel Cancer, Head and Neck Cancer and Lung Cancer.
 - **Bhabatron** is a teletherapy machine developed by BARC and has been installed in 50 cancer hospitals.
 - It is cheaper than any imported telecobalt machine.
 - 2. **Internal Radiation Therapy or brachytherapy**
 - Radioactive material is placed in the body near cancer cells.
 - It makes it possible to treat a cancer with a larger dose of radiation that can't be given with external beam radiation therapy.

- Tiny titanium encapsulated Iodine-125 seeds have been developed by BARC and have provided an avenue to treat eye cancer.
2. **Food Security (1. Nuclear Agriculture 2. Food Preservation 3. Assessing the quality of output)**
- Use of ionizing radiation based technologies provide **safe hygienic and economically viable** solutions to address issue of agricultural productivity
1. **Nuclear Agriculture**
- Ionizing radiation is being used by BARC to induce mutation in plant breeding, and 42 varieties of different crops have been released to Indian farmers for commercial cultivation in the country.
 - e.g. groundnuts, mungbean, blackgram, pigeon pea, cowpea, mustard etc.
 - Advantages
 - Higher yield
 - Earliness
 - Large seed size
 - Resistance to biotic and abiotic stress
2. **Food Preservation - Produce and Preserve**
- Almost 30% of the food produced in India is lost due to spoilage because of pest attack, contamination and moulds infestation. These are encountered both during harvesting as well as post-harvest handling storage of the edible and cash crops.
 - **Limitation of using pesticides**
 - Health hazards
 - Disturbance to ecology
 - Development of resistance in pest
 - **Radiation Processing** can provide a viable, effective, and eco-friendly alternative to chemical fumigants and microbial decontamination, as the latter affect human health and environment adversely.
 - There is an utmost need to adopt and integrate the irradiated foods into the country's supply chains and promote the widespread use of this technology to ensure food safety and security.
 - **Advantages of using radiation processing**

- Disinfestation of insects, pests in cereals, pulses and grain.
- Microbial decontamination (hygienization) of dry species etc. for preservation/shelf life extension by applying pre-determined radiation doses.
- Increasing the exportability of Indian food produce.
- Elimination of parasites and pathogens of public health importance in food
- Delay in ripening and senescence in fruits and vegetables
- Inhibition of sprouting in tubers, bulbs and rhizomes
- **Radiation in no ways make production radioactive.**
 - Radiation therapy has been approved by WHO, IAEA, WTO, FSSAI etc.
 - As per the Department of Atomic Energy, as of Dec 2022, there are 25 irradiation facilities operational in the country in private, semi-government and government sector for food preservation.

3. X-Rays to assess the quality of food crops:

- Portable X-Ray imaging system can be very useful in grain value chains where the time needed to assess the economic value of grain by threshing or milling is a significant barrier.
 - » For e.g., a team comprised of scientists from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad and the Fraunhofer Development Center for X-Ray Technology (EZRT) in Erlangen, Germany have for the first time used x-Ray radiography to determine key market-related traits of peanuts while still inside the hull. (Sep 2022)
- X-Ray Radiography has the potential to be the right technology for in-field evaluation of farmers' produce which the International Committee for Food Value and Safety calls for.



3. Energy Security - Nuclear is Clean and Green

4. Societal Application: Sludge Hygenisation - from waste to wealth

5. Hydrogel - Healing the wound

- The process was developed by BARC scientists and technologically has been transferred for commercial purpose.

- Hydrogel is a thin transparent sheet of gel and is an excellent medical tool particularly useful for burn and injury dressings.
- **Production**
 - It is prepared by cross linking molecules of hydrophilic polymers like PVA either chemically or by Gamma/Electron beam irradiation.
 - A 3D network of gel like structure is formed which holds large quantities of water. Gamma Irradiation achieves gel formation and sterilization in one step.

6. Water Resources

1. Isotope Hydrology techniques
2. Measuring contaminants in water

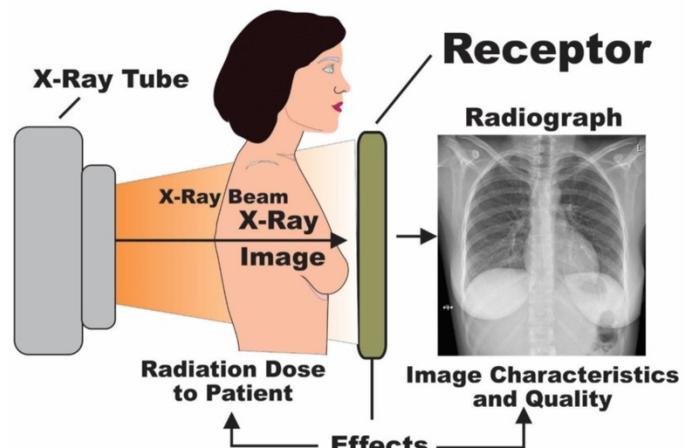
7. Industrial Applications

1. Radiation Sterilization of Medical Products
2. Radiography

- Radioisotopes which emit gamma rays are more portable than x-ray machines, and may give higher-energy radiation, which can be used to check welds of new gas and oil pipeline systems, with the radioactive source being placed inside the pipe and the film outside the weld.
- Radiography can also be used to gauge the thickness and density of materials or locate components that are not visible to other means.

1) X-RAY RADIOGRAPHY

- **X-Ray Radiography:** X-Ray radiography uses very small amount of ionizing radiation to produce pictures of the body's internal structure. These are amongst the oldest and most frequently used form of medical imaging. They are often used to help diagnosed fractured bones, look for injury or infection and to locate foreign objects in soft tissues.
 - » **How does it function?** During a radiographic procedure, an x-Ray beam is passed through the body. A portion of the X-Rays are absorbed or scattered by the internal



structures and remaining x-ray pattern is transmitted to a detector so that an image may be recorded for later evaluation.

- **Tomography:** It is any x-Ray technique in which shadows of superimposed structures are blurred out by moving x-Ray tube. Computational Tomography (also known as CAT Scanning), provides cross sectional imaging.
- **Details of Computerized Tomography (CT) Scan:** It combines a series of X-Ray images taken from different angles around your body and uses computational processing to create a cross-sectional image (slices) of the bones, blood vessels, and soft tissues inside your body. CT Scan can provide more detailed information than plain X-rays do.
- **Applications:** CT scan has many applications, but it is particularly suitable for quickly examining people who may have internal injuries from car accidents or other types of traumas.
- **Risks:** During a CT scan amount of radiation is greater than what you would get during a plain X-ray because the CT scan gathers more detailed information. The low doses of radiation in CT-Scan have not been shown to cause long-term harm, although at higher doses, there may be a small increase in your potential risk of cancer.

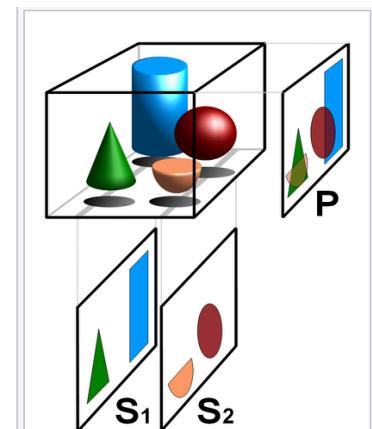


Fig.1: Basic principle of tomography: superposition free tomographic cross sections S_1 and S_2 compared with the (not tomographic) projected image P

A) CT SCANS ASSOCIATED WITH INCREASED RISK OF BLOOD CANCERS (DEC 2023: SOURCE – TH)

- **Radiation doses** at moderate (over 100 mGy) to high (over 1 Gy) values are known to cause hematological malignancies (blood cancers) in both children and adults and other cancers. However, there is uncertainty about risk at low doses (less than 100 mGy) that are typically associated with diagnostic CT examinations. A recent study published in Nature Medicine, (Nov 2023) suggests that even low doses of radiation have a small probability to cause blood cancer.
- **Analysis:** The results strengthened the body of evidence of increased cancer risk at low radiation doses and highlight the need for continued justification of pediatric CT examinations and optimization of doses.
- **Note:** gray (Gy) is the unit of ionizing radiation dose in the International System of Units (SI), defined as the absorption of one joule of radiation per Kg of matter. It measures the energy deposited by ionizing radiation in a unit mass of matter being irradiate and is used for measuring the delivered dose in radiotherapy, food irradiation, and radiation sterilization.

3. PYQS

1	In which one of the following areas did the Indira Gandhi Centre for Atomic Research make significant progress in the year 2005? [Prelims 2006] (a) Reprocessing the uranium-plutonium mixed carbide fuel of the Fast Breeder Test Reactor (b) New applications of radioisotopes in metallurgy (c) A new technology for the production of heavy water (d) A new technology for high level nuclear waste management
2	In which one of the following locations is the ITER project to be built? [Prelims 2008] A. Northern Spain B. Southern France C. Eastern Germany D. Southern Italy
3	To meet its rapidly growing energy demand, some opine that India should pursue research and development on thorium as the future fuel of nuclear energy. In this context, what advantage does thorium has over Uranium? [Prelims 2012] 1. Thorium is far more abundant in nature than Uranium. 2. On the basis of per unit mass of mined mineral, thorium can generate more energy compared to natural Uranium. 3. Thorium produces less harmful waste compared to Uranium. Which of the statements given above is/are correct? A. 1 only B. 2 and 3 only C. 1 and 3 only D. 1, 2 and 3
4	India is an important member of the ' International Thermonuclear Reactor '. If this experiment succeeds, what is the immediate advantage of India? [Prelims 2016] A. It can use thorium in place of Uranium for power generation. B. It can attain global role in satellite navigation. C. It can drastically improve the efficiency of its fission reactors in power generation. D. It can build fusion reactors for power generation.
5	In India, why are some of the nuclear reactors kept under "IAEA Safeguards" while other are not? [Prelims 2020] (a) Some use uranium and others use thorium (b) Some use imported uranium and others use domestic supplies (c) Some are operated by foreign enterprises and others are operated by domestic enterprises (d) Some are state owned, and others are privately owned



TARGET PRELIMS 2024

BOOKLET-4; S&T-4

COMPUTER, IT: AI, ML, CHATGPT ETC.

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By Abhishek Inamdar
M.Sc. Mathematics, BITS Pilani

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2. ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

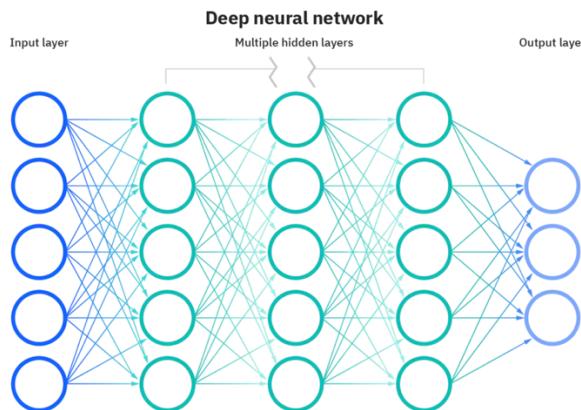
- » Intro
 - Artificial Intelligence is the science and engineering of making intelligent machines, especially intelligent computer programs which can complete tasks that typically require human intelligence.
 - » With the **explosion of available data and expansion of computing capacity**, the world is witnessing rapid advancements in AI, ML, and deep learning.
 - Machine learning is a science that involves **development of self-learning algorithms**. Machine learning uses statistics (mostly inferential statistics) to develop self-learning algorithm. It is a type of artificial intelligence.
 - » **Note:** All Machine Learning is AI, but not all AI is machine learning
 - » For e.g., symbolic logic (rules engines, expert systems, and knowledge graphs) as well as evolutionary algorithms and Bayesian statistics could all be described as AI, and none of them are machine learning.
 - » In Machine Learning the computer program should learn from experience "i.e., given data" such that the overall performance on doing a certain task increase.
 - i. Input data
 - ii. Model Training
 - iii. Output
- Applications of Artificial Intelligence and Machine Learning
 - Advertisements, Online shopping suggestions etc.
 - Spam filtering
 - Search engines
 - Fighting Black Money (e.g., Project Insight of India)
 - Space Exploration (e.g., identifying exoplanets from pictures)
 - Health Sector:
 - **Diagnosis:** E.g., a Bengaluru based startup has developed a non-invasive, AI-enabled technology to screen for early signs of breast cancer.
 - **Treatment:** AI powered Clinical Decision Support (CDS) tools can aid in developing appropriate and accurate diagnostic and treatment recommendations. E.g. Apollo hospital has launched Apollo Clinical Intelligence Engine, a CDS, open to use by all Indian doctors.
 - **Supply chain resilience:** By accurately predicting the demand and supply for medicines.
 - **Development of new Medicines/Molecules** – For e.g. AI can help in identifying and studying new molecules.
 - **Improvement in Governance:** E.g. For **COVID-19**, AI enabled chatbot was used by MyGov for ensuring communications.
 - Developing new materials (E.g. Google Deepmind predicted the structures of 2 million new materials)
 - Education (e.g., Personalized learning through adaptive tools; customizing professional development courses etc.)
 - Agriculture Sector:

- Tech like image recognition, drones etc can help farmers kill weeds more effectively to increase productivity.
- **Efficient resource utilization** – AI enabled solution for water management crop insurance etc are also being developed.
- **AI Powered decision making:** For e.g: ICRISAT has developed an **AI-power sowing app**, which utilises weather models and data on local crop yield and rainfall to predict and advise local farmers on when they should plant their seeds more accurately.
- **AI4AI (AI for Agriculture Innovation)** initiative has been launched by the WEF to transform agriculture sector in India. Under this, 'Saagu-Baagu' initiative has been launched in the state of Telangana.
 - **Disaster Management:** An AI-based flood forecasting system has been deployed in Bihar and is now being deployed throughout the country. It gives warnings 48 hours earlier about impending floods.
 - **Improve Ease of Doing Business**
 - Natural Language Processing (NLP)
 - Image Processing (Facial Recognition)

1) ADVANCEMENTS IN MACHINE LEARNING

A) NEURAL NETWORKS

- Neural network, also known as Artificial Neural Network (ANNs) or simulated neural networks (SNNs), are a subset of machine learning and are at the heart of deep learning algorithms. Their name and structure are inspired by the human brain, mimicking the way biological neurons signal to each other.
- A neural network can fine tune its output based on the feedback given to it during stages of training.
- ANNs consist of node layers, containing an input layer, one or more hidden layers, and an output layer. Each node, or artificial neurons, connects to another and has an associated weight and threshold. If the output of any individual node is above the specified threshold value, that node is activated, sending data to the next layer of the network. Otherwise, no data is passed along the next layer of the network.



- **Note:** ANN also rely on training data to learn and improve their accuracy over time.

- **Neural Networks vs. Deep Learning:**
 - Terms are sometimes used interchangeably. ‘Deep’ in deep learning is just referring to the depth of layers in a neural network. A neural network that consists of more than three layers – which would be inclusive of the inputs and output – can be considered a deep learning algorithm. A neural network that only has two or three layers is just a basic neural network.

B) DEEP LEARNING

- Deep learning is a machine learning technique that teaches computers to do what comes naturally to humans: learn by example. In deep learning, a computer model learns to perform classification tasks directly from images, text, or sound. It can achieve state of art accuracy, sometimes exceeding human-level performance. Models are trained by using a large set of labeled data and neural network architecture that contain many layers.
 - Most deep learning methods use neural network architecture, which is why deep learning models are often referred as Deep Neural networks. The term deep usually refers to number of hidden layers in the neural network.
- » Some Criticism of AI
- Idea of intelligent machines is obscene anti human and immoral.
 - Would make life more mechanical.
 - A lot of investment has taken place -> many AI companies going bankrupt
 - Taking away the human jobs

C) GENERATIVE ARTIFICATION INTELLIGENCE LIKE CHATGPT (CHAT GENERATIVE PRE-TRAINED TRANSFORMER)

ABOUT CHATGPT:

It is an AI tool developed by OpenAI.

OpenAI is a research institution and company that focuses on developing AI intelligence technology in a responsible and safe way. It was founded in 2015 by a group of entrepreneurs and researchers, including **Elon Musk, Sam Altman, and Greg Brockman**.

- ChatGPT is based on Generative Pre-trained Transformer Architecture.
 - It is trained on massive amount of text data from the internet. It used 570 GB of text data mined from the internet.
 - It is a type of neural network and was first introduced in 2017 in a paper titled “Attention is all you need”. A neural network can fine tune its output based on the feedback given to it during stages of training. This allows the model to better understand the context and meaning of the input and to generate conversational response.
 - Thus, we can say that ChatGPT is fine tuned to provide conversational responses, as against essay-type content. It is because the neural network behind it has been additionally trained on conversational transcripts with human feedback.

- But it is more than a chatbot. It can do tasks like writing software applications, new poems, stories etc.
- ChatGPT can become a powerful pedagogy tool on any topic to anyone, because we can instruct it to “explain it to me like I am a six-year-old”. It can explain in simple terms anything from philosophy to cooking recipes, including new recipes of its own.

It is a **Language Model** (rather than a chatbot) that can produce text that sound like human response in a conversation setting.

What is language model?

It is a software that prints out a sequence of words as output that are related to some words given as input with appropriate semantic relation. In practical terms, it means that it can perform tasks like answering questions and carrying on a conversation with humans. It is often used in Natural Language Processing (NLP) applications, such as speech recognition, automatic translation, and text generation.

It is also a **Neural Network**

It can be thought of as a large network of computers that can fine tune its output of words based on the feedback given to it during stages of training; this training process and the technology together are called **Reinforcement training**. The input data is typically huge corpus of text.

Another key idea of “Word embedding” has been used. It represents words as a matrix of numbers that can be manipulated inside computers. When a neural network processes these numbers, it can differentiate words according to different contexts: for example, when “shoot” appears with “gun” the neural network knows that the words that will follow may mostly be “bullets” or “victims”, whereas when “shoot” appears with “camera”, the neural network knows that the following words may be “picture” or “pixel”.

With a further refining technique called “Transformer”, a neural network can accurately understand the context of a sentence or a paragraph. This “comprehension” can be used for multiple purposes like answering a question, summarising a paragraph or an article, translating documents and so on.

GOOGLE BARD

Google’s Generative AI model

ABOUT GOOGLE GEMINI (DEC 2023)

- Google GEMINI is a new multimodal general AI model, which the tech giant calls its most powerful yet.
- It is now available to users through Bard, some developer platforms, and even the new Google Pixel 8 Pro phones.
- The flexible AI model comes in three sizes – Ultra (yet to be released), Pro, and Nano – is being seen as Google’s answer to ChatGPT, which has been ahead of the game so far when it comes to generative AI.

- Google claims that GEMINI Ultra is the first model to outperform human experts on massive multitask language understanding (MMLU), which uses a combination of 57 subjects such as math, physics, history, law, medicine, and ethics for testing both world knowledge and problem-solving abilities.
- So, IS GEMINI better than ChatGPT 4?
 - **Hard to say now.** But it does seem to be more flexible. Its ability to work with videos and on devices without internet, gives it some edge.
- **Some Concerns** about Generative AI:
 - **Teachers are unhappy about it** as they feel that it can be used to turn in plagiarized essays which could be hard to detect for invigilators. Recently, New York City's Education department banned ChatGPT in its public schools.
 - **Skilled white collar jobs** like that of computer programmers in the IT sector is at threat.
 - **India's IT services-based exports** may get impacted.

D) MULTIMODAL AI

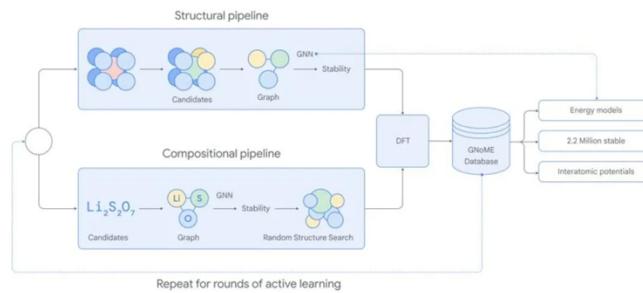
- **Definition:** Multimodal AI is a type of AI that can process and understand information from multiple types of sources like text, images, audio, and video. By integrating information from different sources, multimodal AI aims to enhance the system's ability to perceive and comprehend the world in a more holistic and human-like manner. It is like brain that can see, hear, and read all at the same time.
- **Advantages:** Multimodal AI can do several things which traditional AI can't:
 - **Understand the meaning of a video:** By combining audio and video, the multimodal AI will be able to tell you what is happening in the video, who the people are etc.
 - **Generate more realistic images:** This is because this AI will consider of things like lighting, shadows, reflections etc.
 - **Create more natural sounding speeches** – It is because the AI will be able to take into consideration the emotions and context of the conversation.
 - **Important areas where they can be used?**
 - **Processing CT scans or identifying rare genetic diseases** all need AI systems that can analyze complex datasets of images, and then respond in plain words.
- E.g. Gemini is Google's multimodal large language model.
- OpenAI is also reportedly working on a new project called **Gobi** which is expected to be a multimodal AI system from scratch, unlike GPT models.

E) GOOGLE DEEPMIND AI BREAKTHROUGH (NOV 2023)

- » **How are new materials discovered in Chemistry -> Trial and Errors -> Expensive and time-consuming process.**
- » **In last decades**, experimentation by humans has resulted in the discovery of the structures of some 28,000 stable materials, which are listed in the Inorganic Crystal Structure Database, the largest database of identified materials.

- » **What is DeepMind AI breakthrough?**
 - » Google DeepMind AI Tool known as **Graph Networks for Material Exploration (GNOME)** has successfully predicted the structures of more than **2 million new materials**. This was done with the help of AI.
 - » While these materials will still need to undergo the process of synthesis and testing, DeepMind has published a **list of 381,000 of the 2.2 million crystal structure that it predicts to be most stable**.

- » **How does GNOME actually work?**
 - » GNOME is a state of art **graph neural network model or GNN**, where the input data for the model takes the form of a graph that can be likened to connections between atoms.
 - » GNOME was **trained using active learning**, a technique to scale up a model first trained on a small, specialized dataset. Developers can then introduce new targets allowing machine learning to label new data with human assistance. This makes the algorithm well suited to the science of discovering new materials, which requires searching for patterns not found in original dataset.
 - » **GNOME** uses two pipelines to discover low energy (stable materials).
 - The **structure pipeline** creates candidates with structures similar to known crystals.
 - The **composition pipeline** follows a more randomized approach based on chemical formulas.
 - The output of both the pipelines are evaluated using established Density Function Theory (DFT) calculations and those results are added to the GNOME database, informing the next round of active learning.



- » **Significance:**
 - **Drastic increase in the number of 'stable materials' known to mankind by ten-fold.**
 - DeepMind claims its current research is equivalent to nearly 800 years of knowledge, given that 3,80,000 of its stable predictions are now publicly available to help researchers make further breakthrough in materials discovery teams.
 - **The breakthrough** has huge implications for sectors such as renewable energy, battery research, semiconductors, and computing efficiency which have been looking for new material to improve the efficiency in the sector.

F) PREDICTING PROTEIN STRUCTURE WITH AI

- The AI based program, **AlphaFold2**, from the company **DeepMind**, has stunned the world by accurately and quickly predicting the structure of proteins, starting from the sequence of amino acids that constitute them.

2) FACIAL RECOGNITION TECHNOLOGY (FRT)

- FRT is a type of biometric technology that identifies and verifies individuals by analysing and comparing patterns in their facial features.
- How does FRT Work?**
 - Data Acquisition:** It involves capturing a facial image or video of the person through cameras.
 - Feature Extraction:** In this phase, various features of the face is extracted (e.g. the distance between the two eyes, shape of the nose, width of the jaw etc.)
 - Feature Matching:** The extracted features are then matched with the database of existing pictures.
 - Identification or verification:** Based on feature matching, the FT technology identifies a person as someone in the database or verifies that the person is who he claims to be.
- Applications**
 - Security and Law Enforcement:** Criminals could be identified from the crowd.
 - Border Control:** FRT can be used to identify travelers at airports and border crossing.
 - Biometric Authentication:** For e.g. FRT can be used for unlocking of phones.
 - Marketing and Advertising:** FRT can be used to track users and user choices which can lead to better marketing
 - Social Media and Tagging:** Social media platforms use facial recognition for photo tagging and to enhance user experience.
- Concerns**
 - Excessive surveillance and violation of Privacy:** Widespread use of facial recognition could lead to mass surveillance and a loss of individual privacy. It may lead to unauthorized tracking, profiling, and potential misuse of personal data.
 - Technology challenges:**
 - FRT is prone to digital attacks or the use of physical or digital portraits, 3-D Models, such as deep-fakes etc.
 - Accuracy** concerns: Sometimes poor accuracy can lead to wrong authentication.

A) ASTR TOOL OF DOT

- why in news?**
 - Department of Telecommunication has developed an Artificial Intelligence-based facial recognition tool called **ASTR** (May 2023)
- About ASTR:**
 - Artificial Intelligence and Facial Recognition power Solution for Telecom Sim Subscriber Verification (ASTR)** can potentially bring down cyber frauds by detecting and blocking possible fraudulent mobile connections.
 - How does it function?**

- In 2021, DoT had ordered all telecom operators that they would have to share their subscriber database including users' pictures with the department. These images constitute the core database on which authorities are running their facial recognition algorithm using ASTR.
- **How ASTR Functions?**
 - Human faces in subscribers' images are encoded using Convolution neural network (CNN) models in order to account for the tilt and angle of the face, opaqueness and dark color or the images.
 - After that, a face comparison is carried out for each face against all faces in the database, and similar faces are grouped under one directory.
 - Two faces are concluded to be identical by ASTR if they match to the extent of at least 97.5%.
- The DoT allows an individual to take nine legitimate mobile phone connections using a single identity proof. In essence, what the ASTR does is -1) it looks up if there are more than nine connections against a single individual's photographs; 2) it runs a search through the database to see if the same person has taken SIMs under different names.
- **Results:**
 - According to the Ministry of Communication, an analysis of more than 87 crore mobile connections was carried out using ASTR in the first phase, where more than 40 lakh cases of people using a single photograph to obtain connections were detected. After "due verification", more than 36 lakh connections were discontinued.

B) DIGIYATRA: AIRPORTS USING FRT IN INDIA

- **What is DigiYatra?**
 - It is an initiative by GoI to make air travel and seamless and hassle free experience using digital technology. It envisages that travelers pass through various checkpoints at the airport through paperless and contactless processing, using facial features to establish their identity, which would be linked to the boarding pass.
- **How does it work?**
 - **Passenger Enrollment:** Passengers download the Digi Yatra app and link it to their Aadhaar card (a 12-digit unique ID). They can create a travel profile with their boarding pass and a self-image capture. These credentials are shared with airport authority.
 - **Facial Recognition:** At the airport, the passengers proceed to Digi Yatra Kiosk where their faces are scanned using a secure Facial Recognition tool. The system verifies the passenger's identity against their Aadhaar details stored in the app.
 - **Seamless Travel:** Once verified, passengers can simply walk through designated e-gates at various checkpoints without needing to show any physical document. The facial recognition system automatically grants them access.
- **Advantages:**
 - **Faster and smoother travel; Paperless travel.**
 - **Enhanced security**
 - **Data Privacy**
- **Who is running DigiYatra?**

- **DigiYatra Foundation:** It is a joint-venture company whose shareholders are the AAI (26%) and Bengaluru Airport, Delhi Airport, Hyderabad Airport, Mumbai Airport, and Cochin International Airport. These five shareholders equally hold the remaining 74% of the shares.

3) DEEPFAKES

- **Why in news?**
 - The Ministry of Electronics and Information Technology (MEITY) has sent an advisory to social media platforms on deepfakes (Dec 2023)
 - Earlier PM Modi had warned against Deepfakes calling on media to educate people on misinformation.
 - Following the controversy created by Deepfake videos of actress Rashmika Mandana and Katrina Kaif's deepfakes being circulated online, the GoI has asked social media companies to remove deepfake within 36 hours of a complaint being registered (Nov 2023)
- **Basics:** Deepfakes refer to manipulated media (audio, video, images etc) created using a form of Artificial intelligence called Deep Learning (or Deep Neural Network). This manipulated content uses lip syncing, swapping of face etc. – mostly without consent.
- **How does the Deepfake technology work?**
 - The technology involves modifying or creating images or videos using a machine learning technique called **Generative Adversarial Network (GAN)**. The AI driven software detects and learns the subjects' movements and facial expressions from the source material and then duplicates this in another video or image.
 - Larger the source material used, better will be the quality of deepfake. Therefore, highest number of deepfakes are made of public figures like politicians and film stars.
 - Through a collaborative work of two softwares, the fake video is rendered until the second software package can no longer detect the forgery. This is known as "unsupervised learning" when machine language models teach themselves. The method makes it difficult for other software to identify deepfakes.
- **Advantages:**
 - Synthetic Media/ Deepfakes can create possibilities and opportunities for all people, regardless of how people listen, speak, or communicate. It can give people voice, purpose, and ability to make an impact at scale and with speed.
 - It has been used by the ALS association in collaboration with a company to use voice cloning technology to help people with ALS digitally recreate their voices in future.
- **Concerns:**
 - Like most new technologies, it can also be weaponized to inflict harm to individuals, institutions, businesses or a country.
 - Crime against women can increase with malicious use of Deepfakes in pornography and can inflict emotional, reputational and in some cases violent outcome for some individuals. (for e.g. viral deepfake video of actress Rashmika Mandana incident)
 - **Endanger Social Harmony** – Communal/caste-based statements.

- Decrease trust towards institutions like government/media – by propagating false propaganda against them.
- **Undermine democracy and impair diplomacy** – false information about institutions, public policy, and politicians powered by a Deepfakes can be exploited to spin the story and manipulate belief.
- How to spot/identify a deepfake?
 - Look for unnatural blinking or lack of it.
 - **Lighting** that just don't sit right.
 - Sometimes, voice could be too robotic.
 - If the video sounds too sensational to be true, trust your gut.
 - Voices that miss the mark on lip synchronization
- Meity has sent another advisory to social media firms to comply with Information Technology (Intermediary Guidelines and Digital Media Ethics Code) Rules, 2021 (Dec 2023)
 - The advisory was aimed at getting social media firms to crack down more forcefully on 'deepfake' clips of people.
 - It mandates that intermediaries communicate prohibited content, particularly those specified under Rule 3(1)(b) of the IT Rules, clearly and precisely to users.
- Recent Advisory released by Ministry of electronics and Information Technology (Nov 2023)
 - IT Rules, 2021 require that all content reported to be fake or produced using deepfake be taken down by intermediary platforms within 36 hours.
 - An advisory was sent to social media platforms in Nov 2023, reminding them that they may lose "safe harbour immunity" under the IT Act, if they fail to remove within 36 hours deepfake content that has been reported.

A) HOW VOICE CLONING THROUGH ARTIFICIAL INTELLIGENCE IS BEING USED FOR SCAMS (JAN 2024)

- Famous Examples:
 - » In April 2023, a family living in Arizona, USA, was threatened to pay ransom for a fake kidnapping pulled off by an AI cloned voice.
 - » In Dec 2023, a Lucknow resident was duped to transfer a substantial amount through UPI.
- India:
 - » A report, titled 'The Artificial Imposter' published in May 2023, revealed that 47% of surveyed Indians have either been a victim or knew someone who had fallen prey to an AI generated voice scam. Thus, numbers are almost twice the global average of 25%.
 - » In fact, India topped the list with the maximum number of victims to AI voice scams.
- How are voice clones done?
 - » Once a scammer finds an audio clip of an individual, there are host of online sites / applications like Murf, Resemble, and Speechify which can be used to generate voice clones.
- Various real time translation tools are also available:

- » For e.g. recently Meta released **SeamlessM4T**, an open-source multilingual foundational model that can understand nearly 100 languages from speech or text and generate translation in real-time.
- » Apple introduced a voice cloning feature in **iOS 7** intended to help people who may be in danger of losing their voice say to degenerative diseases.
- » On 2nd of Jan 2024, MIT and Tsinghua University in Beijing, China, and members of AI Startup MyShell released **OpenVoice**, an open-source voice cloning tool that is almost instant and offers granular controls to modify one's voice that isn't found on other such platforms.

4) GPAI (THE GLOBAL PARTNERSHIP ON ARTIFICIAL INTELLIGENCE)

- **Why in news?**
 - » Global Partnership on AI (GPAI) members unanimously adopt New Delhi Declaration on AI (Dec 2023)
- GPAI is an **international and multi-stakeholder initiative** to guide the **responsible development and use of AI**, grounded in human rights, inclusion, diversity, innovation, and economic growth.
 - » This is also a first initiative of its type for evolving better understanding of the challenges and opportunities around AI using the experience and diversity of participating countries.
 - » GPAI was first proposed by Canada and France in 2018 G7 summit, and was officially launched in June 2020 with 15 members (including India)
 - » **Currently** (as of Dec 2023), it consists of 29 members (28 countries and EU).
 - **China**, a major techpower is not a part of the grouping.
 - » It is supported by a Secretariat hosted by OECD, Paris.
- **Dec 2023 Meeting:**
 - » India hosted the summit and will also chair GPAI in 2024.
 - » This summit was important as it was the first summit after the explosive release of ChatGPT.
 - » The GPAI has unanimously adopted 'New Delhi Declaration'.
 - » **Key Highlights of the New Delhi Declaration:**
 - It underscores the need to mitigate risks arising from the development and deployment of AI systems. It flagged concerns emanating from such systems including misinformation, unemployment, lack of transparency, and fairness, protection of IP and personal data and threat to human rights and democratic values.
 - It also promotes equitable access to critical resources for AI innovation including computing and high quality diverse data sets.
 - It also fosters inclusivity so that countries outside the purview of GPAI can also reap AI benefits.
 - It also says that global framework for the use of AI should be rooted in democratic values and human rights; safeguarding dignity and well-being; ensuring personal data protection; the protection of IPR etc.
 - Members also agreed to support AI innovation in the agriculture sector as a new 'thematic priority'. Earlier GPAI themes include healthcare, climate action and building resilient society.

A) AI SAFETY SUMMIT AND BLETCHLEY DECLARATION (NOV 2023)

- **AI Safety Summit, 2023**
 - » AI Safety summit was an international conference discussing the safety and regulation of AI. It was held in the UK at Bletchley Park on 1st and 2nd Nov 2023.
 - » It was the first ever global summit on AI which is planned to become a recurring event.
 - » **27 countries** from across the globe including the US, the UK, China, Australia, and India, as well as EU, agreed on Bletchley Declaration on AI Safety.
- **Key Highlights: Bletchley Declaration**
 - » It aims to enhance global cooperation on (AI) safety.
 - » It has a twofold focus:
 1. **Identifying** shared AI-related risks and enhancing scientific understanding of these risks
 2. **Creating cross country policies** to address these risks.
 - » **Definition of Frontier AI:** Frontier AI refers to highly advanced generative AI models with potentially dangerous capabilities that can pose significant risk to public safety.
- **About Bletchley Park:** This is a site of historic importance in computing.
 - During WW-II, it played an important role in breaking the 'unbreakable' Enigma Code which was used by Nazis.
 - It also contributed to the development of the Colossus – often considered the world's first programmable electronic computer.

5) REGULATING ARTIFICIAL INTELLIGENCE

- **Why in news?**
 - » EU has reached a landmark agreement to regulate AI (Dec 2023)
- **Need of Regulating AI:**
 - » **Controlling Big-Techs:** Most of the advanced development in AI is taking place in the Big-Technology companies like Microsoft, Google, Meta etc who have access to immense data and computing power.
 - » **Controlling Misuse:** Frontier AI has led to increase in the risk of deepfakes, harmful information, and cyber frauds.
 - » **Negative impact on economy:** AI may pose a threat to jobs and inclusive development in future.
 - » **Preventing violations of Privacy, IPR etc.**
 - » **Model Collapse Scenario:** ML models train on Data sets. But AI generated Data sets may create discrepancies and incorporate mistakes of previous AI models.
- **EU has adopted the world's first law on regulating AI** in Dec 2023.
 - » The EU Parliament will now vote on the proposed act early next year (i.e. in 2024), but with the deal done, it's just a formality.
- **What does the EU law propose?**
 - » The law regulates the use of Artificial Intelligence (AI).
 - » It classifies AI systems in four categories based on the associated risks and provides for different level of regulation for each category.

- » It includes safeguards on the use of AI within the EU, including clear guardrails on its adoption by law enforcement agencies.
 1. The deal includes strong restrictions on facial recognition technology, and on Using AI to manipulate human behaviour.
 2. Government can only use real-time biometric surveillance in public areas only when there are serious threats involved, such as terrorist attacks.
- » **Provision for strong penalties:** The deal threatens stiff financial penalties for violations of up to 35 million euros or 7% of a company's global turnover.
- » **Consumers** have been empowered to launch complaints against any perceived violations.
- » The legislation also proposes to be "a launch pad for EU start-ups and researchers to lead the global AI race".
 1. The act works as a unique legal framework for the development of AI you can trust. It will help in development of technology which doesn't threaten people's safety and rights.

- **Significance:**

- » Strong and Comprehensive rules in EU can set a powerful example for many governments considering regulations.
- » **AI Companies** who follow these regulations in EU are also expected to extend some of these protections in other jurisdictions.

- **Comparing EU's approach with other regulations:**

- » EU has taken a tougher stance which segregates AI as per use case scenario based primarily on the degree of invasiveness and risk;
- » UK has seen regulation on the other end of the spectrum with a 'light-touch' approach that aims to foster innovation in this nascent field.
- » USA's approach lies in between that of EU and UK.

- **Leadership in tech regulation:**

- » Over the last decade, Europe has taken decisive lead over the US on tech regulation.
 1. EU has enforced the landmark **GDPR (General Data Protection Regulation)** since May 2018. It is an overarching law focused on privacy and requires individuals to give explicit consent before their data can be processed and is now a template being used by over 100 countries.
 2. EU has also passed a pair of sub-legislations – the **Digital Services Act (DSA)** and the **Digital Markets Act (DMA)**. These take off from GDPR's overarching focus on the individual's right over her data.
 - a. DSA focuses on issues like hate speech, counterfeit goods etc.
 - b. DMA has defined a new category of "dominant gatekeeper" platforms and is focused on non-competitive practices and abuse of dominance by these players.
- » On AI, though, the US has made an attempt to take a lead by way of the new White House Executive Order on AI, which is being offered as an elaborate template that could act as a blueprint for every other country looking to regulate AI. In Oct 2022, USA released a blueprint on an **AI Bill of Rights** – seen as a building block for the subsequent executive order.

A) AI REGULATION EFFORTS IN INDIA

- GoI plans to bring a Digital India Act to regulate AI.

- NITI Aayog has already released National Strategy on Artificial Intelligence which focuses on Responsible AI for all.

LevelupIAS



TARGET PRELIMS 2024

BOOKLET-5; S&T-5

COMPUTER & IT - 2

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2. SUPERCOMPUTERS

- A supercomputer is a computer with a high-level computational capacity compared to a general-purpose computer or Supercomputer is a computer with great speed and memory. They are usually thousands of time faster than ordinary personal computers made at that time.
- As per the 62nd edition of TOP500 released in Nov 2023, following are the most powerful supercomputers currently:
 - » **USA's Frontier** is the most powerful supercomputer in the world reaching 1194 petaflops (1.194 Exaflops)
 - » **USA's Aurora system** is at 2nd spot with a capacity of 585.34 PFlop/s.
 - **Note:** Aurora is currently being commissioned and will reportedly exceed Frontier with a peak performance of 2 EFlops/s when finished.
 - » **Eagle** (installed in the Microsoft Azure Cloud in the USA), is at 3rd Spot. This is the highest rank a cloud system has ever achieved. It has the capacity of 561.2 PFlop/s.
 - » **Fugaku (of Japan)** is now ranked 4th (it was ranked second till July 2023 and ranked one till Nov 2021). Its capacity is that of 441.02 PFlop/s.
 - » **LUMI (of European Union, Finland)** is ranked 5th with a capacity of 379.70 PFlops.
- **Uses:** Super computers are generally used for scientific and engineering applications that must handle very large databases or do a great amount of computation (or both). Some of the key areas where supercomputers contribute are:
 - » Weather forecasting
 - » Climate research (E.g. Pratyush at IITM, Pune)
 - » Code-breaking
 - » Genetic analysis
 - » Oil and gas exploration – Seismic processing in the oil industry: Supercomputers help to detect and accelerate deeper geological insights.
 - » Molecular modelling
 - » Other jobs that need many calculations including engineering, product design, complex supply chain optimization (actually any kind of optimization), Bitcoin mining etc.

1) SUPERCOMPUTING IN INDIA

- In India, Indigenous development of Supercomputers began in 1980s. India's first Supercomputer was Param 8,000 which was created in 1991.
- Currently, as per the 62nd edition of TOP500 released in Nov 2023, the most powerful supercomputer in India is **AIRAWAT – PSAI** which is ranked 75 with a total capacity of 13.17 Petaflops. Thus in **terms of supercomputing power** India is way behind the world leaders.

A) AIRAWAT – PSAI

- C-DAC has implemented AI Research Analytics and Knowledge Dissemination Platform (AIRAWAT) of 200 AI Petaflops at C-DAC, Pune under the initiative of Ministry of Electronics and IT, GoI.
- C-DAC has designed and commissioned the converged HPC-AI dense GPU infrastructure integrated with the existing PARAM SIDDHI AI (PSAI) system to make the cumulative compute capacity of **410 AI PF (13.17 PF DP)**.

- The system is installed under the **National Program on AI** by GoI.
- **Note:** AI FLOPS refers to the floating-point operations per second **specifically dedicated to AI workload**. It refers to **FLOPS** required for training an AI Model.

B) OTHER IMPORTANT SUPERCOMPUTERS OF INDIA

- **Param Pravega** (3.3 Petaflops); setup under National Supercomputing Mission
- **Param Siddhi AI** (4.6 petaflops) (210 AI Petaflops); Setup under National Supercomputing Mission
- **Pratyush (IITM)** and **Mihir** (National Centre for Medium Range Weather Forecasting) (NCMRWF), Noida are other fast super computers in India.

C) NATIONAL SUPERCOMPUTING MISSION (NSM)

- A visionary program, launched in 2015, to enable India to leapfrog to the league of world class computing power nations.
- The mission is jointly steered by DST and MEITY.
- **Implemented by** Centre for Development of Advanced Computing (C-DAC); Indian Institute of Science (IISc), Bangalore.
- **Super Computing Grid:** The mission envisages empowering our national academic and R&D institutions spread over the country by installing a vast supercomputing grid comprising of more than 70 high performance computing facilities.
- **Human Resource:** The mission also includes development of highly professional High-Performance Computing (HPC) aware human resource for meeting challenges of manpower scarcity in the sector.
- **Recent Developments**
 - **BullSEQUANA Super Computer:** French Company **Atos** have signed an agreement with C-DAC (Centre for Development of Advanced Computing) for designing, building and installing BullSequana – the super computer in India
 - The supply of Bullsequana XH200 will be used for creating the network of 70 high performance computing facilities under NSM.
 - The total computing power of the Bullsequena will be greater than 10 petaflops.

3. QUANTUM COMPUTER

- **Basics:** How classical computers work:
 - » **Classical Computers** have bit as a fundamental unit which can be **0 or 1**. These computers take a series of bits (e.g., 11001100110101) and switch some of these bits to give us output. Here a bit must be processed in an exclusive binary state at any point of time i.e., either 0 or 1. The **millions of transistors and capacitors at the heart of the computer can only be in one state at any point**. There is a limit as to how quickly these devices can be made to switch state.
- Classical computers have enabled the information revolution that we are part of today. But these **classical computers can't do a number of things** including Optimization, Simulation of large molecules, factoring of large numbers etc.

- **But** Quantum computing may help us solve the above problems someday.
- **Quantum computers are based on the principle of quantum theory.** They gain enormous processing power due to the ability of quantum computer to perform task using all possible permutations simultaneously.
- **Quantum Computers** use **qubit** (Quantum bit). These qubits can take values 0 or 1 or any of the infinite **superpositions** between 0 and 1. When Qubits are in superposition, it has some probability of being in state 0 and some probability of being in state 1.
 - » **Qubits** are usually made of things like electrons, photons or even a nucleus. In case of electron spin up correspond to state 0 and spin down correspond to state 1.
 - » According to quantum law, the particle then enters a superposition of states, in which it behaves as if it were in both states simultaneously. Each qubit utilized could take a superposition of both 0 and 1. **Thus, the number of computations that a quantum computer could undertake is 2^n** , where n is the number of qubits used
 - » Quantum computing also borrows inspiration from another property of quantum mechanics called entanglement, wherein the two qubits could be connected in such a way that the state of one qubit intrinsically affects the state of the other qubit.
 - » Each operation of a quantum computation is performed by a **quantum gate**, which like classical gate, changes the state the qubits are in.
- **Quantum Supremacy:** It refers to quantum computers being able to solve a problem that a classical computer cannot. The term was coined by theoretical physicist John Preskill of the Caltech in 2012.
 - » **Google** recently used a 53 Qubit processor (Sycamore) to generate a sequence of millions of numbers, that conform to an algorithm generated by google. A classical supercomputer checked some of these values and they were correct.
 - » **Google's Quantum computer claimed 'Supremacy'** because it reportedly did the task in 200 seconds that would have apparently taken a supercomputer 10,000 years to complete.
- **Some Problems faced by Quantum Computing Sector:** While the above concept sounds promising, but there are still tremendous obstacles to be overcome.
 - » **Interference:** During the computation phase of a quantum calculation, the slightest disturbance in the quantum system (a stray photon or a wave of EM radiation) causes the quantum computation to collapse, a process known as **Quantum Decoherence**.
 - » **Error Corrections:** Because truly isolating the quantum system has proven so difficult, error correction systems for quantum computing have been developed.
 - » **Output observance:** Observing the final output also risks corrupting the data.
- **The breakthroughs in the last 20 year** including the **quantum supremacy** achieved by Google have increased the chances of developing practical quantum computing mechanisms. However, it is not clear whether the practical application is less than a decade away or a hundred years into the future.
- **Examples of Quantum Computers:** While the idea governing quantum computers have been around since the 1990s, the actual machines have been around since 2011, most notably built by Canadian company D-Wave systems.

- The recent Google's **53 qubit Quantum computer** is called **Sycamore**. Google is also spending billions and targets to build its own working quantum computer by 2029.
- **IBM** plans to have a 1,000-qubit quantum computer. For now, IBM allows the use of its machines by those research organization, institutions etc which are part of its quantum network.
- **Microsoft** also offers companies access to quantum technologies via its Azure Quantum Platform.

- **Applications:** The potential that this technology offers are attracting tremendous interest from both the governments and the private sector. The quantum computers have the potential to easily tackle computational problems that may be tough for the classical computer. The basic advantage is speed as it can stimulate several classical computers working in parallel.
 - **Military Applications** include breaking of advanced encryption using brute force searches.
 - **Advanced Cryptography:** Quantum uncertainties could be used to create private keys for encrypting messages to be sent from one place to another.
 - **Climate Change and Weather Forecasting**
 - **Faster Data analysis in industrial science applications** will enable faster solution to business problems in the era of big data.
 - » **Improved Optimization** for complex problems like NP-hard problems. This may lead to faster optimization of very large-scale problems involving complex network structures, computational biological science, and physical sciences.
 - » **Transform Healthcare and Medicine:** Drug Development and Discovery
 - » **Other civilian applications** include **DNA Modelling** and **complex material science analysis**.
 - » **Improved Machine Learning Outcomes** by enabling more efficient optimization of these algorithms so that ML capabilities become more efficient, accurate and fast.
 - » **Teleporting the information from one location to another** without physically transmitting the information. Entangling of quantum particles allow us to achieve this.

- **India and Quantum Computing:**
 - » There are no quantum computers in India yet.
 - » **Cabinet Approves Rs 6003 Crore National Quantum Mission** (April 2023)
 - » In **Budget 2020-21**, government has announced **National Mission on Quantum Technologies and Applications** which will be allocated Rs 8,000 crore over the next 5 years.
 - » Although the amount is low to begin with but given the advances in technology and India's ability to create low-cost solutions, the money may suffice.
 - » In Aug 2021, India launched **QSim** to aid Quantum Computing research in India.

1) NATIONAL QUANTUM COMPUTING MISSION (APRIL 2023)

- NQM, planned during 2023-2031, will mainly work towards strengthening India's research and development in the quantum arena alongside indigenously building quantum-based computers.
- It entails development of satellite-based quantum communication between ground station and receiver located 3,000 kms away during the first three year.
- For long distance communication, tests will be conducted in coming years.
- Under NQM, there would be four broad themes:
 - » Quantum Computing

- » Quantum Communication
 - » Quantum Sensing and Meteorology
 - » Quantum Material and Devices
- **Thematic hub for each will be established** at research institutes and R&D centres who are already working in the field of research.
 - **Department of S&T (DST)** will lead the mission, supported by other departments.
 - The mission puts India among the top six leading nations involved in the R&D in quantum technologies. Presently, R&D work in quantum tech is underway in USA, China, Canada, France, Finland and Australia.

2) QUANTUM ENTANGLEMENT

- » **What is quantum entanglement?**
 - Two particles, having ‘interacted’ with each other at some stage, were found to have got ‘entangled’ in a way that the behaviour of one produced an instantaneous reaction in the other even if the two were no longer connected in any way and were separated by large distances.
- » **2022 Nobel Prize in Physics** has gone to Alain Aspect (France), John F Clauser (USA) and Anton Zeilinger (Australia). These three scientists over the last four decades, have conclusively established that the ‘entanglement’ phenomenon observed in quantum particles was real, not a result of any ‘hidden’ or unknown forces, and that it could be utilized to make transformative technological advances in computing, hack-free communication, and science fiction like concept of ‘teleportation’.
- » **Details of their contribution:**
 - The first half of the 20th century, saw the development of Quantum Physics which explained the seemingly bizarre behaviour of sub-atomic particles with remarkable accuracy.
 - Quantum theory explained many phenomenon of quantum particles such as Superposition and Entanglement which were completely against everyday experience.
 - **Albert Einstein**, in particular was very uncomfortable with this. His Special theory of relativity prohibited any signal from travelling faster than the speed of light. The seemingly instantaneous communication due to entanglement went against Einstein’s theory. Therefore, Einstein proposed that something was missing and the Quantum theory was incomplete.
 - **However**, experimentalists were discovering that almost every prediction made by quantum theory were being obeyed by sub-atomic particles. Till, that time, experiment to test entanglement didn’t appear feasible.
 - **In 1964, John Bell** showed how phenomenon of entanglement could be established by experimentalists.
 - » The famous Bell’s inequality, if maintained in the results of the experiment, would mean that Einstein was right. If violated, it would provide the predictions of quantum theory.
 - **John Clauser** was the first person to set up an experiment to test entanglement. In 1972, his experiments produced results that were clear violations of Bell inequality

- Alain Aspect is credited with vastly improving the set-up of Clauser and removing all the loopholes critics had found. His experiments also produced results that violated Bell's inequality.
 - Anton Zeilinger meanwhile had already started using entanglement property to open up new technological possibilities. He demonstrated that it was possible to teleport the quantum states of particles to another location without the particle moving anywhere and without a medium.
 - These experiments conducted by Clauser, Aspect and Zeilinger have decisively demonstrated that entanglement was real and in accordance with quantum theory and it was not being driven by any hidden forces as suggested by Einstein and others.
- » The satisfactory theoretical explanation of phenomenon, however, continue to elude scientists.

Application: The entanglement property is now being utilized to build the next generation of computers called quantum computers which exploit the quantum behaviour of particles to overcome the challenges considered unsurmountable. It is also being used for quantum cryptography.

3) QUANTUM GATES: DEVICES THAT TRANSLATE QUANTUM EFFECTS TO COMPUTING AWESOMNESS

- A gate (in traditional computer) is a circuit that changes the states of bits in a predictable way. The speed with which the gate works determine how fast the computer is.
- Understanding the limitation of these gates:
 - » Modern computers use semiconductor transistors to build circuits that function as gates. A semiconductor chip hosts more than 100 million transistors on 1 sq mm.
 - » As transistors become smaller, they become more susceptible to quantum effects. This is not desirable as this will make existing technology unreliable for computational tasks. So, there is a limit to how many transistors a computer can have.
- A Quantum gate is a physical process or circuit that changes the state of qubit or a collection of qubit.
 - » In quantum computers, quantum gates act on qubits to process information. For e.g., a quantum NOT gate changes the state of qubit from 0 to 1 and vice versa.
 - » It can be an electromagnetic pulse which changes the state of qubit.

LOGIC FUNCTION	LOGIC SYMBOL	BOOLEAN EXPRESSION	TRUTH TABLE	
			INPUTS	OUTPUTS
AND		$A+B=Y$	B	A Y
			0 0	0
			0 1	0
			1 0	0
OR		$A+B=Y$	1 1	1
			0 0	0
			0 1	1
			1 0	1
inverter		$A=\bar{A}$	1 1	1
			0	1
			1	0
			0	1
NAND		$\overline{A+B}=Y$	0 1	1
			0 0	1
			1 1	0
			1 0	1
NOR		$\overline{A+B}=Y$	0 1	0
			0 0	0
			1 1	0
			1 1	0

4) QSIM – (CLASS DISCUSSION)



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4. CLOUD COMPUTING

- **Intro**
 - Cloud computing is a type of Internet-based computing that provides shared computer processing resources and data to computers and other devices on demand. It is a model for enabling ubiquitous, on-demand access to a shared pool of configurable computing resources which can be rapidly provisioned and released with minimal management efforts.
 - E.g.
 - Computer networks, Storage (OneDrive, Google Drive etc.), Servers, applications, and services
 - **Advantages** – Reduced upfront cost; focus on core business; Faster deployment of application; Scalability and Elasticity; pay as you Go model; Agility; Device and Location independence; Maintenance, Multitenancy, Performance and Better Security.
- » **Concerns**
- Loss of control over certain sensitive data
 - Limited customization options
 - E.g., a restaurant with a limited menu is cheaper than a personal chef who can cook anything you want.
- **Technology behind cloud:** There are two vital technologies at the heart of Cloud Computing:
 - **Virtualization:** It lets computer resource to be shared through multiple virtual machines.
 - **Network:** It lets data requests flow to and from the datacenters or the Cloud through the Internet.

In cloud computing hardware resources are distributed across multiple locations and there is diverse choice of software that is available to consumers.
 - **Service Models:** IaaS, PaaS, SaaS etc represent various cloud service models. They offer different levels of service and control.
 - **Infrastructure as service (IaaS)**
 - It provides on-demand access to fundamental resources like Virtual Machines, storage, networking, and servers.
 - These are online services that abstract the user from the details of infrastructure like physical computing resources, location, data partitioning, scaling, security, back up etc.
 - E.g. AWS, Microsoft Azure.
 - It is ideal for companies with strong technical team and need for high customization.
 - **Platform as Service (PaaS)**
 - The provider typically develops toolkit and standards for development and channels for distribution and payment.
 - In PaaS model, cloud providers deliver a computing platform, typically including operating system, programming-language, execution environment, database, and web server.
 - E.g. **Google App Engine**.
 - Software as a Service (SaaS)

- User gain access to application software and databases (e.g. Google Photos – In this consumer pays based on the giga-bytes that is required to store photos, Gmail etc.)
- Cloud providers manage the infrastructure and platforms that run the applications.

5. EDGE COMPUTING (CLASS DISCUSSION)

6. WEB BROWSERS: HOW DO THEY FUNCTION?

- **Why in news?**
 - » How do web browser work? (Dec 2023: Source - TH)
- **Definition:**
 - » A web browser is software that allows you to find and view websites on the Internet. They translate code into the dynamic webpage that forms the backbone of our online experience.
 - » **Different Browsers over the years:**
 - » In 1990, the English Computer Scientist Tim Berners-Lee introduced the concept of World Wide Web and with it came the first web browser, also known as WorldWideWeb.
 - » The next watershed moment was Mosaic browser in 1993. It was developed by US National Centre for Supercomputing Application. It introduced the concept of displaying images alongside text. It revolutionized our interaction with the web and made internet visually engaging.
 - » In 1994 came the Netscape Navigator and it became the most popular browser of its time. It brought features like bookmarks and user-friendly URL bar. It simplified the navigation and made the web more accessible.
 - » Late 1990s saw the period of the 'Browser Wars'. Microsoft's Internet Explorer (IE) and Netscape Navigator were the primarily contenders. This competition led to a lot of innovation in various browsers. But, by 2,000 IE emerged as undisputed leader mostly on the back of the success of Windows operating system which generally shipped with IE as default browser which most of the people used. But this monopoly also led to stagnation and lack of innovation.
 - » In 2004-05, this monopoly was broken with the arrival of Mozilla's Firefox. Firefox was developed by a community of volunteers and was based on open-source principles. It introduced groundbreaking features like tabbed browsing, and pop-up blocking. It also allowed users to extend their personal browsers with add-ons.
 - » In 2008, Google launched Chrome, which swiftly gained in popularity for its speed and minimalist design. It also revitalized the browser market and encouraged innovation across the board.
 - » Today, the most popular browsers are Google Chrome, Firefox, Microsoft's Edge and Apple's Safari.

- **How do Browsers work?**

Modern web browsers have multiple core components, each of which is a complex technology in itself.

A) Request and Response

- When you enter a website's address (in the form of Uniform Resource Locator (URL)) into your browser's address bar (or when you click a link), you set in motion a sequence of digital communication. The browser sends a request to a server, asking for the contents of the specific web browser you're interested in. This request travels through a network of servers, like dispatching a letter through a series of post offices. Upon reaching the server, the request is received and processed.
- The server then formulates a response containing the information (or data) required to construct the web pages. This response embarks on its journey back to your browser, carrying the digital blueprint for the page you requested.

B) Deconstructing The Response

- The response from the server is an amalgam of various files. Typically, these files have information encoded in three languages: HTML, CSS, and JavaScript. Each set of information plays a pivotal role in shaping the final presentation of the web page.
- **HTML (Hyper Text Markup Language)** provides the architectural blueprint of webpage. It defines structure of the webpage, outline elements like headings, paragraphs, images, and links. HTML is the foundation on which browser construct a visual layout.
- **CSS (Cascading Style Sheets)** imparts style and aesthetics to the HTML structure by controlling attributes like color schemes, fonts, spacing, and positioning. CSS ensures that webpages come with its unique identity.
- **JavaScript** is a dynamic engine, making webpages interactive and responsive. It allows interactive elements like pop-ups, forms, animations, and Realtime updates, creating an engaging user experience.

C) Rendering

- With HTML, CSS and JavaScript in hand, a browser begins the process of rendering. This involves deciphering the HTML to understand the structural arrangement, applying CSS for stylistic finesse, and executive JS to infuse interactivity.
- The process is remarkably swift, assembling the final webpage and presenting it to user in a cohesive and visually appealing manner in much less than a second, depending on the amount of data.
- **Rendering engines** are in themselves a key piece of technology that enables screens to display graphics.

D) Managing Data

- Browsers serve as adept custodians for your digital footprint, so they also implement instruments like **cookies** and **cache** to enhance your online experience.
- **Cookies** are small snippets of data stored on your computer by websites you visit. They retain information such as login status, site preference, and shopping cart content. This allows you to navigate seamlessly, without having to re-login to a site when you close and reopen it in a short span of time.
- **Cache** is a repository of frequently accessed files. When you revisit a webpage, the browser checks its cache to see if it already has a copy of the required files. If so, it retrieves them from the cache itself rather than re-downloading them from the server.

E) Security

- Web browsers use an array of security measures to protect your data as they fly between your computer to various servers, via the internet, and even when they're stored on your computer. They do this by using **encryption protocols**, such as **HTTPS**, to create secure tunnels for data exchange shielding the information from prying eyes.
- Browsers also use **warning systems** to alert you about potentially malicious websites, preventing inadvertent exposure to threats.

Future of Internet Browsers:

- As technology hurtles forward, web browsers evolve in tandem. They are **embracing new technologies** like **Web Assembly**, a format that **enables near-native performance** within the browser environment.
 - o **Note:** Web Assembly is a type of code that can run on modern webbrowsers – it is low-level assembly-like language with a **compact binary format** that runs with near native performance and provides languages such C/C++ with a compilation target so that they can run on web. It is also designed to run along JavaScript, allowing both to work together.
- **Support for VR and AR** experience is also on the horizon, promising immersive online interactions.
- **Privacy features** are being bolstered, providing users a greater control over their digital footprint.

7. INTERNET OF THINGS (IOT)

- Introduction

- IoT is a network of physical objects embedded with sensors, software, and other technologies for connecting and exchanging data with other devices and systems via the internet.
- A **thing** on the internet of Things, can be a **person with a heart monitor implant**, a **farm animal with a biochip transponder**, an **automobile with a built-in-sensors to alert the driver when tire pressure is low - or any other natural or manmade object that can be assigned an IP address and provided with the ability to transfer data over a network**.
- This is achieved by **sensors** and finally fabricated **micro-controllers**.
 - o Microcontrollers are **small computers themselves** and are used internally by various single board computers like Arduino and Raspberry Pi.
 - o **Sensors** are used to detect and collect information and **micro controllers to transport information**.
 - o Together, they can **make anything to a thing in IoT**.

- **Movement from IPV4 (32 bit address) to IPV6 (128 bit address)** also played a **role in making IoT possible**.

- Advantages

- **Reduce waste, loss, and cost** -> by early detection of problems and taking corrective steps
- We would know **what things needed replacing, repairing, or recalling** and whether they were fresh or past their best. This helps in increasing the **reliability** of a device.

- **Applications**
 - a. **Health Care Sector:** IoT can improve the reliability and performance of the life-critical system. For e.g., the IOT based devices can be used in combination with cardiac monitor to raise an alarm to the doctors in case of abnormality.
 - b. **Agriculture Sector:** IoT can be used to gather live pedological data that can be used by scientists to improve the yield of the land. It can also help in implementing **precision agriculture**.
 - c. **Transportation Sector:**
 - **Early detection of wear and tear** (preventing accidents)
 - Self-Driving Cars – will need IOT for real time decisions
 - Traffic Management – real time traffic data -> better traffic management.
 - d. **Energy Management**
 - Managing temperature in a Nuclear Power Plant (using sensors and IoT)
 - Real time efficiency analysis of Solar Power panels.
 - e. **Research and Development:**
 - E.g. – Recent development of wireless communication system for satellites by NASA through which Satellites can communicate with each other.
 - f. **Safety and Security**
 - Real time tracking of criminals – using tagging and IoT.
- **Some Limitations of IoT**
 - » **High Initial cost of set up** -> Since IoT is based on expensive sensors
 - » **Increased cyber security concerns** -> with increased number of devices connected to internet
 - » **Compatibility issues** -> due to lack of the international standardization on IoT devices.

8. INDUSTRIAL REVOLUTION 4.0

- The **First Industrial Revolution** used water and steam power to mechanize production.
- The **Second** used electric power to create mass production.
- The **Third** used electronics and information technology to automate production.
- Now a **Fourth Industrial Revolution is building on the Third**. It is characterized by a **fusion of technologies that is blurring the lines between the physical, digital, and biological spheres**.
 - It is characterized by integration of advanced technologies such as AI, IOT, Robotics, big data, and more into various industries and aspects of society.
 - It combines Machine to Machine Communication, Industrial Big Data Analytics technology, cyber security, and automation. It's driving new levels of efficiency and productivity.
- **Three reasons** why 4th IR is not merely a prolongation of the 3rd IR, but rather the arrival of a Fourth and distinct one: Velocity, Scope and Systems impact.
 - The **speed** of current breakthroughs has no historical precedent. The 4th Industrial Revolution is evolving at an exponential rather than a linear pace.
 - It is disrupting almost every industry in the country.
 - The breadth and depth of these changes herald the transformation of entire systems of production, management, and governance.

- **Need of Industry 4.0:**
 - » Impetus to next surge of growth
 - » Harness the potential of Big Data, AI etc in every field.
 - » Improve governance by using new age tech.

9. BIG DATA

- **Intro**
 - » Big Data is a collection of data that is huge in volume (petabytes and exabytes of data) yet growing exponentially with time. It is a data with so large size and complexity that none of the traditional data management tools can store or process it efficiently. Big Data can be structured, semi-structured and Unstructured. But they generally have potential to be mined for information.
 - » **Examples of Big Data:**
 - BSE which generates Gigabytes of data per day
 - Social media – Around 500+ terabytes of new data get ingested into the database of social media site Facebook every day.
 - Data from search engines (like Google, Bing etc.) and Online portals like Amazon.
- **Challenges** include capture, analysis, data curation, search, sharing, storage, transfer, visualization, querying, updating, and information privacy.
- Big data is **characterized by 3 Vs** – Volume, Velocity and Variety.
- **Advantages – Accuracy, Better Correlation**
- **Key areas where it can be used**
 - » Internet
 - » Finance
 - » Urban Informatics
 - » Business informatics
 - » Meteorology
 - » Genomics and healthcare
 - Find new cures, optimize treatment, and even predict diseases before any physical symptoms appear
 - » Complex physical simulations
 - » Environment research
 - » Improve the performance of Individuals
 - (At sports, at home or work), where data from wearable sensors in equipment and wearable devices can be combined with video analytics to get insights that traditionally were impossible to achieve)
 - » Security Agencies
 - To prevent cyber attack
 - Detect credit card frauds
 - Foil terrorism

- Even predict criminal activity
- » Improve our homes, cities, and countries
 - Optimizing heating and lighting in our homes
 - Optimizing traffic flow in our cities
 - Optimizing Energy Grid across the country
- **Relation between cloud computing and big data**
 - » Cloud computing is very important in BIG data analytics due to its application sharing and cost-effective properties

10. NET NEUTRALITY

- **Why in news?**
 - » 120+ startups have written to TRAI opposing Telecom Service Providers (TSPs) push for regulating over the top (OTT) services (Oct 2023)
- Net Neutrality (also network neutrality, internet neutrality or net equality) is the principle that ISPs and Governments should treat all data on the internet equally, not discriminating or charging differentially by user, content, site, platform, application, type of attached equipment, or mode of communication.
- The term was coined by Columbia University media law professor **Tim Wu** in 2003 as an extension of the long-standing concept of a common carrier.
- **Arguments for Net Neutrality**
 - » **Free Flow of Data**
 - » **User Intolerance for slow loading sites**
 - » **Competition and Innovation**
 - » **Preserving Internet Standards**
 - » The advocates also argue that authorizing network providers to override a transport and application layer separation on the internet would signal the decline of fundamental internet standards and international consensus authority.
 - » **Preventing Pseudo Services**
 - » **End to End Principle**
 - Network neutrality is needed in order to maintain the end-to-end principle. It is this simple but brilliant end to end aspect that has allowed the internet to act as a powerful force for economic and social good.
- **Arguments against Net Neutrality**
 - » **Financing Infrastructure Improvements**
 - » **Counterweight to server-side non-neutrality.**
 - » **May prevent overuse of bandwidth.**
 - » **May prevent access to useless websites.**
- **Net Neutrality in India:**

- » In 2016, TRAI banned **Free Basics service (Internet.Org)** in India based on "Prohibition of Discriminatory Tariffs for Data Services Regulations".
- » In Sep 2020, TRAI recommended the creation of a multi-stakeholder body (MSB) to ensure that Internet access providers adhere to the provisions of net neutrality. TRAI also said that the net neutrality principles adopted by DoT were technology neutral and would apply equally to 5G technology.

11. TOPICS TO BE COVERED IN FUTURE BOOKLETS

- Encryption/Decryption – Public Cryptography, Digital Signature
- Quantum Cryptography
- BlockChain – BitCoin- Other Crypto Currencies
- NFTs
- AR/VR/Meta Verse
- Web 3.0
- Wireless Communication (5G/6G), Bluetooth, WiFi, NFC, RFID etc.
- Optical Fiber Communication / FSOC
- Electronics – Basics
- Semiconductor manufacturing in India
- LED; (OLED) (PMOLED), Flexible LED Display
- LASER and other optoelectronics
- Wireless Charging
- 3D Printing
- BarCode / QR Code



TARGET PRELIMS 2024

BOOKLET-6; S&T-6

COMPUTER & IT - 3

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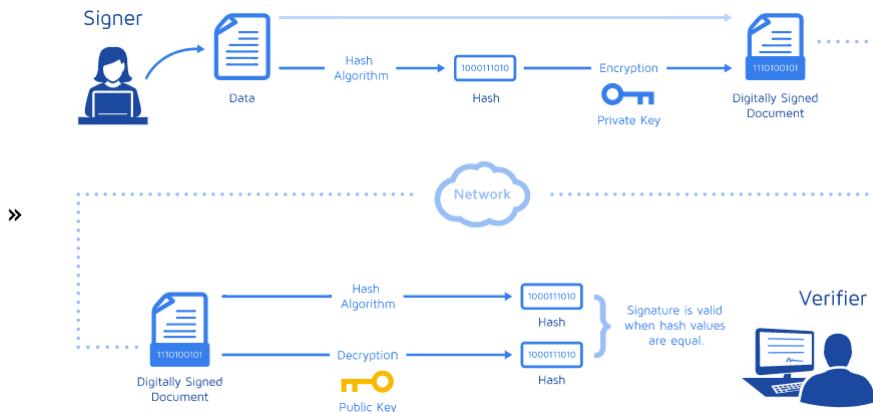
2. CRYPTOGRAPHY

- **Introduction**
 - » Encryption is conversion of electronic data into another form, called cipher text, which cannot be easily understood by anyone except authorized parties.
 - » **Key purpose:** Confidentiality, Authentication, Integrity and Non-Repudiation
- **Historical development**
 - » Spartans using stick of fixed diameter.
 - » **Symmetric Algorithms** (Same key for encryption and decryption)
 - Ceaser Shift cipher.
 - Polyalphabetic substitution -> which uses multiple substitute alphabets to limit the use of frequency analysis to crack a cipher.
 - Most famous example: Enigma electro-mechanic rotor cipher machine used by Germans during WW-2.
 - » All the above methods used the same key for encryption and decryption.
 - » **Limitations:** Requires secure channel for key transfer
 - » **Asymmetric Cryptography or Public Key Cryptography**
 - » It uses pairs of keys.
 - Public key that may be disseminated widely.
 - Private key which is known only to the owner.
 - » Public key algorithms, unlike symmetric key algorithms, do not require a secure channel for initial exchange of one (or more) secret keys between the parties.
 - » Famous examples: Digital Signature algorithm, RSA algorithm (based on the problem of factoring the product of two large prime numbers - the factoring problem), AES etc.
 - » **Where is Encryption used today?**
 - » Before coming of the Diffie-Hellman key exchange (public key algorithm) and RSA algorithm, governments and their armies were the only real users of encryption.
 - » Now, the broad use of encryption in **the commercial and consumer realms** to protect data both while it is being sent across a network (data in transit) and stored, such as on hard drive, smartphone, or flash drive.
 - » Other uses included uses in Modems, Set Top Boxes, Smart Cards, SIM Cards etc.

1) DIGITAL SIGNATURE

- Digital signature is a mathematical technique (cryptography mechanism) that is used to validate the authenticity and integrity of a message, software, and digital document.
- It offers security features like evidence of origin, identity, and Status of an electronic document, transaction or message and can thus acknowledge informed consent by a signer (i.e. nonrepudiation).
- **How Digital Signature Works?**
 - » It uses public key cryptography such as RSA. The individual who is generating the digital signature uses their own private key to encrypt signature-related data.

- » The only way to decrypt this data is with signer's public key. This is how signer's signatures are authenticated.
- **How to create digital signature?**
 - » To create a digital signature, signing software – such as an email program – creates a one-way hash of the electronic data to be signed. The private key is then used to encrypt the hash. The encrypted hash – along with other information, such as hashing algorithm is the digital signature.



- » **Note:** Digital signature technology requires all the parties to trust that the **individual creating the signature has been able to keep their own private keys secret**.
- **Uses of Digital Signature**
 - » **Government** publishes electronic versions of various **documents** such as budget, laws, bill etc. with digital signatures.
 - » **Various legal works** like processing tax returns, filing applications, verifying business to government transactions etc. use digital signature.
 - » Industries use the digital signature to **speed up the process**, including product design, quality assurance, manufacturing enhancements etc.

2) END TO END ENCRYPTION

- **Why in news?**
 - » The recent leaking of WhatsApp chats of several Bollywood celebrities has brought back questions around WhatsApp's privacy and security
- **Introduction**
 - » End to End Encryption (E2EE) is a method of secure communication that prevents third parties from accessing data while it's transferred from one end system or device to another.
 - » In E2EE, the data is encrypted on the senders' system or device and only recipient is able to decrypt it. Nobody in between, be they an Internet Service Provider, Application Service Provider, or hacker, can read or tamper with it.
 - » The cryptographic keys used to encrypt and decrypt the message are stored exclusively on the endpoints; a trick made possible through the use of public key encryption.
- **Whatsapp Encryption (started from April 2016)**
 - » **Step-1: Key Generation:** When you install Whatsapp, the app generates a pair of cryptographic key – a public key and private key.

- » **Step-2: Key Exchange:** When you communicate with someone, your device and recipient's device exchange each other's public key. The exchange happens automatically in the background using a secure Signal Protocol.
- » **Step-3: Message Encryption:** While sending a message, your device uses recipient's public key to encrypt so that only recipient will be able to decrypt. The encryption and decryption process happen locally on the devices involved meaning that Whatsapp servers don't have plaintext of your message. Therefore, even if Whatsapp servers are compromised, your messages are secure.
- » **Feature of Perfect Forward Secrecy:** It ensures that even if some malicious actor gets access to your private key, they would be able to decrypt messages sent after the compromise, past messages are secure.
 - This is done with the help of ephemeral (temporary) session keys.
- » **Feature of verification of identity through security codes:** Whatsapp allows users to verify the identity of their contacts by comparing security codes. These codes are unique to each conversation and help ensure that the keys used for encryption are not tampered with.

3) QUANTUM CRYPTOGRAPHY/ QUANTUM KEY DISTRIBUTION

- **About Quantum Cryptography:** It is a protocol to distribute secret keys using the principles of quantum mechanics. It is a new technique that ensures the confidentiality of information transmitted between two parties, by exploiting counter intuitive behavior of elementary particles called as photons.
 - » **How Quantum Mechanics is used – Heisenberg's Uncertainty Principle**
 - » The security of the quantum key distribution is guaranteed by the laws of quantum physics.
 - Following uncertainty principle, an eavesdropper cannot know everything about a photon that carries a bit and will destroy a part of the information. Hence eavesdropping causes errors in transmission line, which can be detected by Alice (sender) and Bob (Receiver).
 - If an eavesdropper, tries to determine the key, she will be detected. The legitimate parties will then discard the key, while no confidential information has been transmitted yet. If, on the other hand, no tapping is detected, the secrecy of the distributed key is guaranteed.
 - » **Other advantage of Quantum Cryptography/Quantum Key Distribution?**
 - It can distribute long key as often as possible between Sender and Receiver
 - » Long term secrecy of confidential data transmission

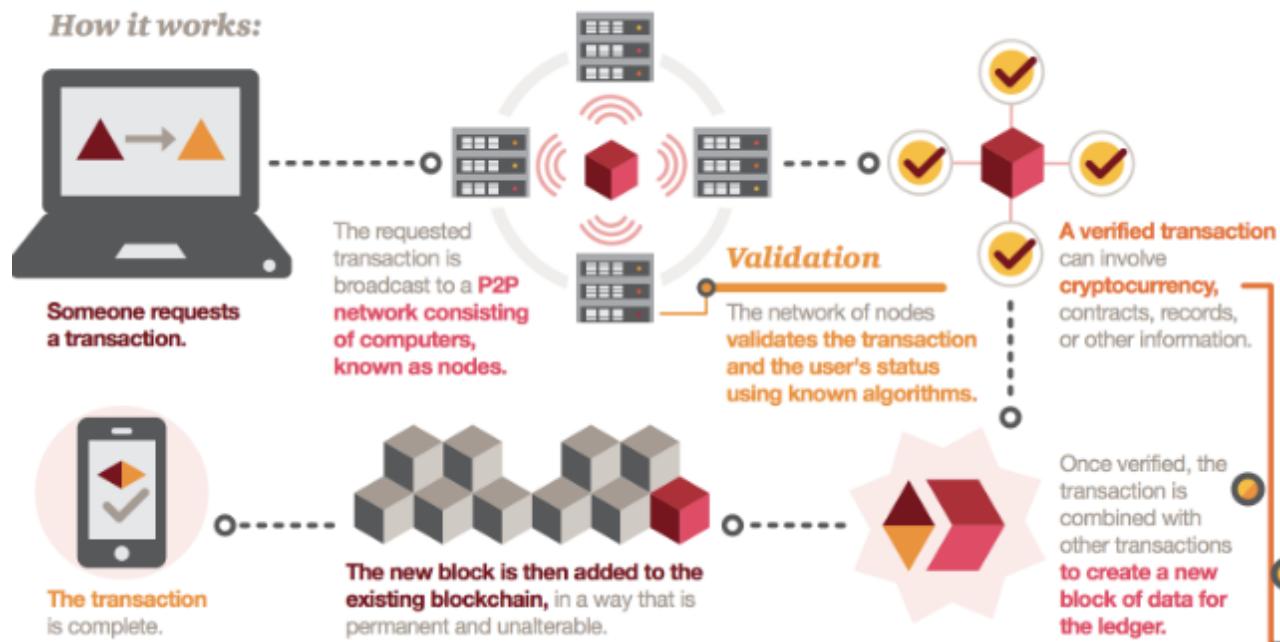
3. BLOCKCHAIN TECHNOLOGY

- **Introduction**
 - Blockchain is an incorruptible, decentralized, digital ledger of transactions that can be programmed to record not just financial transactions but virtually anything of value. Using this technology, participants can confirm transactions without the need of central certifying authority. In other words, blockchain is a distributed database that is used to maintain a continuously growing list of records/transaction, called blocks.
 - It was first used in the design and development of Bitcoin – Cryptocurrency in 2009 by **Satoshi Nakamoto**.

- It offers all parties involved in a business network a secured and synchronized record of transactions. It records every sequence of transaction from beginning to end, whether it is 100s of transaction in supply chain or a single online payment.
 - **Block:** As each transaction occurs it is put into a block.
 - **Chain:** Each block is connected to one before and after. Groups of transactions are blocked together, and a fingerprint of each block is added to the next thus creating an irreversible chain.
- **Data/Transactions** stored in the blocks are secured against tempering using cryptographic hash algorithm and are validated and verified through consensus (consensus protocol) across nodes of blockchain network.

- How blockchain transaction functions

How it works:



- Positives/Advantages

- **Security** -> Built in robustness -> no single point of failure i.e. no centralized points of vulnerability that hackers can exploit.
- **Trust** -> Increased Transparency and incorruptibility
 - Data is embedded within network as a whole, by definition it is public.
 - Altering any unit of information on the blockchain would mean using a huge amount of computing power to override the entire network.
 - In theory, this would be possible. In practice, it's unlikely to happen.
- **Permanent Ledger**
- Reduces the role of intermediary.
- Speeds up the process.
- Lowers transaction cost
- Applications in various sectors

- Applications (Current and Future Potential)

- **Economy and Finance** offers the strongest use cases for the technology.
 - **Financial transactions** are typically granted by third party and block chain could be used to automate the process, reducing overall costs, by cutting out the middleman with autonomous smart contract acting as trusted intermediaries between parties on the network.
 - **Faster, Cheaper settlements could** save billions of dollars from transaction costs while improving transparency.
 - **Stocks, mutual funds, bonds, and pensions** may one day be stored on blockchains as many financial organizations explore the technology.
- **Automotive:** Consumers could use the blockchain application to manage the fractional ownership in autonomous cars.
- **Public Ledger Information:** Many governments are looking to adopt this technology to store information about the citizens and census. A decentralized platform to safely store data regarding, birth, death crime etc. can contribute to effectively curbing fraudulent activities. Even our judiciary can benefit by using this platform to store court judgments, making our legal system more transparent and accessible to litigants.
- **Voting:** Using a blockchain code, constituents could cast votes via smartphone, tablet etc. resulting in immediately verifiable results. Voting by blockchain can eliminate election frauds by making each vote stored as a block on the block chain, rendering it impossible to tamper with.
- **Healthcare:** Patients encrypted information could be shared with multiple providers without the risk of privacy breaches.
- **Smart Contracts:** Every agreement, every process, every task, and every payment would have a digital record and signature that could be identified, validated, stored, and shared. Intermediaries like lawyers, brokers, bankers might not be necessary.
- **Secure File storage**
 - Distributing data throughout the network protects files from getting hacked or lost.
- **Identity Management:** Decentralized, used controlled digital identity holds the potential to unlock economic opportunity for refugees and others who are disadvantaged, while concurrently improving the lives of those simply trying to navigate cyberspace securely and privately.
 - There is definite need for better identity management on the web.
- **Supply chain auditing**
- **Protection of intellectual property**
 - Smart contracts can protect copyright and automate the sale of creative works online, eliminating the risk of file copying and redistribution.
 - Further, a blockchain storage can provide a consolidated platform where trademark and copyright filings can be stored. With entries that can't be tampered with and accurate time stamps, the number of disputes concerning IP may well decrease.
- **Anti-Money laundering and Know Your Customer (KYC)**
- AML and KYC practices have a strong potential for being adapted to blockchain

4. CRYPTO CURRENCY

- Cryptocurrency is a form of **digital cash** which uses **encryption technology** to make it secure. Since, this is a completely digital system, it doesn't exist in physical form.
- **Records of cryptocurrency transactions** have to be stored in a secure database. **Blockchain** serves the role of an incorruptible ledger for most of the cryptocurrencies.
- People can store their cryptocurrency in **virtual wallets** that resemble online bank accounts.

A) CRYPTO MINING

- Crypto mining refers to the process by which new units of cryptocurrency are created by solving complex mathematical problem.
- The miner who mines the cryptocurrency gets to add a new block of verified transactions to the blockchain.
- **Remember some key aspects:**
 - » **Resource intensive:** Solving mathematical problems consume a lot of processing power leading to environmental concerns.
 - » **Increasing Competition:** As coins keep getting mined, future coin becomes more difficult to mine.
 - » **Not all cryptocurrencies** may use mining.

BHUTAN TO EMERGE AS CARBON NEUTRAL HUB FOR CRYPTO MINING

- **In May 2023**, Singapore based mining company, Bitdeer (BTDR) announced a partnership with Bhutan to build a \$500 million closed end fund which will be used to build mining facilities powered entirely by carbon-free hydropower.
- The first phase of the project – Gedu data centre, with a total aggregate electrical capacity of 100 MW, has been operational since Aug 2023.

1) BITCOINS

- **Bitcoin** is the first cryptocurrency created and held electronically. It is a decentralized system (No one controls it). Bitcoins aren't printed, like Rupees or dollars - they are produced by people, and increasingly businesses, running computers all around the world, using software that solve mathematical problems.
- **Who created bitcoins -> Satoshi Nakamoto?**
- **Limited number bitcoins**
 - » The bitcoin protocol - the rules that make bitcoin work - say that only 21 million bitcoins can ever be created by miners. However, these coins can be divided into smaller parts (the smallest divisible amount is one hundred millionth of a bitcoin and is called a 'Satoshi', after the founder of bitcoin).
- **What is bitcoin based on?**
 - Bitcoin is based on **mathematics**. Around the world, people are using software programs that follow a mathematical formula to produce bitcoins. The mathematical formula is freely available, so that anyone can check it.
- **Advantages/Positive Characteristics of Crypto Currencies**
 - **Decentralized:** No central control and hence flexibility to use.
 - **Easy, Fast Set up:**
 - » Conventional banks -> complicated process to open bank account, merchant account for payment more complicated
 - » Bitcoin address can be set up in seconds, no questions asked, and with no fees payable.
 - **Protects Privacy/Anonymous**
 - » Users can hold multiple bitcoin addresses, and they are not linked to names, addresses, or other personally identifying information.

- **Completely Transparent**
 - » Bitcoin stores details of every single transaction that ever happened in the network in a huge version of a general ledger, called the **blockchain**. The blockchain tells all.
 - » If you have a publicly used bitcoin address, anyone can tell how many bitcoins are stored at that address. They just don't know that it's yours.
- **Transaction fee is minuscule and transaction is fast** (almost real time, even cross border)
- **It's non-repudiable.**
 - » When your bitcoins are sent, there's no getting them back, unless the recipient returns them to you. They're gone forever.

▫ Limitations/Disadvantages of Cryptocurrencies

- **Acceptance is limited** -> banned in countries like China and India
- **Loss of wallet -> no recovery option**
 - » If hard drive crashes, or wallet corrupts data. This can bankrupt a wealthy Bitcoin investor within seconds with no form of recovery
- **Volatile** -> no valuation guarantee
- **No grievance redressal/ No Buyer protection** in case of online purchase
 - » If seller doesn't send the bought goods, nothing can be done -> there is no provision of refund/reverse transaction
- Risk of **unknown technical flaws**
- **Built in deflation (in bitcoin)**
- **No physical form** -> Cannot be used in physical stores
- **Extremely high processing power/energy requirement** -> Environmentally unsustainable. According to a study by University of Cambridge, Bitcoin currently uses more energy than Argentina every year.
- Can be used for **criminal activities**
 - » Lack of centralized control allows its use for criminal activities such as by ransomware attackers.
- This may also be used by money launderers to launder black money.

2) LIBRA (DIEM) (PROJECT ABANDONED IN JAN 2022)

3) MOST FAMOUS CRYPTOCURRENCIES

- Bitcoin (BTC)
- Ethereum (ETH)
- Tether USDT (USDT)
- BNB (BNB)
- Solana (SOL)

4) CRYPTOCURRENCY AND INDIA

- In **April 2018**, RBI prohibited banks from providing services to firms and individuals who deal in bitcoin and other such virtual currencies. But, in **March 2020**, the **Supreme Court had set aside the RBI Ban on cryptocurrency transactions** by setting aside the April 2018 circular of the RBI prohibiting banks and entities regulated by it from providing services in relation to virtual currencies (VCs). The Court found the RBI circular "disproportionate" with an otherwise consistent stand taken by the Central Bank that VCs are not prohibited in the country. Further, the court held that the RBI didn't consider the availability of alternatives before issuing a circular.
- In 2019 **Inter-Ministerial Committee** (IMC) chaired by **Subhash Chandra Garg** that was setup to assess the viability of virtual currencies in India had also recommended that India should **ban private crypto currencies such as Bitcoin**. Through a **draft bill** they recommend a maximum of 10-year punishment for those who mine, trade, buy or sell cryptocurrencies.
 - » What is **IMC's view on Distributed Ledger Technologies (DLT)** and Cryptocurrencies?
 - i. IMC recognizes the potential of DLT and Blockchain.
 - ii. Therefore, it recommends the Department of Economic Affairs to take necessary measures to facilitate the use of DLT in the entire financial fields after identifying its uses.
 - iii. The IMC also **recommends that regulators – RBI, SEBI, IRDA, PFRDA, and IBBI – explore evolving appropriate regulations for development of DLT** in their respective areas.
 - » However, IMC has recommended a **ban on “private” cryptocurrencies**. It recommended the **introduction of a single cryptocurrency** for the whole country that is backed by Reserve Bank of India.
 - » **Why?**
 - i. Non-official virtual currencies can be used to defraud consumers, particularly unsophisticated consumers or investors.
 - ii. Further such currencies often experience tremendous volatility in their values.
 - iii. The scaling up of private blockchain based currencies require **crippling level of energy resources**. According to a report by Bank of International Settlement, Bitcoin processing already consumes as much energy as is used by Switzerland; it called this an environmental disaster.
 - iv. If the private cryptocurrencies are allowed to continue, **RBI would lose control over the monetary policy and financial stability**, as it would not be able to keep a tab on the money supply in economy.
 - v. Further, the anonymity of private digital currencies makes them **vulnerable to money laundering** and **use in terror financing activities** while making law enforcement difficult.
 - vi. Finally, there is **no grievance redressal mechanism** in such system, as all transactions are irreversible.

A) THE CRYPTOCURRENCY AND REGULATION OF OFFICIAL DIGITAL CURRENCY BILL, 2021

- **Yet to be officially approved by the Union Cabinet**
- It seeks to create a facilitative framework for creation of the official digital currency (to be issued by RBI)
- **Note:** RBI is looking at launching a pilot project for an official digital currency soon.
- It also seeks to prohibit all private cryptocurrencies in India. However, it allows for certain exceptions to promote the underlying technology of cryptocurrencies and its uses.

B) BUDGET 2022-23

- Virtual Digital Assets (VDAs) will be taxed at 30% (on the gain on the sale of such assets). Benefits of basic exemption limit is also not applicable. No deduction in respect of any expenditure other than cost of acquisition shall be allowed. Also, TDS of 1% shall be deducted on the transaction value from 1st July Subject to certain conditions.
- They mainly include Crypto currencies, NFTs etc. Prima facie, this excludes digital gold, central bank digital currency, or other traditional digital assets and hence aimed at specifically taxing cryptocurrencies.

5. NFT

6. WEB 3.0

- **Background: Understanding Web 1.0 and Web 2.0**
 - Web 1.0 is the world wide web or the internet that was invented in 1989. It became popular in 1993. The internet in the Web 1.0 was mostly static web pages. Here most of the users visited websites and read and interacted with the static material available there. It was a closed environment and users themselves couldn't create post content and reviews.
 - **Web 2.0** started in some form by late 1990s. By 2004, most of the features of web 2.0 was available for implementation. Here websites were more dynamic where users could create content, post comment, write reviews etc. They could also upload photos and videos. Primarily, a social media kind of interaction is the differentiating trait of Web 2.0.
- **Concerns of Web 2.0:**
 - Most of the data on internet is owned and controlled by a few behemoth companies. It has created issues related to data privacy, data security and abuse of such data. It has kind of disappointed experts that the original purpose of internet has been distorted.
- Web3 or Web 3.0 is a term used to describe the next phase of the internet.
 - It runs on the decentralized technology of blockchain and would be different from web 1.0 and web 2.0. Here, users have ownership stakes in platforms (unlike now where tech behemoths control everything). Here users will control their own data.
 - Thus, the need of intermediaries (like Amazon, Facebook, etc.) is removed. This will end data monopoly.
 - The **key concepts in Web3** seen so far are peer to peer transactions and block chain.
- The spirit of Web3 is **Decentralized Autonomous Organization (DAO)** which is that all business rules and governing rules in any transaction are transparently available for anyone to see and the software will be written conforming to these rules.
 - **Crypto-Currency and Blockchain** follow the DAO principle. With DAO, there is no need for a central authority to authenticate or validate.
- **Summarizing significance of web3.0:**
 - Prevents monopoly over data.
 - Promotes data privacy.

- Increase competition in fields like search engine businesses as control over content now restricted to just a few companies would end.
- New technology will give India an opportunity to innovate and develop.

- Future of Web 3.0: Will it take off?

- Tech honchos like Elon Musk and Jack Dorsey don't see a future for Web3.
- There are technological changes required: For e.g., it will require deviation from the current architecture where there is a front-end, middle layer and back-end. Web3's architecture will need backend solutions for handling block chain, persisting and indexing data in block chain, peer to peer communications and so forth. Similarly, middle layer would also need to change to handle block-chain based backend.

7. AUGMENTED REALITY/ VIRTUAL REALITY

A) AUGMENTED REALITY

- AR is the integration of digital information with the user's environment in real time. AR is a technology that layers computer generated enhancements atop an existing reality to make it more meaningful through the ability to interact with it.
 - AR is developed into apps and used on mobile devices to blend digital component in real world in such a way that they enhance each other but can also be told apart easily.
- **Boeing researcher Thomas Caudell coined the term in 1990.**
- **Current application of Augmented reality**
 - Google glass, heads-up displays in car windshields are perhaps the most-well known consumer AR products.
 - It is used in many industries including health care, public safety, gas and oil, tourism and marketing.

▪ VIRTUAL REALITY

- VR is an artificial, computer-generated simulation or recreation of a real-life environment or situation.
 - It immerses the user by making them feel like they are experiencing the simulated reality firsthand, primarily by simulating their vision and hearing.
- VR is typically achieved by wearing a headset like the Facebook's Oculus equipped with the technology and is used prominently in two different ways.
 - To create and enhance an imaginary reality for gaming, entertainment, and play.
 - To enhance training for real life environments by creating a simulation of reality where people can practice beforehand (such as flight simulators for pilots)

8. METAVERSE

- **Definition:**
 - » Metaverse is a digital place inhabited by the digital representations of people (Avatars) and things. It is a new vision of internet.
 - <https://youtu.be/Qw6UCwCt4bE>
 - » Metaverse is a network of 3D virtual worlds focused on social connections.
 - » It is often described as iteration of internet as a single, universal virtual world that is facilitated by the use of virtual and augmented reality.

- » Metaverse has its origin in the 1992 science fiction novel “Snow Crash” as a combination for “meta” and “Universe”. In this he envisioned lifelike avatars who met in realistic 3D buildings and other virtual reality environments.
 - » Some of the platforms already developed can be considered metaverse (e.g., “**second life**”).
- **E.g., applications of Metaverse:**
- » Meta envisions a virtual world where digital avatars connect through work, travel or entertainment using VR headsets. For e.g., it may include fake houses where you can invite all your friends to hang out in.
 - <https://youtu.be/Uvufun6xer8?t=237>
 - » Microsoft envisages that it could involve virtual meeting rooms to train new hires or chat with your remote coworkers.
 - » **Entertainment:** Attend a Concert virtually
 - <https://www.youtube.com/watch?v=Uvufun6xer8&t=775s>
- **Key Challenges:**
- » **VR headsets** are still very clunky, and most people experience motion sickness or physical pain if it is worn for too long.
 - » **Many Technological challenges** – For e.g., if the person would be wearing headsets, how the facial expressions would be scanned and made available in real time.
 - » **Lack of Common Standards:** Various big tech players are building their own versions of an extended virtual reality.
 - » **Cyber Security:** For e.g., by not limiting the number of avatars, Metaverse would allow users to create online representations of others without their consent or verification. While celebrities may be protected by various impersonation mechanisms. Common people would be more vulnerable.
 - Users are going to require regulatory support which integrates governments, industries, and other users.
- **What is being done and what is the way ahead?**
- » Mark Zuckerberg, the CEO of the newly named Meta (formerly Facebook), estimates it could take 5 to 10 years before key features of the metaverse become mainstream. But various components of metaverse already exist – Ultrafast broadband speed, virtual reality headsets and persistent always-on online worlds are already up and running.
 - » Open-Source Platforms like Web3D Consortium, World Wide Web Consortium, XR Association, and several other industry players have come together as the Metaverse Standards forum to build interoperability into the metaverse.
 - » It is important that the work on regulating metaverse starts parallelly. Here civil society, tech companies and government will need to work together to evolve appropriate rules and cybersecurity framework.

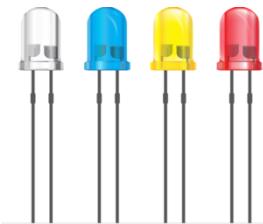
9. ELECTRONICS – BASICS

- 1) Semiconductors:** These are materials which have a conductivity between conductors (generally metals) and nonconductors or insulators (such as most ceramics).

- » They can be pure elements like silicon or germanium, or compounds such as gallium arsenide or cadmium selenide.
 - » In a process called **doping** small number of impurities are added to pure semiconductors causing large changes in the conductivity of the materials.
 - » They are crucial in the development of electronic devices and there would be no radio, TV, Computers etc. without semiconductors.
 - » An important property of semiconductors is that it has very high resistivity at 0K and its resistivity falls as the temperature goes up unlike metals which have high conductivity at 0K and whose resistivity increase as the temperature increase.
 - » Semiconductor devices also display other **useful properties** such as passing current more easily in one direction than the other, showing variable resistance and sensitivity to light or heat.
 - » Because **electrical properties** of a semiconductor can be modified by doping, or by the application of electric fields or light, devices made by semiconductors can be used for amplification, switching, and energy conversion.
- 2) **Diode:** It is defined as a **two-terminal electronic component** that only **conducts current in one direction**. An ideal diode will have **zero resistance** (negligible) in one direction, and **infinite resistance** (very large) in the reverse direction. It is effective like a valve for electric current.
- A **PN junction** is the simplest form of a semiconductor diode. In ideal conditions, this PN junction behaves like a **short circuit** when it is forward biased (current flowing in forward direction), and as an **open circuit** when it is in the reverse biased (current flowing in reverse direction).
- 3) **Transistor:** It is a semiconductor device used to **amplify or switch electronic signals and electric powers**. It is one of the basic building blocks of modern electronics. It is composed of semiconductor material usually with at least three terminals of connection to an external circuit.
- 4) **Amplifier:** It is an electronic device that can increase the power of a signal (a time varying voltage or current). It is a **two-part electronic circuit** that uses electric power from a power supply to increase the amplitude of a signal applied to its input terminals, producing a producing a proportionately greater amplitude signal at its output.

10. OPTOELECTRONICS

- Optoelectronics is a special discipline of electronics that focuses on light emitting or light detecting electronic devices.
- Light emitting devices **use voltage and current to produce electromagnetic radiation (i.e. light)**. These are commonly used for illumination or indication purposes.
 - » E.g. LEDs
- **Light Detecting Devices**, such as photo transistors, **convert received electromagnetic energy into electric current or voltage**. (e.g. photo resistors, solar cells etc.)
- **Light Bulbs** such as **incandescent lights**, are devices that convert electric current into visible lights. **Tungsten wire** has high resistivity and it converts light into heat which results into visible light (photons) to be emitted.



- **Halogen lamps** use a filament that resides inside a gas-pressurized bulb. The pressurized gas consists of an inert gas and a small amount of halogen element such as bromine or iodine. The combination of a halogen gas (small amount of iodine or bromine in inert gas) and tungsten filament produces a **halogen cycle** chemical reaction which **redeposits evaporated tungsten to the filament**, increasing its life and maintaining clarity of the envelope. This allows filament to operate at a higher temperature than a standard incandescent lamp of similar power and operative life;
- **Fluorescent bulbs** are very different. They consist of **mercury vapor filled glass tube** whose **inner wall** is coated with a material that fluoresces. When electrons which are emitted from the fluorescent bulb's inner cathode electrode, collide with the mercury atoms, UV radiation is emitted. This **UV radiation is absorbed by the lamp's fluorescent coating, which in turn releases a visible light.**
- **LEDs:** Discussed in detail below.
- **Laser diode** is a **semiconductor laser device** that is very **similar in both form and operation**, to a light emitting diode (LED). The laser diode is electrically equivalent to a **PIN diode**. A Pin diode is a diode with a wide undoped intrinsic semiconductor region sandwiched between a p-type semiconductor and an n-type semiconductor.
- **Photo Resistors** are light controlled variable resistors, also known as light dependent resistors (LDRs). **Generally**, when a photo-resistor is placed in dark, it has high resistance and when it is illuminated the resistance drops dramatically. They are used in **light sensitive switching devices**.
- **Photo diodes** are semiconductor devices that **convert light energy (i.e. photons) directly into electric current**.
- **Solar Cells** are photodiodes with exceptionally large surface areas.

11. LIGHT EMITTING DIODES

- **Introduction**
 - » A light emitting **diode** is a **semiconductor devise** that **emits visible light when an electric current passes through it.**
 - » The light is **not particularly bright** but, in most LEDs, **it is monochromatic, occurring at a single wavelength.**
 - » The **output from an LED can range from red** (at a wavelength of approximately 700 nanometers) to a blue violet (about 400 nanometers).
 - » Some LEDs emit infrared (IR) energy (830 nanometers or longer); such devices are known as **infrared-emitting diodes (IRED).**
- **Technical Details**
 - » An LED or IRED **consists of two elements of processed material** called the **P-type semiconductors and N-type semiconductors.** These two elements are **placed in direct contact**, forming a region called **P-N junction.** In this respect, the LED and IRED **resemble most other diode types** but there are important

differences. The LED and IRED had transparent package, allowing visible or IR energy to pass through. Also, the LED and IRED has a large PN-junction area whose shape is tailored to the application.

- » **Electrons in the semiconductor** recombine with electron holes, releasing energy in the form of photons.
- **Benefits of LED and IRED**, compared to incandescent and fluorescent illuminating devices, include:
 - » **Low Power Requirement**: Most can be operated with battery power supplies.
 - » **High Efficiency**: Most of the power supplied to an LED or IRED is converted into radiation in the desired form, with minimal heat production.
 - » **Long life**: when properly installed, an LED or IRED can function for decades
- **Other associated benefits**
 - » Climate change
 - » Power deficiency help
 - » Mercury pollution protection (CFLs)
- **Typical Applications include**
 - » **Indicator lights**: These can be two-state (i.e., on/off), bar graph, or alphabetical-numeric readouts.
 - » **LCD panel backlighting**: Specialized white LEDs are used in flat panel computer display
 - » **Fiber Optic Data Transmission**: Ease of modulation allows wide communications bandwidth with minimal noise, resulting in high speed and accuracy
 - » **Remote Control**: Most home entertainment "remotes" use **IREDs** to transmit data to the transmitter.
 - » **Optoisolator**: It is a semiconductor device that uses a short optical transmission path to transfer an electrical signal between circuits or elements of a circuit, while keeping them electrically isolated from each other.
 - » **Lighting**: LED bulbs
 - [Unnat Jyoti for Affordable LED \(UJALA Scheme\)](#)

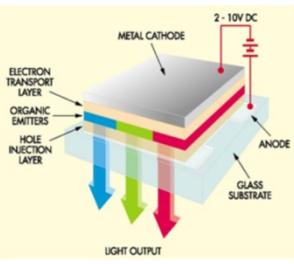
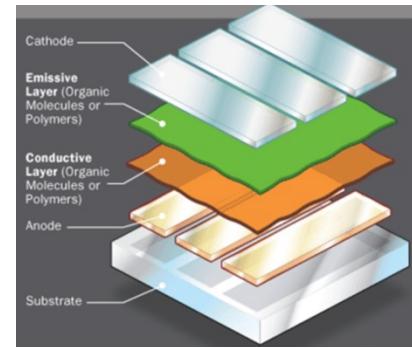
12. ORGANIC LEDs

- **OLEDs** are solid-state semiconductor devices composed of thin films of organic molecules that create light with the application of electricity. They are 100 to 500 nm thick or about 200 times smaller than human hair.
- **Advantages**: OLEDs can provide brighter, crisper displays on electronic devices and use less power than conventional LEDs and LCDs (liquid Crystal displays).
- **How OLEDs work?**

OLEDs have two layers or three layers of organic material. It consists of **following parts**:

 - **Substrate** (clear plastic, glass, foil): The substrate supports the OLED.
 - **Anode** (Positive Terminal) (transparent) – the anode removes electrons (adds electrons “holes”) when a current flows through the device.
 - **Organic Layers**: These layers are made of organic molecules or polymers:

- a) **Conducting Layers:** This layer is made up of organic plastic molecules that transport "holes" from the anode. One conducting polymer used in OLEDs is **Polyaniline**.



OLED Structure

- b) **Emissive Layers:** The layer is made up of organic plastic molecules (different ones from the conducting layer) that transport electrons from the cathode; this is where light is made. One polymer using in the emissive layer is **Polyfluorene**.
- c) **Cathode (negative terminal):** (may or may not be transparent depending upon the type of OLED) – The cathode injects the electron when a current flows through the device.

How OLEDs emit light?

Attach a voltage across cathode and anode.	
As the electricity starts to flow, the cathode receives electrons from the power source and the anode loses them (or it receives holes)	
Added electron is making the emissive layer negatively charged (similar to n-type layer in a junction diode), while the conductive layer is becoming positively charged (similar to p-type material)	
Positive holes are much more mobile than negative electrons, so they jump across the boundary from the conductive layer to emissive layer. When a hole (lack of electron) meets an electron, the two things cancel out and releases a brief burst of energy in the form of a particle of light – a photon.	

- The color of light depends on the type of organic molecule in the emissive layer. Manufacturers place several types of organic films on the same OLED to make colored display.

- **The intensity or brightness** of the light depends on the amount of electrical current applied: the more current, the brighter the light.
- Unlike LEDs, which are small-point light source, **OLEDs are made in sheets that are diffuse-area**. OLED technology is developing rapidly and there are handful of products offering with efficacy, lifetime, or color quality specs that are comparable to LEDs.

Types of OLEDs: They are several types of OLEDs:

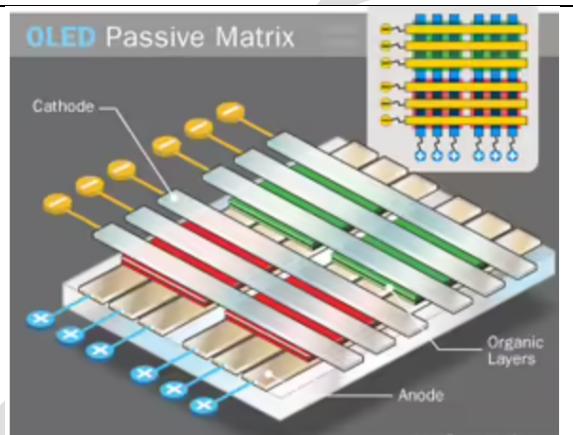
Passive-Matrix OLEDs (PMOLED): It consists of strips of cathode, organic layers, and strips of anodes. The anode strips are arranged perpendicular to the cathode strips. The intersection of the cathode and anode make up the pixels where light is emitted. External circuit applies current to selected strips of anode and cathode, determining which pixels get turned on and which pixels remain off. Brightness of each pixel is proportional to the amount of applied current.

Advantages: Easy to make

Limitations: Consumes more powers than other types of OLED, mainly due to power needed for external circuit.

Application: Suitable for text and icons and thus are best suited for screens (2 to 3 inch) such as those used in cell phones, PDAs, and MP3 players.

Note: Even with external circuitry, passive matrix OLEDs consume less battery power than the LCDs that currently power these devices.

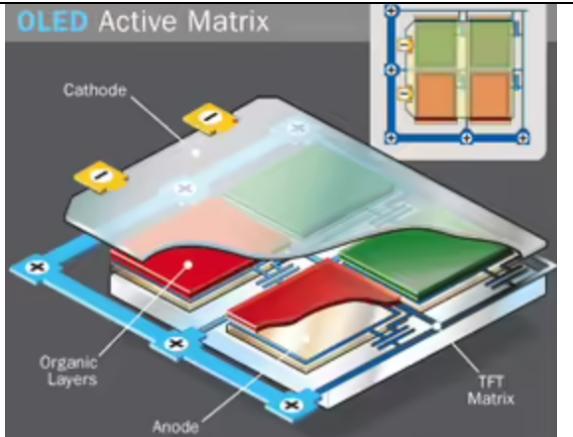


AMOLED (Active-matrix OLED): They have full layers of cathode, organic molecules and anode, but the anode layers overlay a thin film transistor (TFT) array that forms a matrix. The TFT array itself is a circuitry that determines which pixels get turned on to form an image.

Advantages:

- Consumes less power than PMOLEDs because TFT array requires less power than external circuitry, so they are efficient for large displays.
- They also have faster refresh rates suitable for videos.

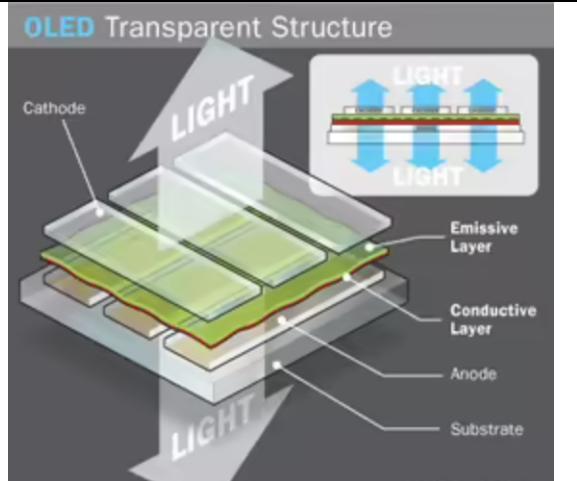
Applications: Computer Monitor, large-screen TVs and electronic signs or billboards.



Transparent OLEDs: They have only transparent components (substrate, cathode, anode) and, when turned off, are upto 85% as transparent as their substrate.

When a transparent OLED display is turned on, it allows light to pass in both directions.

It can be PMOLED or AMOLED. This technology may be used for heads-up displays.



Top Emitting OLEDs: They have substrate that is either opaque or reflective.

They are best suited to active-matrix design. Manufacturers may use top-emitting OLED displays in smart cards.

Foldable OLEDs: They have substrate made of very flexible metallic foils or plastics. They are lightweight and durable. Their use in devices such as cell phone and PDAs can reduce breakage, a major cause of phone repairs. They can also be used for making smart clothing.

White OLEDs: they emit light that is brighter, more uniform and more energy efficient than that emitted by fluorescent lights. They also have the true color quality of incandescent lighting. Because OLEDs can be made in large sheets, they can replace fluorescent lights that are currently used in homes and buildings.

Their use can reduce the energy cost of lighting.

Advantages of OLEDs:

- » **OLEDs** can be configured as large-area, more diffuse light sources whose soft light can be viewed directly. This eliminates the need of shades, diffusers, lenses, or parabolic shells.
 - This diffused light allows them to be used very close to the task surface without creating glare for the user.
- » **OLEDs** can be made very thin, increasing their eye appeal and allowing for easy attachment to the surface of walls and ceilings.
- » The Plastic, organic layers of an OLED are thinner, lighter, and more flexible than the crystalline layers in LED or LCD.
- » **OLEDs** are brighter than LEDs.
- » Because the organic layers of an OLED are much thinner than the corresponding inorganic crystal layer of an LED, the conductive and emissive layer of an OLED can be multilayered. Further, it doesn't require glass for support (which is needed by LED)

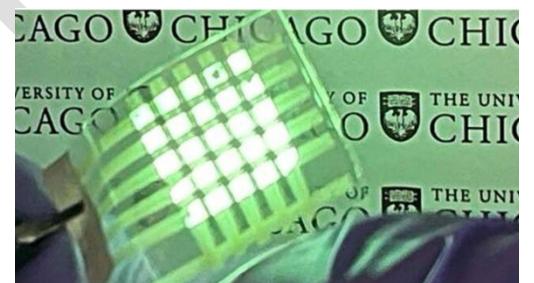
- » **OLEDs** are much more energy efficient.
- » OLEDs don't require backlighting like LCDs. LCDs work selectively blocking areas of backlighting to make the images that you see, while OLEDs generate light themselves. Because OLEDs don't require backlighting, they consume much less power than LCDs (most of the LCD power goes to the backlighting). This is specially important for battery-operated devices such as cell phones.
- » **OLEDs** are easier to produce and can be larger in size. Because OLEDs are essentially plastic, they can be made into large, thin sheets.
- » OLEDs have larger field view, about 170 degrees. Because LCDs work by blocking light, they have an inherent viewing obstacle from certain angles.
- » **OLEDs** can be made up of almost any shape and can be deposited on flexible substrates.

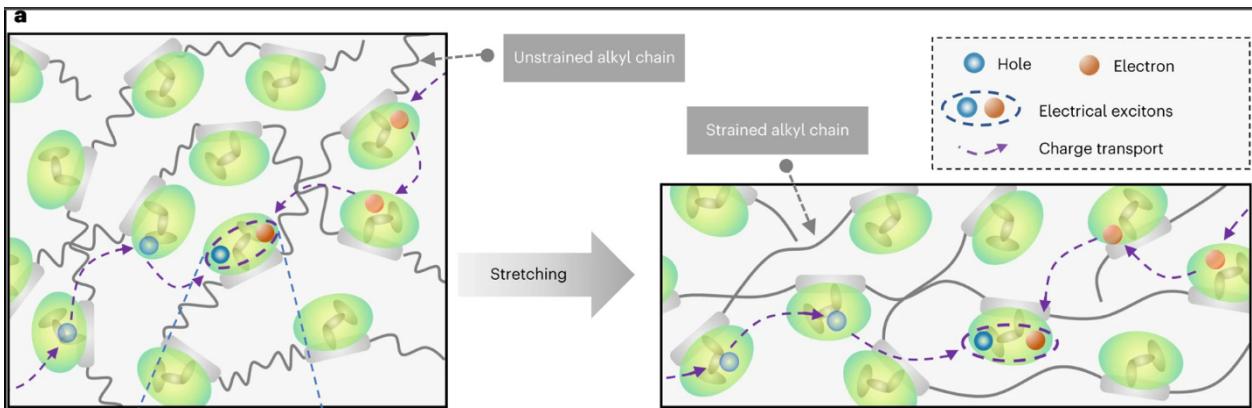
Limitations of OLEDs:

- » **Lifetime:** Blue organics currently have much shorter lifetime.
- » **Expensive manufacturing**
- » **Water can easily damage OLEDs.**

13. FLEXIBLE OLEDS

- **Why in news?**
 - Researchers have developed a stretchable OLED display technology that could power wearable electronics and other flexible form factors devices in future (April 2023)
- **Details**
 - Researchers at the University of Chicago have developed an OLED material that is so flexible that it can be bent in half or stretched to more than twice its original length while still emitting light.
 - It represents a new technology that could possibly be used to develop stretchable fabric-like displays in the future. It could be used in flexible displays for a variety of applications, including wearable electronics, health sensors, and even foldable devices, according to the University of Chicago.
- **Need:** The material that are currently used in OLED displays are very brittle and are not very stretchable. With this in mind, the researchers set out to create a material than maintained the light-emitting properties of OLED but was also stretchable.
- **Design Strategy:** Design strategy of inserting flexible, linear units into polymer backbones can greatly increase stretchability without affecting light-emitting performance.





14. LASER (LIGHT AMPLIFICATION BY SIMULATED EMISSION OF RADIATION)

- Introduction

- A laser is a device that generates an intense beam of coherent monochromatic light (or other electromagnetic radiation) by stimulating of photons from excited atoms or molecules.

▫ How does laser differ from normal light?

- **Monochromatic:** Same Wavelength/frequency (whereas normal light contains multiple wavelength)
 - This wavelength is determined by the amount of energy released when the excited electrons drop to a lower orbit.
- **Coherent** (ordinary light is not coherent): It means that all light waves are in phase with one another.
- **Very narrow, highly directional and doesn't diverge:**
- The laser beam is **extremely intense**.

- Uses: Lasers are used in

- Precision tools to cut through diamonds or thick metal.
- Laser surgery
- Skin treatment
- Optical disk drive
- Laser printers
- Barcode scanners
- Fiber optics
- Free space optical communication
- Drilling, cutting and welding materials
- Military and law enforcement devices
- Laser light display in entertainment
- Remote sensing

Lasers in India

India currently has two lasers that produce 100 Terawatt (10^{12}) beams.

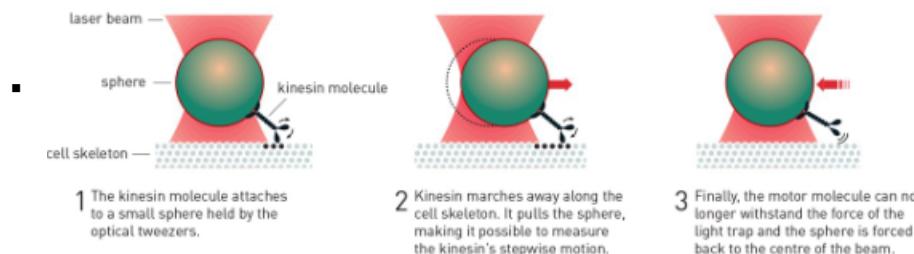
The Raja Ramanna Centre for Advanced Technology in Indore is in the process of installing two petawatt systems, while another is likely to be installed in Hyderabad.

- Nobel Prize in Physics, 2018 for LASER Physics Work

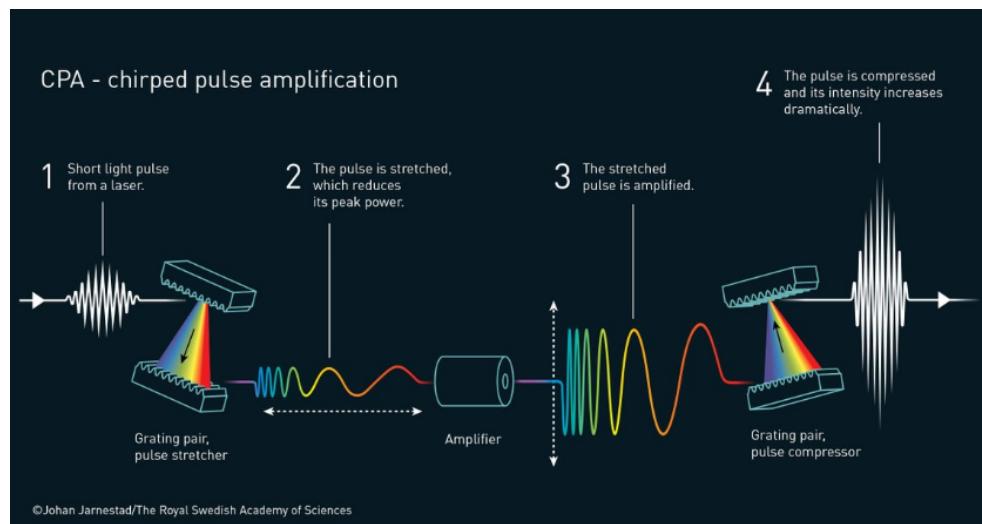
- Arthur Ashkin received the prize for the **optical tweezers** and their applications to biological system

- These optical tweezers are able to grab particles, atoms, viruses, and other living cells with **laser beam fingers**.

A motor molecule walks inside the light trap



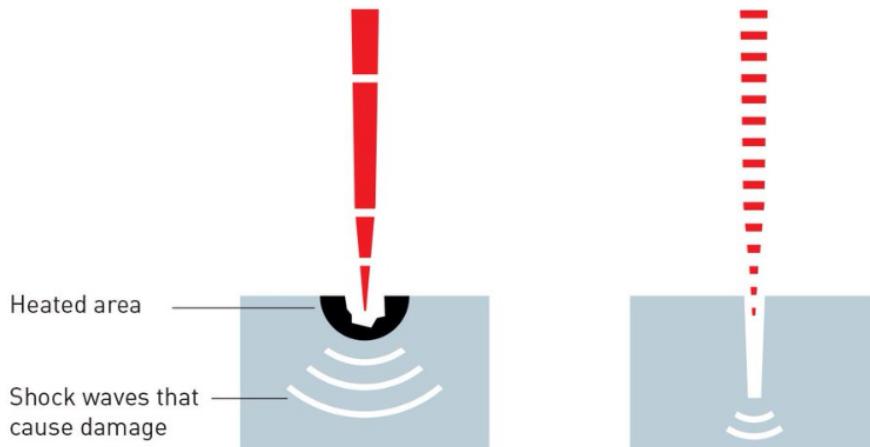
- These optical tweezers are widely used for isolating and examining very small particles, such as individual atoms, DNA strands, or biological cells.
- This helped scientists understand the behavior of single atom or cells, instead of studying the average behavior of an aggregation of such particles.
- The tweezers can capture living bacteria without harming them, a breakthrough achieved back in 1987.
- **Note:** Arthur Ashkin, at the age of 96, has become the oldest scientist ever to be awarded a Nobel Prize.
- **Gerard Mourou and Donna Strickland** were jointly awarded for their method of **generating high-intensity, ultra-short optical pulses**.
 - They created ultrashort high-intensity laser pulses without destroying the amplifying material, thus paving the way towards the shortest and most intense laser pulses ever created by mankind.
 - **Note: Donna Strickland** is only the third women to receive nobel prize in physics. Before her, **Marie Curie** had won it in 1903 and **Maria Goeppert-Mayer** in 1963.
 - **What was the problem earlier?**
 - Within a few years of the invention of laser, laboratory tabletop lasers had started achieving very high power of about a gigawatt. But after this state of peak power was reached, more intense pulses of power could not be produced without damaging the amplifying material.
 - **How the problem was solved?**
 - The two scientists increased the duration of the pulses before the light was amplified so that the intensity comes down.
 - The light could then be amplified normally.
 - This amplified pulse could then be compressed back to its original time duration, and thus increasing its intensity by several orders of magnitude.
 - Their innovative technique, known as '**chirped pulse amplification**' (CPA), has now become standard for high intensity lasers, including the ultra-sharp beam used in corrective eye surgeries. It allows to cut and drill very precisely in various matter.



- **How shorter high intensity laser pulse can be beneficial?**

Nanosecond laser

Femtosecond laser



- With ultrashort and intense laser pulses, we can see events that previously seemed instantaneous. Laser pulses shorter than 100 attoseconds reveal dramatic world of electrons.
- It has also made it possible to cut and drill holes in material and living matter incredibly precisely.
- This has allowed corrective eye operations for millions of users.

A) LIDAR

- It stands for Light Detection and Ranging. It is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distance) to the Earth.
- These light pulses - combined with other data recorded by the airborne system - generate precise, three-dimensional information about the shape of the earth and its surface characteristics.
- LiDAR instrument principally consists of a laser, a scanner, and a specialized GPS receiver.
- **Two types of LIDAR** are **topographic** and **bathymetric**.
 - Topographic LIDAR** typically uses a near-infrared laser to map the land, while
 - Bathymetric Lidar** uses water-penetrating green light to also measure seafloor and riverbed elevations.
- **Applications**
 - Used in projects related to roads, canals, surface transport, city planning, landslides, irrigation etc.

- The system can be brought to use for engineering designs, conservative planning, floodplain mapping, surface feature extraction (trees, shrubs, roads and building) and vegetation mapping (height and density).

15. WIRELESS CHARGING

- Inductive charging (also known as wireless charging) uses an electromagnetic field to transfer energy between two objects through electromagnetic induction.
- The **induction of an electromotive force (voltage)** by the motion of a conductor across a magnetic field or by a change in magnetic flux in a magnetic field is called '**Electromagnetic Induction**'.

- **Understanding Law of Induction in 1830:**

- **Michael Faraday** discovered **Law of Induction** in 1830.

- **First Law:** Whenever a conductor is placed in a varying magnetic field, EMF induces and this emf is called an induced emf and if the conductor is closed circuit than the induced current flows through it.

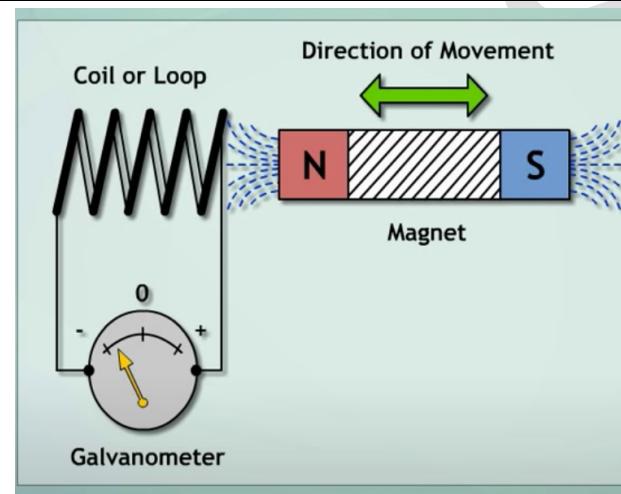
- **Second Law:** The **magnitude of EMF** id equal to the rate of change of flux linkages.

- The machines like generators, transformers, motors etc. work on the principle of electromagnetic induction.

- Similarly, while magnets can create magnetic fields, electric fields can also create magnetic fields.

- In fact, every time you change a magnetic field, you create an electric field. This is called Faraday's Law of Induction.

- Similarly, every time you change an electric field, you create a magnetic field. This is called the Maxwell-Ampere Law

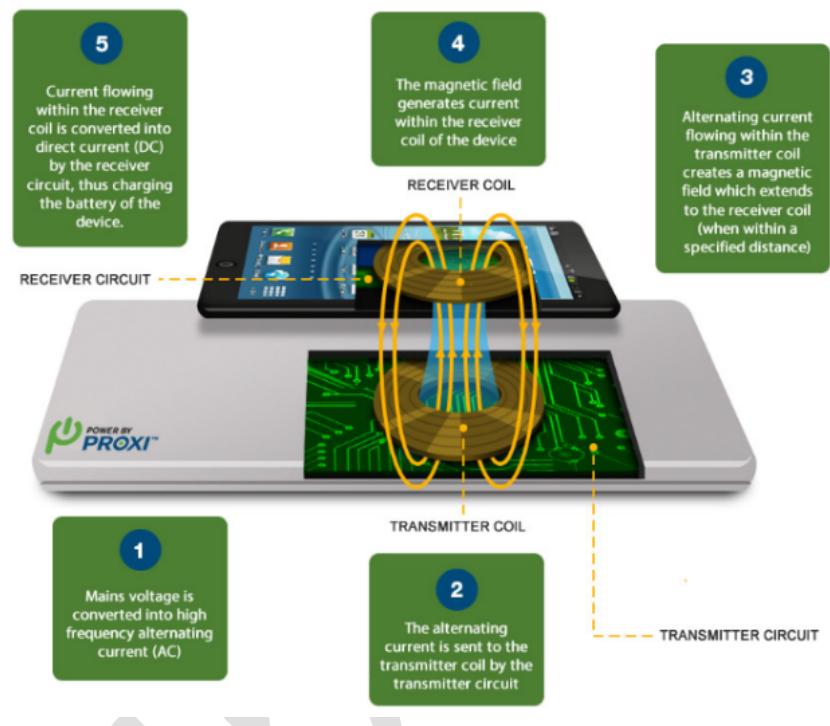


- **This is what happens in wireless charging.** Energy is sent through inductive coupling to an electrical device, which can then use the energy to charge batteries or run the device.
-
- **Advantages of inductive charging/wireless charging?**
 - **Protected Connection** -> No Corrosion, less risk of electric faults, short circuits etc.
 - **Low infection risk**
 - **Durability**

- Increased convenience and aesthetic quality

- Limitations
 - Less efficient
 - Slower Charging
 - More Expensive
 - Inconvenient

- Multiple Standards
 - Magne Charge, Qi etc are multiple standards being used in the market. This confuses the user and same charger cannot be used for all the devices.



16. FREE SPACE OPTICAL COMMUNICATION

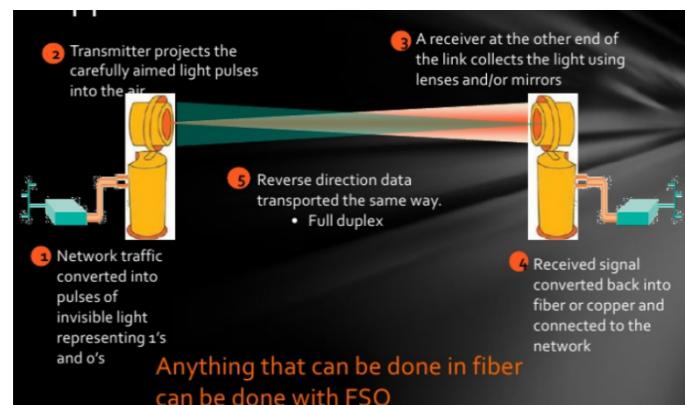
- Introduction

- It is a communication technology which uses light propagating in free space to wirelessly transmit data for telecommunications or computer networking.
- Most of the time laser beams are used, although non-lasing sources such as Light emitting diodes (LED) or IR-emitting diodes (IREDs) will serve the purpose too.
- “Free space” could mean air, outer space, vacuum etc.

- How does FSO work?

- The basic principle is similar to fiber optics transmission other than the fact that here the energy beam is collimated and sent through clear air or space, rather than guided through optical fiber.
- At the source, the visible or IR energy is modulated with the data to be transmitted. At the destination, the beam is intercepted by a photodetector, and data is extracted from the visible or IR beam (demodulated).
- Optical transceiver on both ends ensure bidirectional (duplex) capabilities.

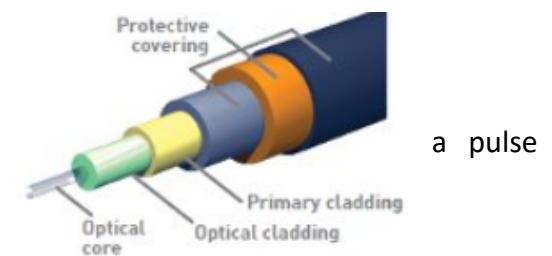
- Line of Sight Requirements



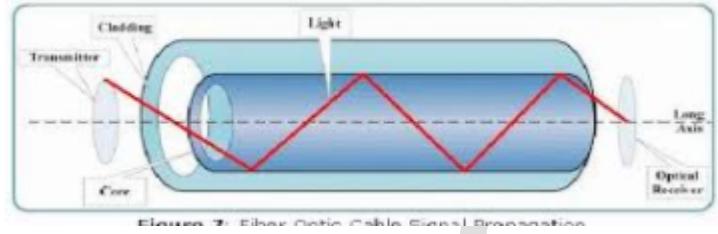
- Theoretically, FSO technologies can work over distance of several kms, as long as the source and the destination are in line of sight.
- **Uses**
 - The technology is very useful where physical connections are impractical due to high cost or other considerations.
 - It can be used for communication between spacecrafts. The first gigabit laser-based communication was achieved by the European Space Agency and called European Data Relay System (EDRS) in 2014. The system is still in operation.
 - LAN-to-LAN connections in campuses for very high-speed Ethernet access
 - To cross a public space (like road) which user doesn't own.
 - For temporary network installations, this is a better option as minimum infra set up is needed.
 - In disaster situation, it can re-establish data connections quickly
 - For high speed inter and intra chip communication.
- **Advantages**
 - Ease of deployment (very less infrastructure investment)
 - Can be used to power devices
 - License free long-range operations (as opposed to spectrum allocation licenses for microwave/radio wave communications)
 - Very high data bandwidth (very high speed of data communication)
 - Immunity from electromagnetic interference
 - Full duplex operation
 - Increased security when working with narrow beams (line of sight operation ensures security)
- **Limitations**
 - Stability and quality of the link is highly dependent on atmospheric factors such as rain, fog, dust and heat.
 - Doesn't work for non-line of sight senders and receivers

17. FIBER OPTICS COMMUNICATION

- **Introduction**
 - FOC is the method of transmitting information from one place to another by sending pulses of light through an optical fiber. Light basically forms the electromagnetic carrier wave that is modulated to carry information.
- **Key components**
 - Transmitter (light source) generates a light stream modulated to enable it to carry the data. Conventionally presence of light indicates "1" and absence of light indicates '0'.



▫ **Fibre Optic cable** is the very thin fibre of glass or other suitable material through which the modulated light stream travels to reach the destination. An optical fibre cable consists of a **core**, **cladding**, and a **buffer** (a protective outer coating). Cladding guides the light along the core by using the method of total internal reflection. The core and the cladding (which is of lower-refractive index) are usually made of high quality silica glass or plastic.



▫ **Optical repeater and amplifier:** In order to overcome the effects of attenuation of the cable, distortion of the light signal along the cable and to ensure that signal gets transmitted over long distances, repeaters and amplifiers are used.

▫ **Receiver (Detector)** converts the pulses of light into equivalent electrical pulses.

- Advantages of fiber optics over electrical cabling

- Lower Signal Attenuation
- Higher Bandwidth
- Can travel longer distances
- Fiber optics cables are much lighter than the coaxial cable (that might otherwise be used). This is very crucial in cases like that of aircraft
- No sparks – important for flammable and explosive gas environment
- Fiber optics do not suffer from stray interference pick up that occurs with coaxial cables.
- Further fiber optics transmission also doesn't suffer from cross talks in contrast to some type of electrical transmission signal.
- Resistant to corrosion due to non-metallic transmission medium.

- Limitations of fiber optics over electrical cable

- Fiber optical system are more expensive to install
 - The cost of cable, the transmitter and receiver is higher in case of fiber optics
- Electrical cable has the capability of carrying electrical currents as well as signals (in properly designated cables), whereas optical fibers can only be carrying signals.

- Applications

- Telecommunication (telephone signals, internet communication and cable tv)
- Due to lower attenuation and interference, optical fiber has large advantages over existing copper wire in long-distance, high demand applications and high-resolution content.

- India and Fiber Optic Communication

- The **National Optical Fiber Network (NFON)** is a project initiated in 2011 to provide broadband connectivity to 2.5 lakh gram panchayats of India (min bandwidth of 100 Mbps) at an initial cost of 20,000 crore rupees.
 - The project intended to enable government of India to provide e-services and e-applications nationally.

- **BharatNet** (rechristening of NOFN) is a project of national importance to establish, by 2017, a highly scalable network infrastructure accessible on a non-discriminatory basis, to provide on demand, affordable broadband connectivity of 2 Mbps to 20 Mbps for all households and on demand capacity to all institutions, to realize the vision of digital India, in partnership with states and private sector.
 - The entire service is being funded by Universal Service Obligation Fund (USOF), which was set for improving telecom services in rural and remote areas of the country.
 - The **objective** is to facilitate the delivery of e-governance, e-health, e-education, e-banking, Internet and other services to rural India.
 - **Implementation:** the project is a centre-state collaboration, with the states contributing free Rights of Way for establishing the Optical Fiber Network.

18.3D PRINTING

- **Intro**
 - 3D Printing (also known as additive manufacturing) is a process where an object is created by adding material layer by layer from a computer blueprint/design. It allows designers to create complex parts for machines, airplanes and cars at a fraction of cost and time of standard means like forging, molding and sculpting.
 - Now, smaller consumer friendly 3D printers are bringing additive manufacturing to homes and businesses.
- **Key steps involved in 3D printing**
 - **Create a blueprint** of the object that requires to be printed. **Modelling software like blenders, CADs etc.** can be used to create the design to be printed.
 - **Printing** works on the layering principle where layers of material is added till the final object is created. Most common material used in 3D printing is plastic, but other material can also be used.
- **Three key advantages of 3D printing are shorter lead time, design freedom, and lower costs.**
- **Main uses:** It's hard to find a sector where 3D printing hasn't had an impact.
 - **Manufacturing and other industrial sector** can now use 3D printing to develop prototype models and test new components.
 - It is also playing a significant role on **fashion industry** with fashion designers experimenting with 3D-printed clothes shoes etc.
 - **Medical Sector** has been one of the biggest beneficiaries of the technology
 - Doctors have been testing biomaterials for regenerative medicines. Some surgeons have even tested 3D printed organs for transplant.
 - **Cultural Heritage preservation, restoration, and dissemination**
 - Many museums in advanced countries have started using the 3D printing technology for actively creating missing pieces of relics.
 - **Homes and other buildings:** Recently a giant 3D printer in China printed 10 houses in just one day and at a cost of less than \$5,000 per house. It proved how cost and time efficient 3D printing can be.
 - **Food Industry:** 3D printing is being used for designing cakes on demand and other food items.
 - **Defence Sector:**
 - For e.g., the corps of Engineers used 3D printing to construct 22,000 temperatures controlled, relocatable, habitat in the high-altitude areas of LAC.

- In addition to 3D printing habitat, the Army's Corps of Engineers in consultation with IIT Gandhinagar, came up with **3D printed permanent defenses** for forward areas. Trials have shown that these 3D printed defences can take direct hit from T-90 tank from 100 meters away and can be constructed in a much shorter time frame compared to regular defensive bunkers.

- **Key Concerns**

- **Intellectual Property Rights:** Once 3D printing becomes very popular, it would be difficult to prevent the IPR violation by individuals at their homes and privately.
- **Health Issues:** Experts have raised concerns about potential health implications of the technology due to exposure to gases and other materials including nanomaterial. Particle emissions from a fused filament generally peaks during printing and may include a large number of ultrafine particles and volatile organic compounds.
- **Public Safety** may become an issue with 3-D printing advanced guns being available with anti-social elements, including terrorists.

19. BARCODE AND QR CODES

A) QR CODE (QUICK RESPONSE CODE) – A TYPE OF 2D BAR CODE

- **What is QR Code and how does it work?**
- Developed in 1994 by a Japanese Cooperation Denso Wave – a subsidiary of Toyota motors.
- QR Code, in full Quick Response Code, **is a type of bar code that consists of printed square pattern of small black and white squares that encode data which can be scanned into a computer system.**
- The black and white square can represent numbers from 0-9, letters A-Z, or characters in non-Latin scripts such as Japanese Kanji.
- The three corners of the QR code contain the finder pattern, a nested series of black and white squares that, when detected by an optical scanner and interpreted by software, allows the scanning device to determine the **orientation of the QR code**.
- **Advantages over barcode**
 - Store hundred times more information
 - Can be scanned from any direction for 360 degrees. This makes it easier for devices to read and lessens the possibility of background interference. Further, it doesn't need a special laser emitting device to read, camera of a smart phone or tablet computer is good enough for scanning the information.
 - Fewer errors – since QR codes have more storage, it can store same information multiple times to reduce the impact of physical damage of the code.
 - More Secure – as it is possible to encode the information in bar codes.
 - In **marketing**, the code's appearance is unique and interesting, increasing the likelihood of engaging the customers.
- **Uses:**
 - Used in advertising, to encode URL of a website that contain a coupon or information about a product.
 - Used in books to help students easily access the webpage.



B) BAR CODE

- Bar code is an optical, machine readable form of data. It is a printed series of parallel bars or lines of varying width that is used for entering data into a computer system. This data usually defines something about the product which carries the barcode.
- Barcodes represent data by varying the widths and spacing of parallel lines.
- **Uses:**
 - **Automation of supermarket checkout** is the most common place where we see bar code scanner. In fact, this use of barcode has almost become universal.
 - **Supply chain management**
 - **Advantages**
 - Speed of processing
 - Better tracking (in case of supply chain management)
 - Low cost and very accurate (compared to key entry)
 - **How does a bar code scanner work?**
 - Laser/LED is reflected back better from the white spaces (and not from the black bar).
 - This reflection is converted into on-off pulse in the binary digit by an electronic circuit attached to the scanner.



20. TOPICS TO BE COVERED IN FUTURE BOOKLETS

- Wireless Communication (5G/6G), Bluetooth, WiFi, NFC, RFID etc.
- VOLTE/ VoIP/ VoWiFi



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COMPUTER & IT - 4

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2. VARIOUS GENERATION OF CELLULAR WIRELESS COMMUNICATION TECHNOLOGY

1) DIFFERENCE BETWEEN 1G, 2G, 3G, 4G, AND 5G

- **G** in terms like 1G, 2G, 3G, 4G etc. refers to a generation of cellular wireless communication technology.
- When there is a change in generation, there is a change in:
 - The fundamental nature of service
 - Non-backwards compatible transmission technology
 - New Frequency bands.

Different Generations, key differences:

Features	1G	2G	3G	4G	5G
Year of introduction	1980s	1990s	Early 2000s	Late 2000s	Late 2010s
Core technology	Analog	Digital (CDMA, , GSM)	CDMA2000	LTE	NR (New Radio)
Services	Voice calls	Voice calls, SMS, Basic mobile Internet;	Integrated high-quality audio, video and data	Dynamic information access, variable devices	Dynamic information access, variable devices with all capabilities
IP Protocol	N/A	Supported	Supported	Fully Supported	Fully Supported
Data Speed		Upto 384 Kbps	Several Mbps	100 Mbps to 1 Gbps	Upto 20 Gbps
MIMO technology	N/A	No	Yes	Yes	Yes

Note: Security keeps on improving with every generation; Latency keeps on decreasing with every generation; Data Speed keeps on improving with every generation.

MIMO Technology: (Multiple Input Multiple Output) (MIMO) is a wireless technology that uses multiple transmitters and receivers to transfer more data at the same time.

Note: Legacy wireless streams used Single-Input Single Output (SISO) technology. They can only send and receive only one spatial stream at a time.

2) VARIOUS 4G TECHNOLOGIES

- **4G phones are supposed to be faster, but there are many technologies and speed varies.**

- The International Telecommunication Union (ITU), a standards body, tried to issue requirements to call a network 4G but they were ignored by carriers, and eventually the ITU backed down.
- 4G technologies include.
 - 1. HSPA+ 21/42**
 - 2. WiMAX (now obsolete)**
 - 3. LTE (Long Term Evolution)**

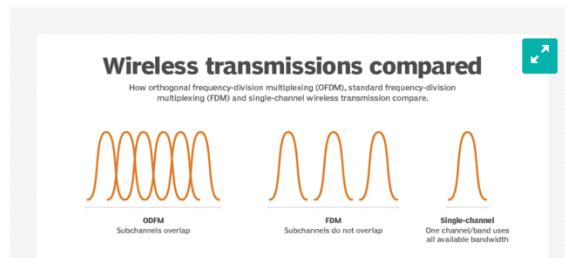
A) LTE

- » LTE is the most popular 4G tech. Some people consider it the only true 4G tech of the bunch and some others say that none of them are fast enough to be called 4G. The **key difference** between 4G LTE and other “4G” technologies is the upload speed.
- » **Other Details about LTE:** LTE only allows transmission of data. **Voice calls** are routed through telecom networks’ older 2G and 3G networks. Therefore, under LTE, we can’t access 4G data and services while on a call.

- » **Key Features of LTE:**

- **Orthogonal Frequency Division Multiplexing (OFDM):** It allows high data bandwidth to be transmitted efficiently while still providing a high degree of resilience to reflection and interference.

In a traditional single-channel modulation scheme, each data bit is sent serially or sequentially one after another. In OFDM, several bits can be sent in parallel, or at the same time, in separate substream channels. This enables each substream's data rate to be lower than would be required by a single stream of similar bandwidth. This makes the system less susceptible to interference and enables more efficient data bandwidth.



Multiple Input, Multiple Output: LTE-A uses MIMO antenna technology. MIMO and OFDM ensure a higher signal to noise ratio at the receiver ensuring good services even in dense regions.

B) VOICE OVER LTE (VoLTE)

- Voice over LTE is a **digital packet technology** that uses 4G LTE to route voice traffic and transmit data. VoLTE provides higher quality calls, better service, and the ability to simultaneously use voice and data.
- **NEED:** Why is VoLTE necessary?
 - » The technology is necessary because **LTE is a data-only networking technology**.
 - **Previous cellular networks** such as 2G and 3G, were designed to carry voice calls – services added cellular data support later through methods that basically “tunneled” data inside of voice-call connections.

- **LTE turns the network around** and uses Internet Protocol Packets for all communications. As such it doesn't support traditional voice call technology, so a new protocol and applications for voice over LTE are needed.
- **How does VoLTE work?**
 - » It is based on the **IP Multimedia Subsystem (IMS) framework**. This allows the service to deliver multimedia as data flows using a common IP interface.
- **Advantages of VoLTE**
 - » **VoLTE** uses the **spectrum more efficiently** than traditional voice calls. It uses less bandwidth because VOLTE's packet headers are smaller than those of unoptimized VoIP/LTE.
 - » It provides for increased battery life when compared to VoIP.
 - » Provides superior audio quality and a clearer calling experience.
 - » **Ends dependency** on the legacy circuit switched voice network to be maintained.
 - » Allows up to **six-way conference calls**.
 - » Ability to **simultaneously use voice and Data**. Eliminates the need to have voice on one network and data on another.
- **Limitations**
 - » Need volte capable smart phones
 - » **Strong 4G coverage** to make and receive calls over 4G network.
 - » For VoLTE call, both devices involved in communication must be compatible with VoLTE.
- **Services in India**
Reliance Jio and Airtel are the leading operator providing the VoLTE. Reliance Jio doesn't have spectrum in 2G or 3G and thus it places all its calls using 4G LTE only (unlike other operators which drop to 2G or 3G for sending and receiving calls).

3) 5G

- 5G refers to **the fifth generation of cellular wireless communication technologies**.
- **Key features of 5G technology** are:
 - **Higher speed; Lower latency; Greater network stability.**
 - **Device Intelligence:** Unlike 4G, 5G has the capability to differentiate between fixed and mobile devices. It uses cognitive radio techniques to identify each device and offer the most appropriate delivery channel. This will allow a much more customized internet connection – according to device capability and local reception environment.
 - **Other technical features of 5G**
 - 5G will use higher frequencies of wireless spectrum (~ **30 GHz to 300 GHz**) range when compared to 4G which uses frequencies below 6 GHz.
 - **Higher Frequency** -> Huge quantity of data; Shorter Wavelength -> smaller antenna sizes.
 - Building on the multiplexing technology of its predecessor, 5G ushers in a new standard called **5G New Radio (NR)**, which uses the best capabilities of LTE. **5G NR** will enable increased energy savings for connected devices and enhance connectivity.
 - These frequencies are **highly directional** and thus can be used right next to other wireless signals without causing interference.

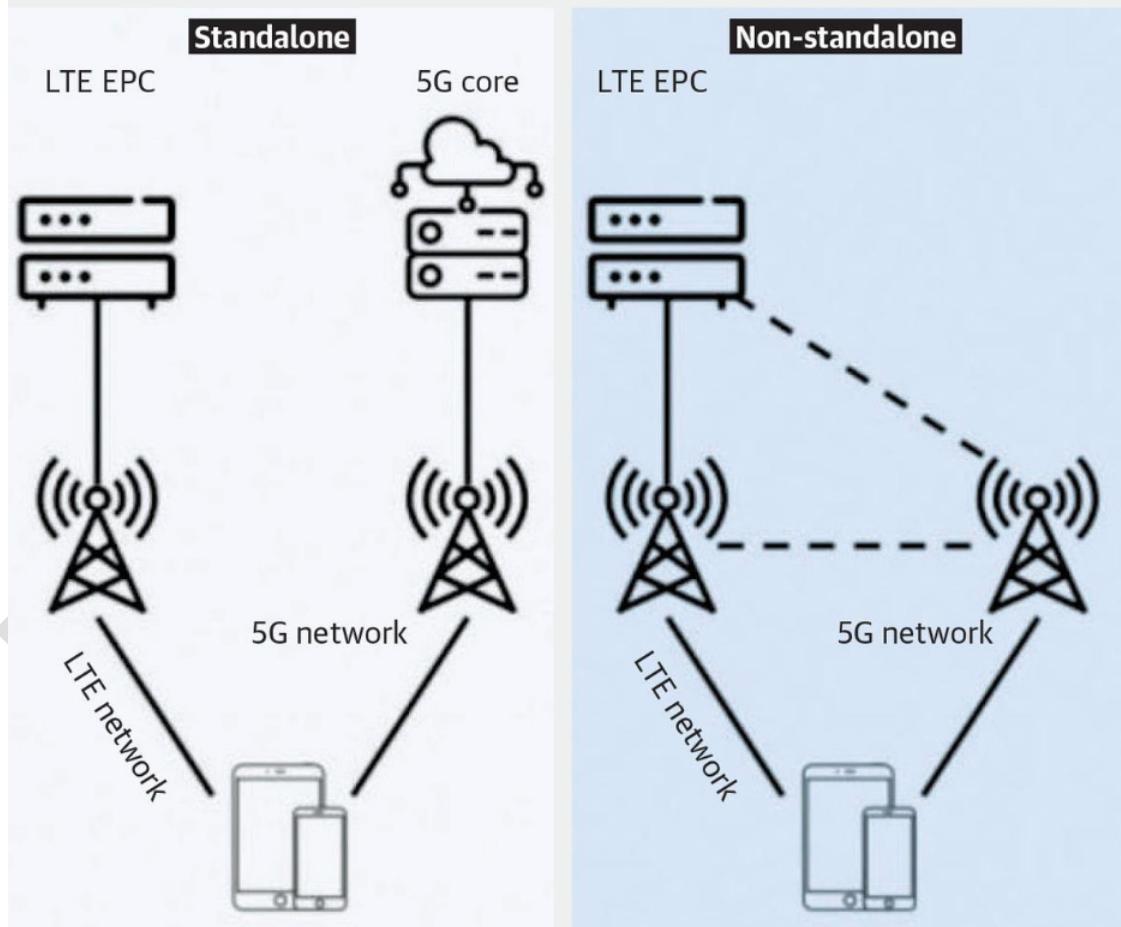
- Several hundreds of thousands of simultaneous connections for wireless sensors
- Spectral efficiency significantly enhanced compared to 4G
- Improved Coverage
- Enhanced signal efficiency

C) STANDALONE AND NON-STANDALONE 5G

- 5G networks are deployed on two modes: **standalone** and **non-standalone**.
- Each architecture has its advantage and disadvantages. The method used by the operators primarily reflect their view of the market for the new technology, and consequent rollout strategy.

5G architecture

When 5G is deployed through a non-standalone framework, the operator uses the existing installed capacities and LTE architecture. However, in a standalone model, the radio access network and the core will be completely new. It gives operators the full range of 5G's capabilities.



- **Standalone Mode:** In this mode, the 5G network operates with dedicated equipment and runs parallel to the existing 4G network. In this architecture, Radio Access Network (RAN) and the core are

completely new, and there will be a clear separation of different network functions in line with the 3GPP recommendations.

- Jio has chosen this method. It has committed an investment of Rs 2 lakh crore for its standalone 5G network.
- **Advantages:** Provides full 5G capabilities and new network functionalities such as slicing that provides greater flexibility to operators to efficiently use their spectrum holding; Simplify network operations; much faster than NSA 5G -> improved user experience; Long term solution.
- **Limitations:** High Initial Investment

- **Non-Standalone Mode (NSA):** In this, the 5G network is supported by the 4G Core infrastructure. The operators can use their existing capacities and LTE architecture to deploy 5G services while implementing a new radio access network (RAN). The operations in the core network will be supported by the existing evolved packet (EPC) from LTE. **Germany** for e.g., used the NSA model to roll out 5G services in 2019.
 - **Advantages:** Reduce initial cost/investment; Maximizes the utilization of existing network; Reduces time of deployment; first national coverage
 - **Limitation:** Only short term/medium term solution; Not as fast as pure 5G
- Given that the non-standalone networks are built on existing infrastructure, the initial cost and rollout times are significantly lower. It lets operators maximize the utilization of existing network infrastructure with relatively lower investment.

Compatibility with existing device ecosystems: Most smartphones today have compatibility to connect to non-standalone 5G network – which are essentially 5G airwaves transmitted through 4G networks. It will require software updates by their OEMs to be able to connect to standalone networks.

D) CHALLENGES OF FIBERIZATION AHEAD OF INDIA'S 5G DEPLOYMENT (CLASS DISCUSSION)

E) 5G SPECTRUM (LOW BAND, MIDDLE BAND, HIGH BAND)

- **5G** differs from previous cell phone standards, in having much wider spectrum than before. It is capable of tuning in many more types of frequencies – and multiple types of frequencies at the same time.
 - **Low Band 5G (600 – 700 MHz):** Low band tower can cover 100s of sq miles with 5G services that range in speed from **30 – 250 megabits per second (Mbps)**. It is the blanket layer for nationwide coverage. It will provide a base and services will not get worse than this. It uses the same frequency (600 MHz) that was once used for analog TV broadcasts. This ensures coverage in far flung rural areas.
 - **Note:** Even low band services are faster than 4G services.
 - **Middle Band 5G (2.5-3.5 GHz):** Mid band tower can cover several mile radii with 5G service that range in speed from **100 – 900 Mbps**.
 - **Note:** Some carriers will be skipping low band 5G, so their middle band 5G services will be the base service.

- **Note:** Cellular industry is considering the mid band 5G as the sweet spot for 5G distance and performance.
- **High Band** (millimeter wave/24-39 GHz) tower covers a one mile or lower radius while delivering superfast speeds (roughly 1-3 gbps speeds). It will be deployed in areas with “**dense urban**” environments and public gathering places that frequently save huge number of people.
- Each of these tiers would improve in performance over time.

F) PRIVATE 5G

- It is a cellular network technology that provides 5G connectivity for a specific, closed user group within a limited geographic area.
- Unlike public 5G networks, which are operated by mobile carriers and accessible to anyone with compatible device and subscription, private 5G networks are owned and operated by private entities, such as businesses, governments, or universities. This gives owner full control over the network, including who can access it, how it is used, and the quality of service.
- **How does it work?**
 - Same tech as public 5G, but they operate on licensed or unlicensed spectrum.
- **Advantages:**
 - **Increased privacy and security:** It allows organizations to implement their own security measures.
 - Improved reliability and performance (since it can be tailored to specific needs of the users)
 - Greater control and flexibility
 - Reduced cost

G) AIRLINES VS 5G IN USA AND SOME OTHER COUNTRIES (CLASS DISCUSSION)

- **what were the problems caused by deployment of 5G ‘C-Band’ spectrum (3.7 GHz – 3.98 GHz)?**
 - The C-band frequency range of 5G wireless technology is very close to the 4.2 to 4.4 GHz range used by altimeters on all aircrafts, something that was established long back

4) 6G

Successor of 5G

Frequency Bands – 95 GHz to 3 THz

It seeks to use Tera Hz band frequency which is still unutilized. Tera Hz band fall between infrared and microwaves. Though the waves have very small wavelength, there is a huge amount of free spectrum which would allow us very fast data rates.

Data rate – Upto 1 TBPS (100 times faster than 6G)

Latency < 1 milli seconds

Application and Advantages (Similar points as 5G)

6G also envisions to enable new applications such as holographic communication, brain-computer interface, quantum internet, and artificial intelligence.

Challenges for India:

Low R&D investments

Terahertz communication are blocked easily by barriers and signal also attenuates easily

5) BHARAT 6G ALLIANCE (B6GA)

Why in news?

DoT launches Bharat 6G Alliance to drive innovation and collaboration in Next-Generation Wireless Technology (July 2023)

Details about B6GA:

It is a collaborative platform consisting of public and private companies, academia, research institutions and standards development organization. It will forge coalition and synergies with other 6G Global Alliances, fostering international collaboration and knowledge network.

The **primary objective** of the B6GA is to facilitate market access for Indian telecom technology products and services, enabling the country to emerge as a **global leader in 6G technology**.

It aims to bring together Indian startups, companies, and the manufacturing ecosystem to establish consortia that drive the design, development and deployment of 6G technologies in India.

It also focuses upon accelerating standard related patent creation within the country and actively contributing to international standardization organizations such as 3GPP and ITU.

6) BHARAT 6G MISSION

- Aim of 6G service rollout by 2030.
- India has also launched a development test bed.
- **More about the Vision document**
 - » **Prepared** by the Technology Innovation Group on 6G (TIG) which was set up by Department of Telecommunication in 2021.
 - » **Mission divided into two phases:**
 - **Phase 1** (2023-2025): Ideation phase – understand various potentials and risks; test proof the concept
 - **Phase 2** (2025-2030): Delivering the potential technology solution
 - » **Constitution of an apex body** to oversee the mission and approve the budget of the mission
- **Significance** of the document:
 - » Assuming leadership in setting the 6G standards
 - » Not delaying adoption (as has happened in previous generations)
 - » Ensuring latest technology coming to India in the fastest way possible.

3. E-SIM

- **What is an eSIM (embedded Sim)?**
 - » An eSIM is a programmable chip that is built (embedded) into smartphones, tablets or other devices. An eSIM is a digital SIM that allows you to use a cellular plan from your carrier without having to use a

physical nano-SIM. The pre-installed (embedded) simcard is activated by installing the “eSIM profile” of a new operator.

- » **Technical Name:** The eSIM is called by its technical name, **eUICC** (Embedded Universal Circuit Card) or virtual SIM.

- **Advantages:**

- » This has very small physical footprint, even smaller than the nano sims available since 2012. Not having a removable sim slot also saves a lot of space. This is especially useful for smaller electronics like smartwatches. Further, not having the sim tray increases the scope of making the device water resistant.
- » It serves the same purpose as a physical SIM, but it is carrier independent and can be programmed via software instead.
- » **Same eSIM profile** can be activated on multiple device (e.g. phone, smart watches etc.) (traditionally, one physical sim card could be used only in one device)
- » **Switching providers is very easy:** Instead of getting a new physical SIM card, all you have to obtain is a configuration file and activate it on the device. Providers generally refer to it as an eSIM profile and offer it as a QR code that you can scan and download.
- » Further, eSIM allows storage of multiple carrier profiles on the smartphones and carrier can be switched between on the fly.
- » **Carriers also benefit** as they don't have to manufacture and provide a physical sim card thus reducing the cost.
- » **Environment friendly** – extra packaging of physical sim card, plastic waste, e-waste etc. could all be reduced.

- **Disadvantages/Limitations:**

- » **Not supported by all carriers yet.**

- In India, **Jio, Airtel, and Vi** all support eSIM. You need to send a message to the carrier asking them to activate eSIM and they usually send a code which has to be scanned via the device on which you intend to use the eSIM. Once done, the eSIM should work.

4. RFID COMMUNICATION

- RFID (radio frequency identification) is automatic recognition technology that uses wireless communication. Here, data is encoded in an RFID tag which might be read by the reader.

- **What is the most important advantage of RFID?**

- » Electronic devices generally need a power source. But, RFID tags use a mechanism where we can send power to device, whenever the device needs it. (Electromagnetic field coupling)
- » We don't need a power source on RFID tags.

- **Kinds of RFID: Passive and Active**

- » **Passive RFID:** RFID tags have neither an electric plug nor a battery. Instead, all of the energy needed to operate them is supplied in the form of radio waves by RFID readers. This technology is called passive RFID.
- » **Active RFID:** Here, there is a power source on the tag.

- **Advantages:**

- » Data can be read from longer distance. (for e.g., even if the tag is high, relatively inaccessible place) etc.
- » Multiple tags can be read at once -> it obviates the need to hold item one by one in order to read the data.
- » Data can also be read from outside the box unlike barcode/ QR code (without opening the box). It is also immune to things like dirt.
- » A passive type RFID can be used semi-permanently without a battery.
- » Since tag contains a memory, the data can be rewritten.

- **Applications:**

- » It enables efficient inventory count at logistics center, backyard, and storefront.
- » Incoming and outgoing record (e.g. FASTag at toll booths)
- » **Brand Protection:** It is a useful tool to prevent grey market and counterfeit products of luxury brands.
- » Tracking: Personnel, asset etc.
- » **Smart Keys** (for doors)

- **Disadvantages:**

- » It takes longer to program an RFID tag (compared to QRCode)
- » RFID can be intercepted easily, even if its encoded.
- » **Foil (2-3 layers of household foil)** can dam the radio waves
- » Privacy concerns: Anybody can access information about anything

5. NEAR FIELD COMMUNICATION

- **What is NFC and How does it work?**

- It is a short-distance wireless communication technology. When two NFC enabled devices are very close to each other (around 4 cm), then they can communicate with each other using radio waves.
 - » **Atleast one of the device should be active device** like smart phone, tablet, or post terminal. Please note that the active device would need an external power supply. The other device may be active or passive (for e.g. NFC tags). Passive device is powered by the electromagnetic field of the active device.
- **NFC supports three modes of communications:**
 - » **Peer to Peer communication mode**
 - E.g., when we share information between two smart phones.
 - In this mode, both devices are active devices. They can communicate with each other by generating radio waves alternatively. When one device transmits data, the other listens to it and vice-versa.
 - » **Reader/Writer Mode:**
 - E.g. when we access data from smart phones using NFC tags.
 - This mode is similar to RFID. Here the active device like smartphones and tablets reads or writes the data on NFC tag using the principle of electromagnetic induction. A time varying electromagnetic field generates the voltage in this passive tag. This voltage powers up the chip in this NFC tag. Once powered up the tag responds with its own information.
 - » **Card Emulation Mode**

- E.g. when smartphones are used for mobile payments.
- Both devices are active device. One device will be a smart phone and the second device is a payment terminal. Here, smartphone acts like a passive smart card and don't generate their own radio waves. They only respond back with the requested data by the payment terminal. Operating principle in this mode is similar to reader/writer mode.

- Applications

- **File sharing**
- **Contactless payments:** NFC is behind the cards that we have over card readers on shops
- **Mobile payments**
- **Pairing different devices**
- **Information sharing using smart posters and business cards**
- **Home automation**
 - » NFC tech is present in new age speakers, household appliances, and other electronic devices that we monitor and control through our smartphones.
 - » E.g. changing temperature of AC, ambient lighting etc.
 - » Automatic closing of doors
- **Healthcare:** NFC is used to monitor patients stats through NFC-enabled wristbands.
- **Library systems:** Keeping tabs on library books
- **Preventing Auto theft**
- **Personal usage**
- **Running unmanned toll booths**
- **Wireless charging**

- Advantages over other forms of communication.

- **NFC vs Bluetooth:** While Bluetooth provides for higher data rate sharing; But **NFC reduces the time required for pairing of devices**. In case of NFC the two devices can be set up in less than 0.1 seconds. Once the pairing between devices is done, for communications either Bluetooth or wifi can be used.
- **NFC vs RFID:** NFC is derived from RFID standards and the working principles are quite similar to RFID. But RFID works on large band of frequencies (LF: 125 kHz or 134 kHz) HF: 13.56 MHz; UHF: 860-960 MHz). But **NFC works on a particular frequency band** i.e. 13.56 MHz band. In case of RFID, the reader sends the request to the RFID tag and in response the RFID tag replies back to the reader. So, in case of RFID there is only one way communication. While in case of **NFC peer to peer communication is possible**.
- **NFC vs QR Codes:** In case of QR codes, scanning if required to access the information. In case of NFC, just by tapping mobile to NFC tag, information can be easily accessed. Therefore, access time required in case of NFC is less than that of QR code. Further NFC is more secure than the QR code. Because in case of QR code, wrong information may be provided by putting another QR code on top of the 1st QR code, while in case of NFC, if someone puts another NFC tag on top of the first one, then neither of the tags would be accessed. Thus, NFC tech is more secure than the QR code technology.

- How secure is this tech?

- Since NFC works at very close distance, it makes it difficult for attackers to record or communication between the devices compared to other wireless technologies.
- The user of the NFC-enabled device determines by the touch gesture which entity the NFC communication should take place with, making it more difficult for the attacker to get connected.

- Peer to Peer communication provides a mechanism to cipher all exchanged data to avoid external interpretation of recorded communication.
- When did NFC tech start?
- In 2004, consumer electronics companies, Nokia, Philips, and Sony together formed the NFC forum, which outlined the architecture for NFC technology to create powerful new consumer driven products.

A) 'TAP TO PAY' FOR UPI LAUNCHED BY GOOGLE PAY

- Google has recently launched a new feature in India, 'Tap to pay for UPI', in collaboration with Pine Labs. The feature makes use of Near Field Communication (NFC) technology.
- The functionality would allow users with NFC-enabled Android Smartphones and UPI accounts linked to Google Pay to carry out transactions just by tapping their phone on any Pine Labs Android point-of-sale (POS) terminal across the country. Till now, Tap to pay was only available for cards.
- Google Pay has been the first among UPI apps to bring Tap to Pay feature working on POS terminals.
- How will this work?
 - Once the users tap their phones on the POS terminal, it will automatically open the Google pay app with the payment amount pre-filled. Users can then verify the amount and merchant name and authenticate the payment, using their UPI PIN.
 - They will be notified when the payment is successful.
 - Advantage: The process is much faster compared to scanning a QR code or entering UPI-linked mobile number which has been the conventional way till now.
- Are other companies using NFC tech for payments using smartphones?
 - In Feb 2022, Apple introduced Tap to Pay on the iPhone. It will allow merchants across the US to use their iPhone to accept Apple Pay, contactless credit and debit cards, and other digital wallets through a tap on their iPhone without the need of any additional hardware or payment terminal.

At checkout, a customer just needs to hold their iphone or apple watch to pay with Apple Pay, their contactless credit or debit card, or other digital wallet near the Merchant's iphone to complete the payment using NFC technology.

6. BLUETOOTH COMMUNICATION

- Bluetooth is a wireless communication technology that can be used for close range of data transmission from one digital device to another. It relies on short-range radio frequency, and any device that incorporates the technology can communicate as long as it is within the required distance.
- It is essentially a one-to-one wireless connection that uses 2.4 GHz band radio waves. This is the same frequency which other wireless technologies in the home or office, such as cordless phones and WiFi routers use.
- Bluetooth creates a 10 meter (33 foot) radius wireless network, called a personal area network (PAN) or piconet, which can network between 2 to 8 devices.
- It is an electronics "standard", which means that manufacturers that want to include this feature have to incorporate specific requirements into their electronic device.

These specifications ensure that the devices can recognize and interact with other devices that use Bluetooth technology.

The "Bluetooth" name is taken from a 10th-century Danish king named Harald Bluetooth, who was said to unite disparate, warring regional factions. Like its namesake, Bluetooth technology brings together a broad range of devices across many different industries through a unifying communication standard.

- **Advantages:**

- Bluetooth offers a uniform structure for a wide range of devices to connect and communicate with each other.
- It has achieved global acceptance and almost any Bluetooth enabled device, anywhere in the world can connect to another Bluetooth enabled device nearby.
- Low power consumption when compared to wifi and other such wireless systems.
- It also costs much less to implement.



TARGET PRELIMS 2024

BOOKLET-8; S&T-8

BIOLOGY BASICS

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1. CELL: FUNDAMENTAL UNIT OF LIFE

1) WHY IS CELL THE FUNDAMENTAL UNIT OF LIFE?

- Cell is the fundamental structural and functional unit of living organisms i.e. it is the smallest living unit of an organism. Thus, it is also the basic fundamental unit of life.
- Every cell is capable of doing some basic things like respiration, obtaining nutrition, and clearing the waste material, or forming new proteins.

2) SHAPES OF CELLS

- With the discovery of electron microscope in 1940, it was possible to observe and understand the complex structure of the cell and its various organelles.
- The shapes and sizes of the cells are related to the specific function they perform. Some cells like Amoeba have changing shapes. Cells shape can be very peculiar. For example, nerve cells have a typical shape.
- **Some organism can have cells of different types**
 - For example, humans have different types of cells

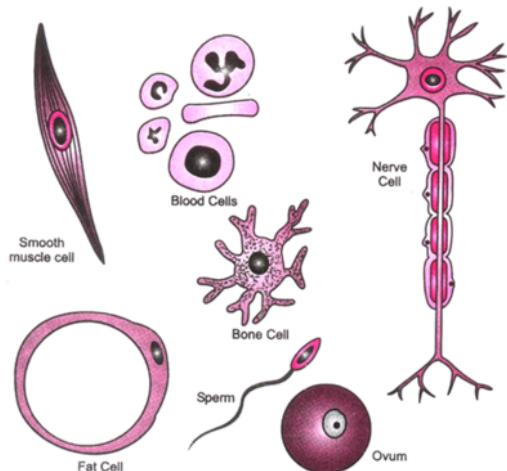


Figure : VARIOUS CELLS FROM THE HUMAN BODY

3) TWO BROAD CATEGORIES OF CELLS – EUKARYOTES AND PROKARYOTES

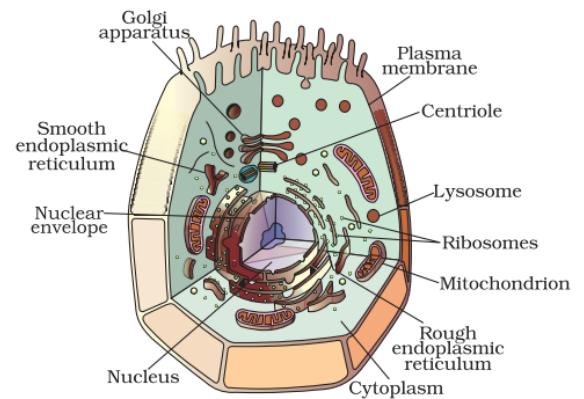
- The difference between the structures of Prokaryotes and Eukaryotes is so great that it is considered to be the most important distinction among group of organisms.
 - i. **Eukaryotic**
 - They have membrane bound organelles such as nucleus.
 - They are advanced cells found in plants and animals
 - They are usually found in multi-cellular animals. But there are a lot of unicellular Eukaryotes too.
 - ii. **Prokaryotic**
 - They don't have nucleus or other well-defined organelles. They do have genetic material, but it is not contained within a nucleus.
 - They are found in primitive cells like that of bacteria and Archaea.
 - Prokaryotic cells are always unicellular such as bacteria. But there is some evidence that some bacterial species can aggregate together and divide labor so that the "colony" is working more

efficiently. This is the characteristic of a multi-cellular organisms, but there is still a lot of resistance to the idea of calling these prokaryotes multi-cellular.

- Prokaryotes are usually much smaller than Eukaryotes.

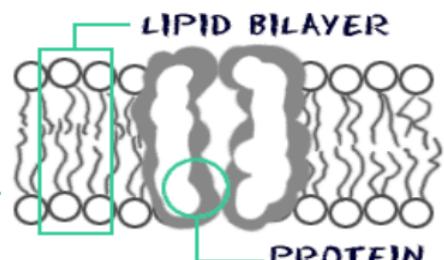
4) STRUCTURAL ORGANIZATIONS OF CELL

- Every living cell has the capacity to perform certain basic functions that are characteristics of all living forms. There is a division of labour seen within a single cell. The cell components called the cell organelles have specialized functions.
- These functions include making new material in the cell, clearing up the waste material from the cell and so on.
- These organelles together constitute the basic unit called the cell. It is interesting to note that all cells are found to have the same organelles, no matter what their function is or what organism they are found in.
- **Three Broad components of the cell**
 - **Plasma Membrane or Cell Membrane**
 - **Nucleus**
 - **Cytoplasm**



A) PLASMA MEMBRANE OR CELL MEMBRANE

- Cell membrane/Plasma membrane is the outermost covering of the cell that separates the contents of the cell from its external environment.
- It allows or permits the entry or exit of some materials in and out of the cells. It also prevents movement of some other materials. The cell membrane is therefore called **selectively permeable membrane**.
- Cell membrane is not a solid structure. Cell membranes are also described as lipid bilayers.
- There are two layers of phospholipids with protein embedded in the layers.
- **How does diffusion of substance take place into the cell?**
 - **Diffusion**
 - Continuous movement of a substance from a region of high concentration to a region where its concentration is low.
 - E.g.: O₂ enter the cell by the process of diffusion when the level of concentration of O₂ inside the cell decreases.
 - CO₂ moves out of the cell when the level of concentration of CO₂ inside the cell increases.



- 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.**

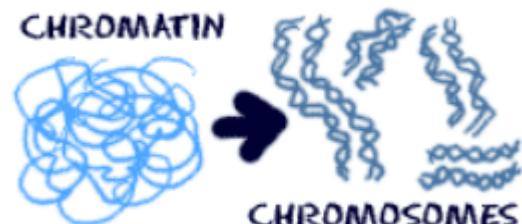
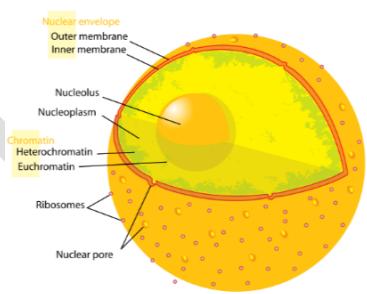
B) NUCLEUS

- 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.

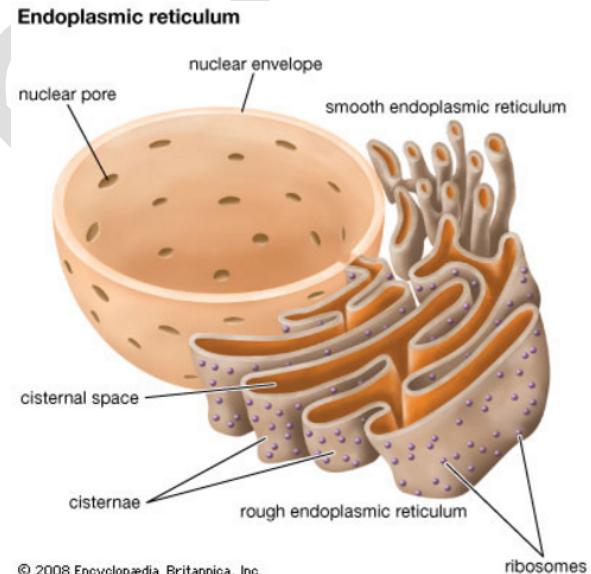
C. Significance of membranes

- 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.



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▪ Smooth Endoplasmic Reticulum (SER)

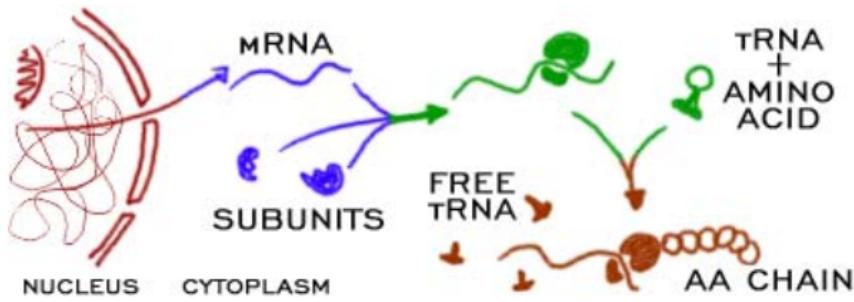
- SER help in manufacturing of fat molecules, or lipids, important for cell function.
 - They are mostly shaped like tubes.
 - Some of these lipids help in building of cell membrane. This process of known as membrane **biogenesis**.
 - Some other proteins and lipids function as enzymes and hormones.
-
- 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

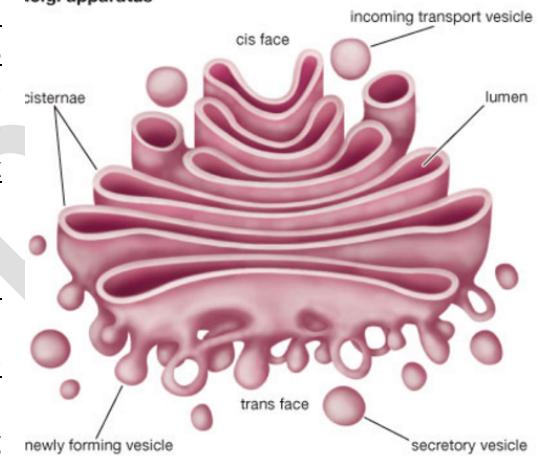
be used in the cell and some will be sent out into intercellular-space.

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.



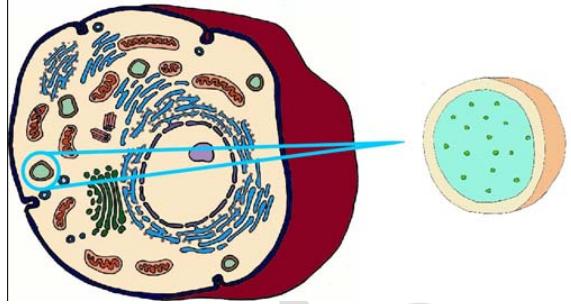
D. Lysosomes

- **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.

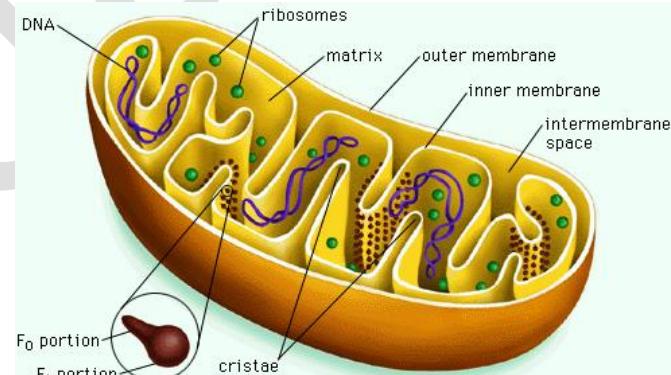
E. Mitochondria

- 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 (Ca^{2+}) ions within cell.



F. PLASTIDS (not found in animal cells)

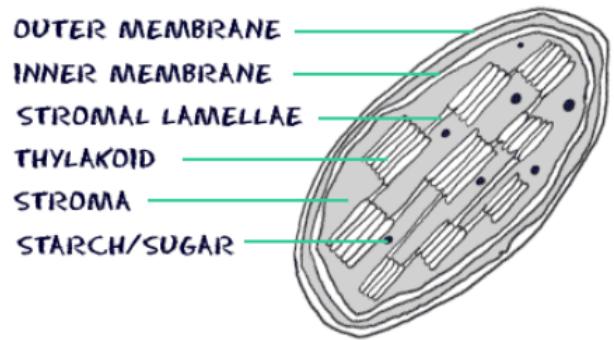
- Structures:

- 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.

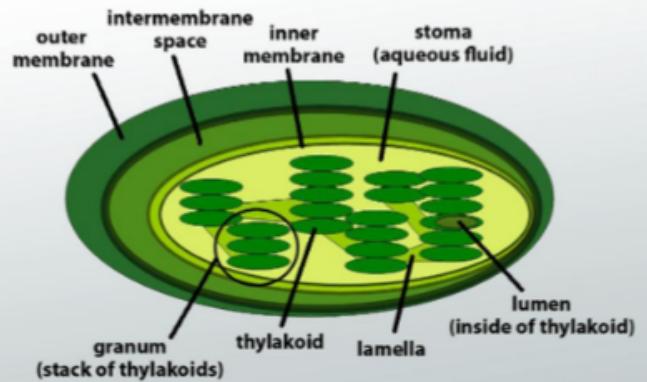


- **Chloroplasts:** Plastids containing the green pigment chlorophyll are known as chloroplasts.

- 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.

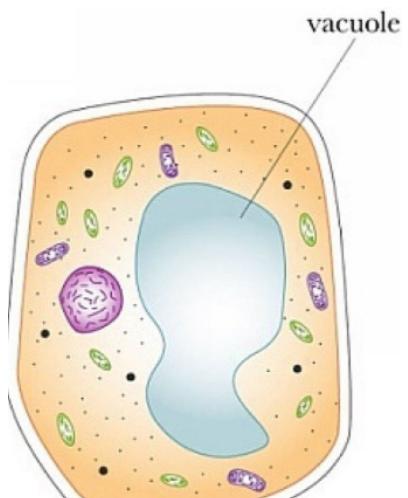
G. Vacuoles

- **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

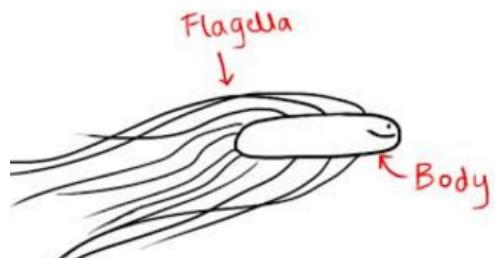
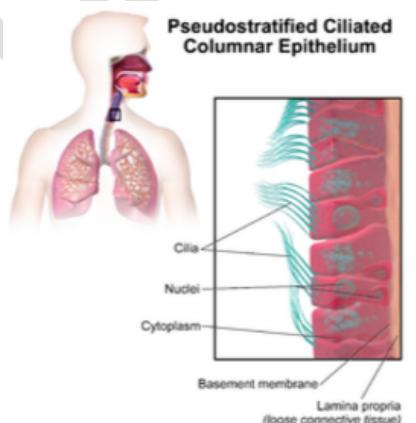
H. **Cytoskeleton** (Not organelles)

- 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.

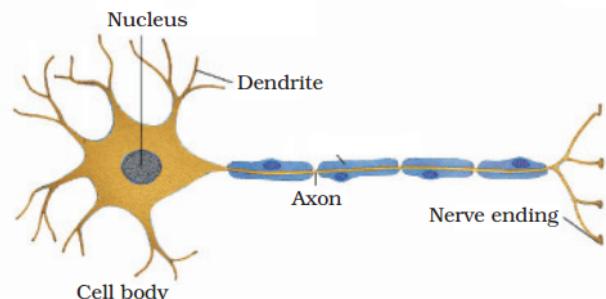
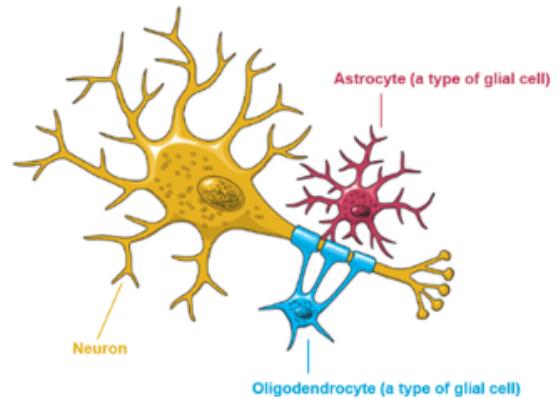


Figure 2.1: A neuron unit of nervous tissue

- 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).

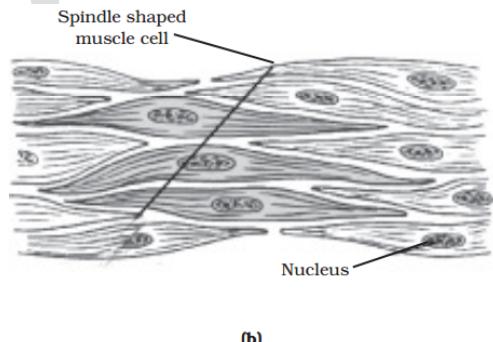
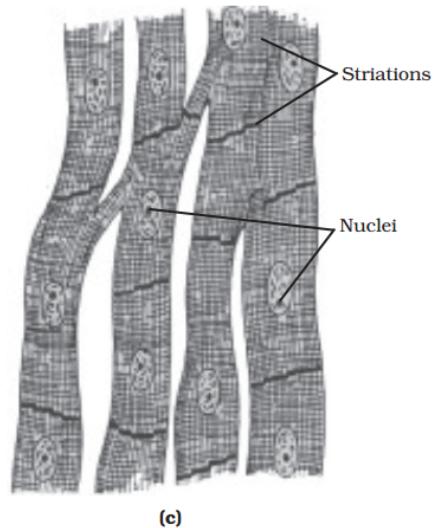


Figure 2.3: Striations



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

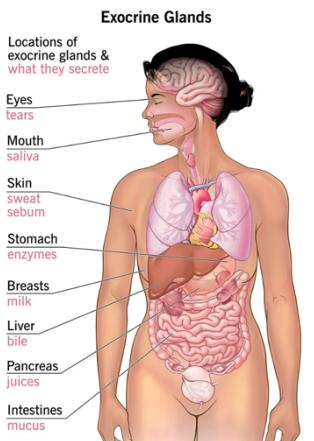
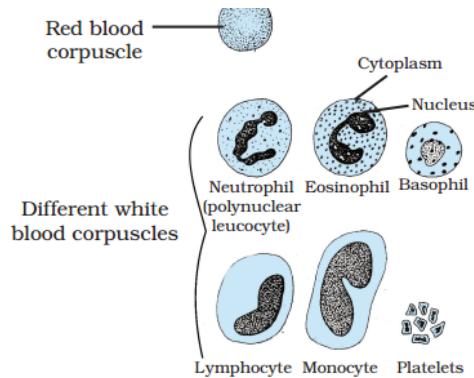
- The covering or protective tissues in animal body are epithelial tissues.
 - It covers most organs or cavities within the body.
 - **This protects** our deeper layers of tissues from injury or infection
 - E.g.: Lining of stomach with epithelial cells that produce mucus -> we don't digest our stomach 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.

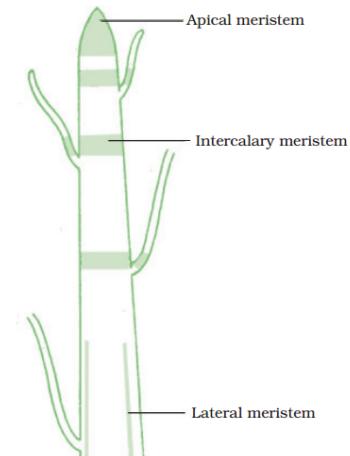


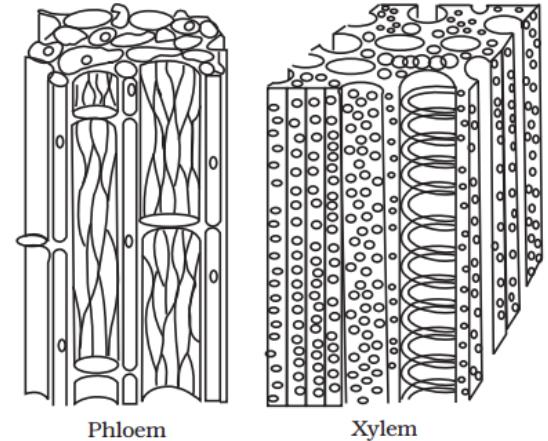
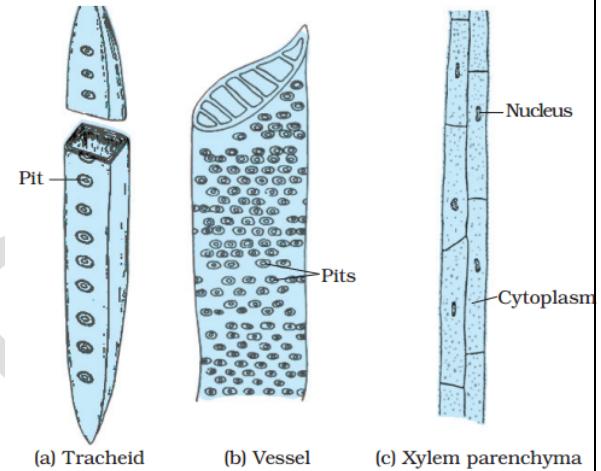
Fig. 6.2: Location of meristematic tissue in plant body

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

Parent 1	AB	AB	AB	AB	B	A	A	O	O	O
Parent 2	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.

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BIOTECHNOLOGY

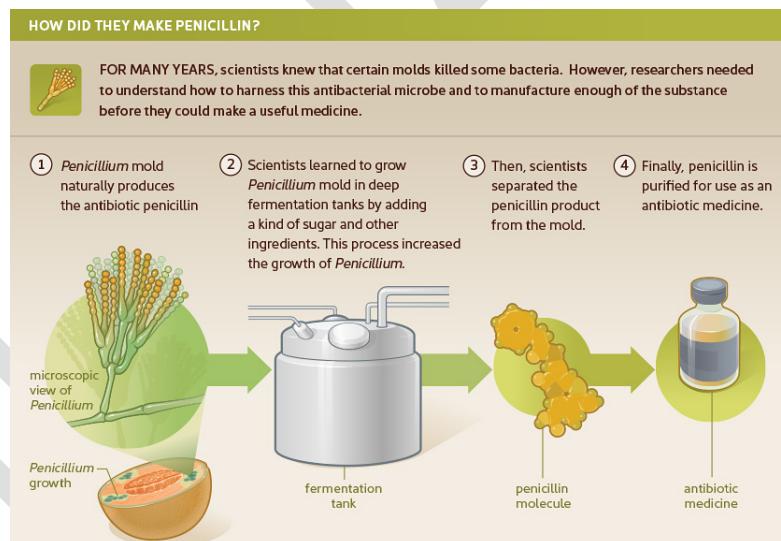
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1. INTRODUCTION

- **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

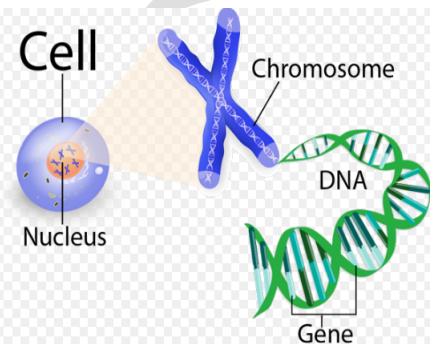
- Most living organisms have DNA as genetic material, DNA (Deoxyribonucleic Acid).
 - Some viruses have RNA as genetic material (e.g. Tobacco Mosaic viruses, QB bacteriophage, etc.)

- 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.

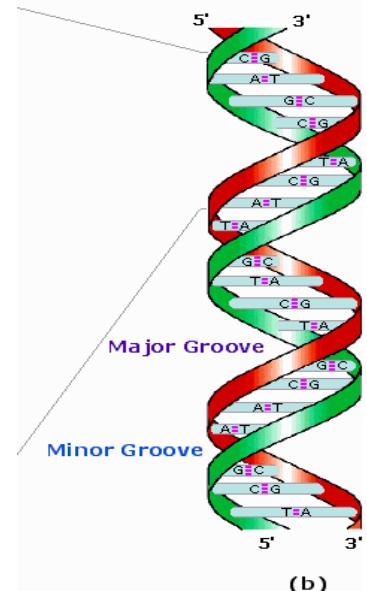


Gene Mapping

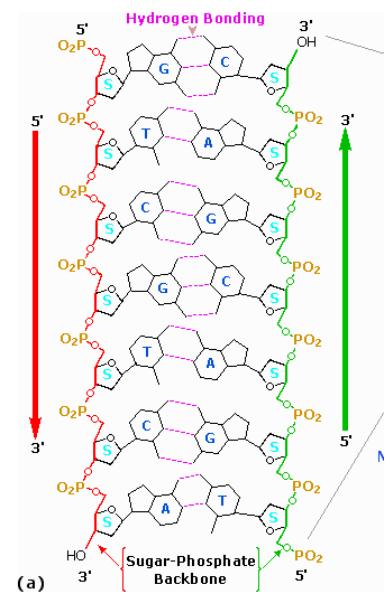
- Determining the gene's functionality and position of the gene in the chromosome is called gene mapping.

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 **3.3×10^9 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.

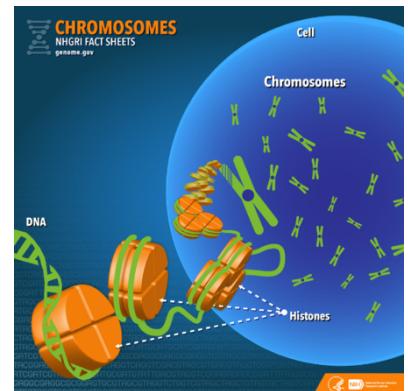
b) DNA BARCODING

- **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

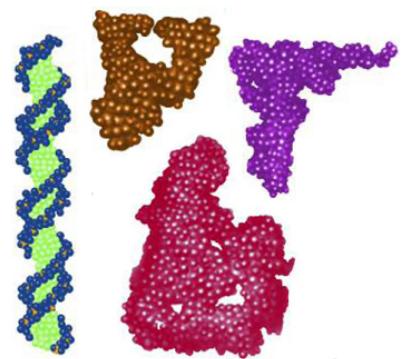
C) CHROMOSOMES

- 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.

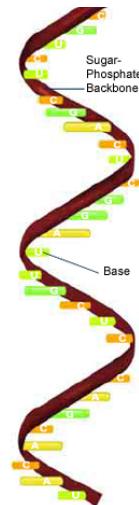


*RNA comes in a variety of different shapes.
Double-stranded DNA is a staircase-like molecule.
Image Credit: National Institute of General Medical Sciences*

- 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

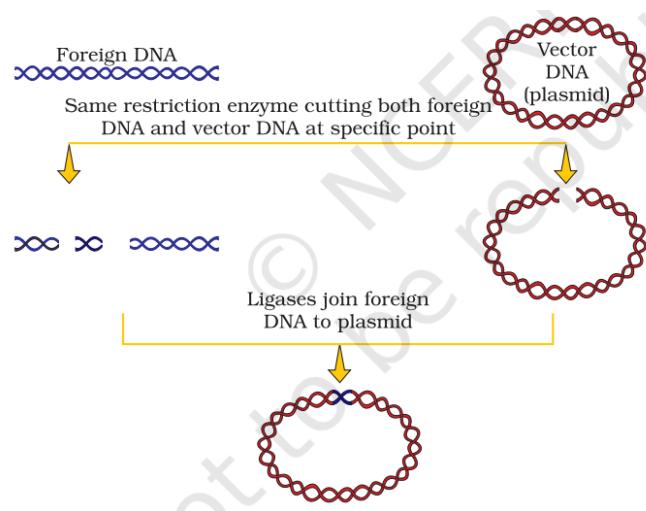
- » To enable growth of only the desired microbe / eukaryotic cell in large quantities for the manufacture of biotechnological products like antibiotics, vaccines, enzymes etc

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

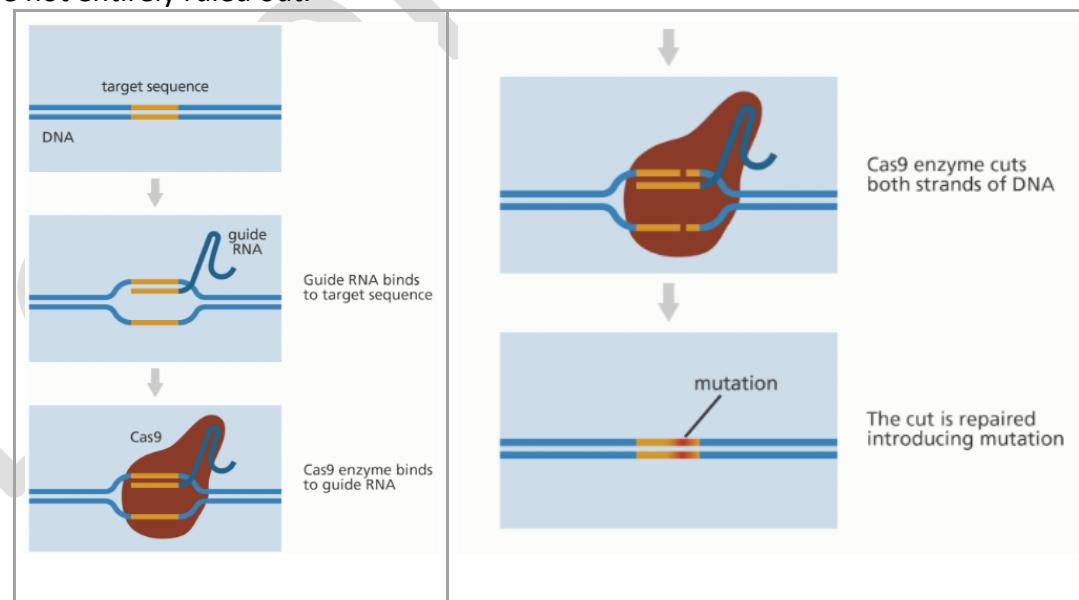
flags to precisely target and cut any foreign DNA, thus protecting the bacteria from future attacks by similar bacteriophages.

- 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
- 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**

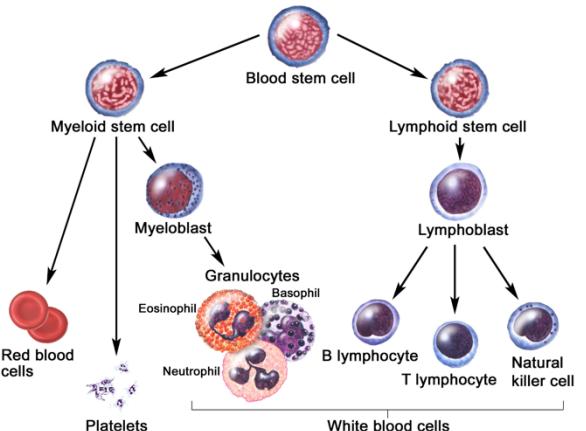
which were caused by so-called single point mutations, or when a change in a single base pair can cause terminal disease.

- 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 2/3rd 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.
 - i) **21 reduced height genes** in wheat Rht1 – Rht21, have been described so far.
 - ii) 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:**
 - a) 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.
 - b) 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 23rd 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)

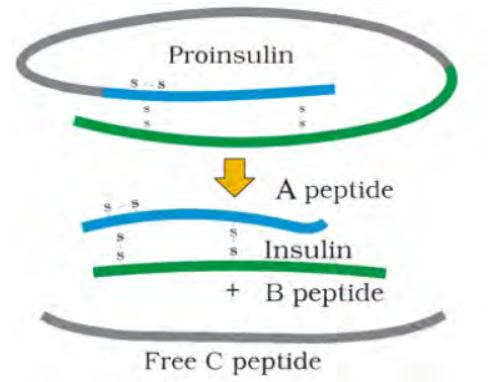
- For e.g., various vaccines for COVID-19 were developed with the help of biotechnology – mRNA vaccines, vaccines with attenuated virus

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.

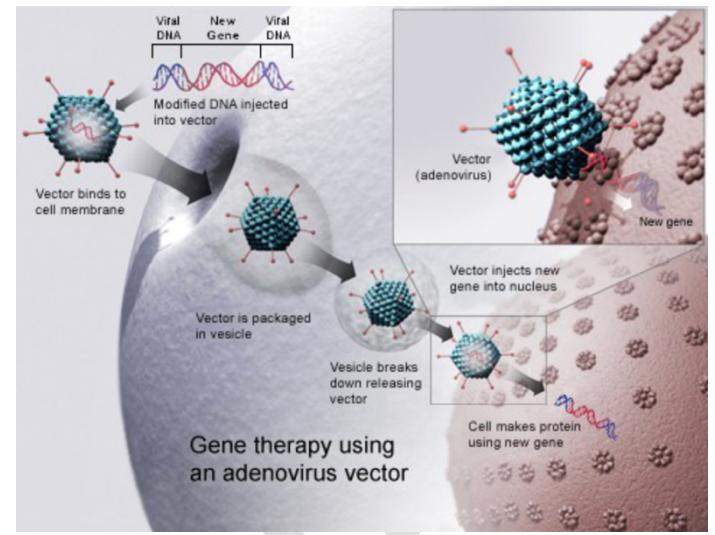
D) GENE THERAPY

- 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 1/10th 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 (α -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"> 1. Researchers using Carbon 14 isotope 2. X-Ray Technician 3. Coal Miner 4. Dyer and Painter <p>Select the correct answer using the codes given below:</p> <ol style="list-style-type: none"> A. 2 alone B. 1, 2 and 3 C. 1, 2 and 4 D. 1, 3 and 4
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"> (a) Protein analysis (b) Chromosome counting (c) Quantitative analysis of DNA (d) DNA fingerprinting
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"> (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
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"> (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
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"> 1. The only source of human stem cells are the embryos at blastocyst stage 2. The stem cells can be derived without causing destruction to blastocyst 3. The stem cells can regenerate themselves in vitro virtually forever 4. Indian research centres also created a few cell lines which can be developed into many types of tissues <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"> 1. It is possible to know pedigree of livestock. 2. It is possible to understand the causes of all human diseases. 3. It is possible to develop disease-resistant animal breeds. <p>Which of the statements given above are correct?</p> <ol style="list-style-type: none"> a. 1 and 2 only b. 2 only c. 1 and 3 only d. 1, 2 and 3 only
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"> (a) to make it pest-resistant (b) to improve its taste and nutritive qualities (c) to make it drought resistant (d) to make its shelf-life longer
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"> 1. Stem cells can be derived from mammals only 2. Stem cells can be used for screening new drugs 3. Stem cells can be used for medical therapies <p>Select the correct answer using the codes given below:</p> <ol style="list-style-type: none"> (a) 1 and 2 only (b) 2 and 3 only (c) 3 only (d) 1, 2 and 3
13	<p>What are the reasons for the people's resistance to the introduction of Bt brinjal in India (2012)</p> <ol style="list-style-type: none"> 1. Bt Brinjal has been created by inserting a gene from a soil fungus into its genome 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 3. There is an apprehension that the consumption of Bt Brinjal may have adverse impact on health 4. There is some concern that the introduction of Bt brinjal may have adverse effect on the biodiversity <p>Select the correct answer using the codes given below:</p>

	<ul style="list-style-type: none"> a. 1, 2 and 3 only b. 2 and 3 only c. 3 and 4 only d. 1, 2, 3 and 4
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"> 1. To enable them to withstand drought 2. To increase the nutritive value of the produce 3. To enable them to grow and do photosynthesis in spaceships and space and space stations 4. To increase their shelf life <p>Choose the correct answer from the codes provided below:</p> <ul style="list-style-type: none"> A. 1 and 2 only B. 3 and 4 only C. 1, 2 and 4 only D. 1, 2, 3 and 4
15	<p>Recombinant DNA technology (Genetic Engineering) allows genes to be transferred (Pre 2013)</p> <ul style="list-style-type: none"> 1. Across different species 2. From Animals to plants 3. From microorganisms to higher organisms <p>Select the correct answer using the codes given below:</p> <ul style="list-style-type: none"> a. 1 only b. 2 and 3 only c. 1 and 3 only d. 1, 2 and 3
16	<p>The Genetic Engineering Appraisal Committee is constituted under the: [Prelims 2015]</p> <ul style="list-style-type: none"> (a) Food Safety and Standards Act, 2006 (b) Geographical Indications of Goods (Registration and Protection) Act, 1999 (c) Environment (Protection) Act, 1972 (d) Wildlife (Protection) Act, 1972
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"> a. A range of enzymes used in genome editing b. The full range of mRNA molecules expressed by an organism

	<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>Consider the following pairs: [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"> 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 2. GM Mustard has the genes that allow the plant cross-pollination and hybridization 3. GM Mustard has been developed jointly by IARI and Punjab Agricultural University <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>What is cas9 protein that is often mentioned in news ? (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"> 1. Assess the age of a plant or animal. 2. Distinguish among species that look alike. 3. Identify undesirable animal or plant materials in processed foods. <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

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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)
Fertility and Family Planning			
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
Maternity and Delivery Care			
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
Child Vaccination and Child Feeding Practices			
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
Infant and Child Mortality Rates (per 1000 live births)			
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)

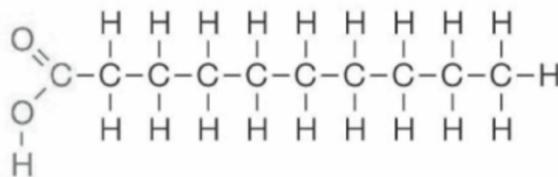
- According to the World Health Organization, approximately 5.4 lakh deaths take place each year globally because of the intake of industrially produced trans fatty acids. They come in both natural and artificial forms.
- Trans fats are the result of **partial hydrogenation of unsaturated fat**. This 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

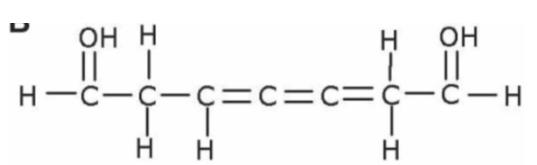
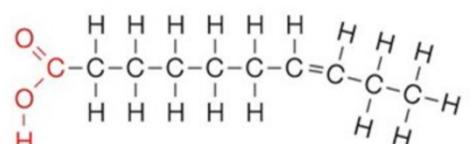


- Common **source** of saturated fats are red meat, whole milk and other whole milk dairy products, coconut oils etc.
- **Health Impacts**
 - Can drive harmful LDL cholesterol.
 - But recent research, have again raised the debate whether saturated fats are actually harmful and cause heart disease.

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



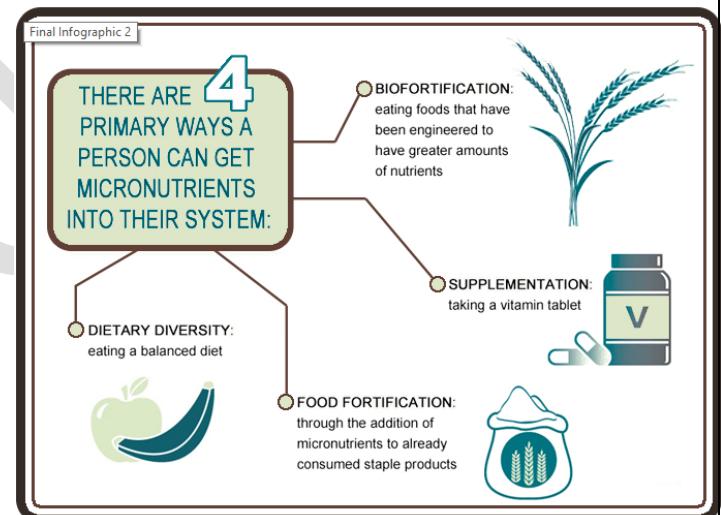
Polyunsaturated fatty acid

- 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"> - Rickets is characterized by <u>weak and soft bones, bowed legs and bone deformities</u>. - <u>Fish, fortified dairy products, liver, oil and sunlight</u> are some rich sources of vitamin D.
Osteoporosis	Vitamin D with Calcium	<ul style="list-style-type: none"> - 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. - <u>Bananas, spinach, milk, okra, soy and sunlight</u> are natural sources of Vitamin D and calcium that act to eliminate this deficiency
Pellagra	Vitamin B3 or Niacin	<ul style="list-style-type: none"> - 4D's: Dementia, diarrhea, dermatitis and death are the four Ds that characterize Pellagra. - <u>Tuna, whole grains, peanuts, mushrooms, chicken etc.</u>
Scurvy	Vitamin C or ascorbic acid	<ul style="list-style-type: none"> - Scurvy basically <u>inhibits the production of collagen</u> in the body which is the <u>structural protein that connects the tissues</u>. - <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 - Vitamin C can be derived from <u>Citrus fruits</u> like oranges, lemon, strawberry etc. and <u>Broccoli</u> regularly.
Beri-Beri	Vitamin B1 or Thiamin	<ul style="list-style-type: none"> - The most common symptoms of this illness are <u>altered muscle coordination, nerve degeneration and cardiovascular problems</u>. - <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

Xerophthalmia or Night Blindness	Vitamin A	<ul style="list-style-type: none"> - 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> - In worsened situations, night blindness can <u>aggravate to complete loss of vision</u> - 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>
Goitre	Iodine	<ul style="list-style-type: none"> - 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> - 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.
Anaemia	Iron	<ul style="list-style-type: none"> - 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>. - 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. -
Kwashiorkor	Protein and Energy	<ul style="list-style-type: none"> - It is characterized by anorexia, <u>an enlarged liver, irritability and ulcerating dermatoses</u>. - These are one of the <u>nutritional deficiencies in children, especially from famine-struck areas</u> and places with poor food supply, Kwashiorkor is caused by malnutrition. - A healthy and balanced diet enriched with protein and carbohydrate sources like eggs, lentils, rice etc helps combat this problem
Depression	deficiency of Vitamin B7 or biotin	<ul style="list-style-type: none"> - This deficiency can be <u>fatal if present in an aggravated form</u>. - <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

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

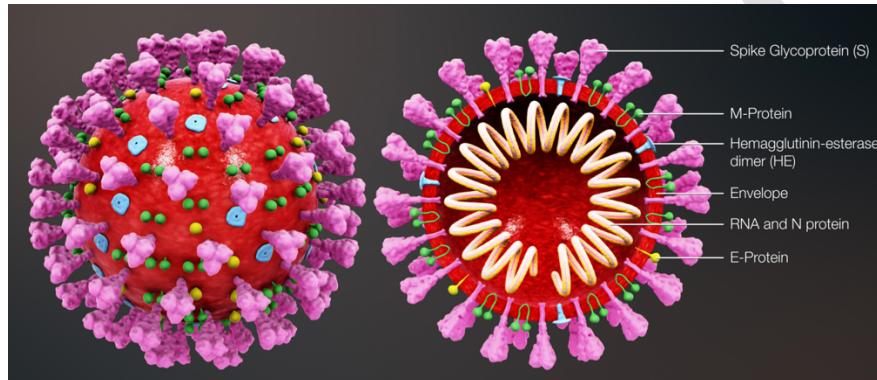
9. COVID-19

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.

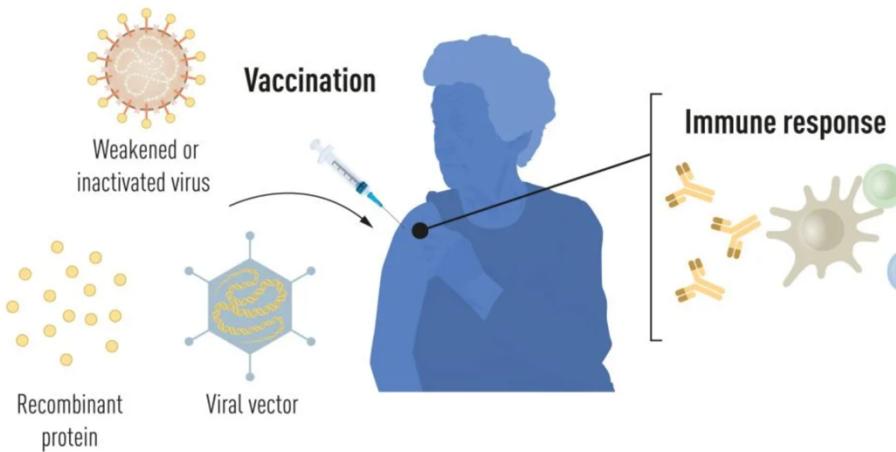
C) RECENT MUTATIONS IN NEWS:

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.

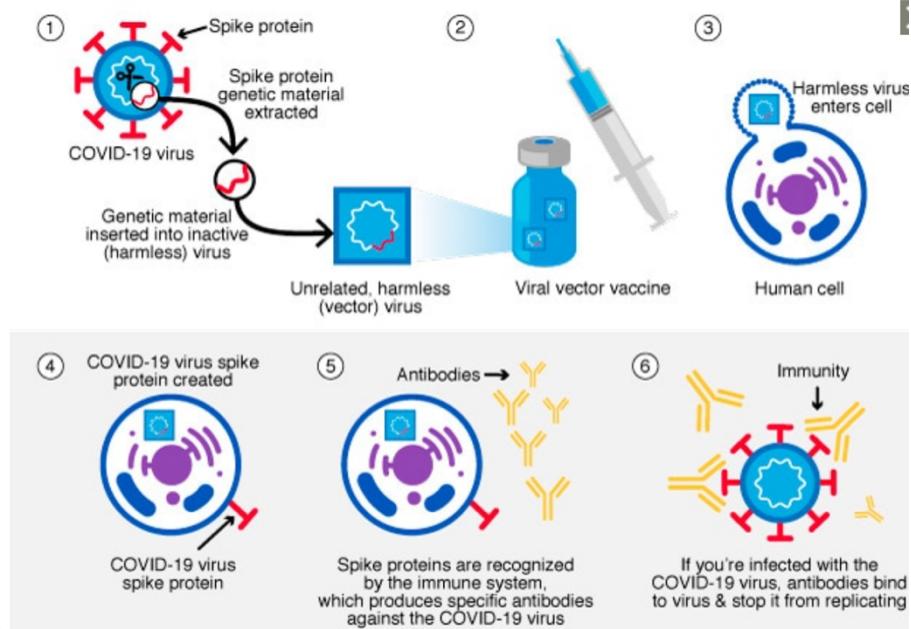
10. VARIOUS TYPES OF VACCINES:

- 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.

In vitro transcription	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
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- 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.

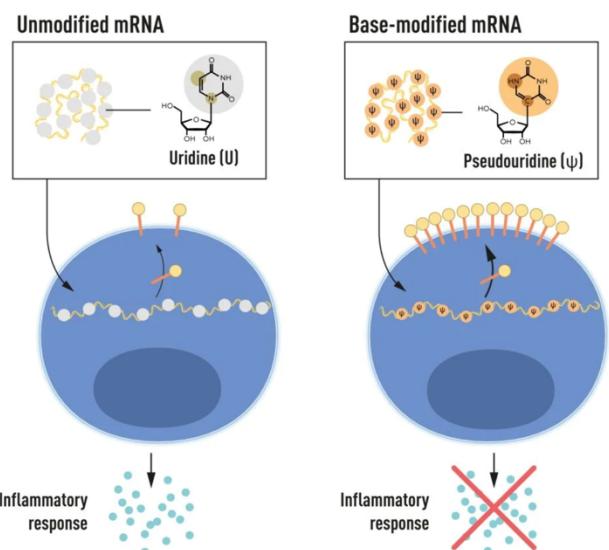


Figure 2. mRNA contains four different bases, abbreviated A, U, G, and C. The Nobel Laureates discovered that base-modified mRNA can be used to block activation of inflammatory reactions (secretion of signaling molecules) and increase protein production when mRNA is delivered to cells.

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- **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:**

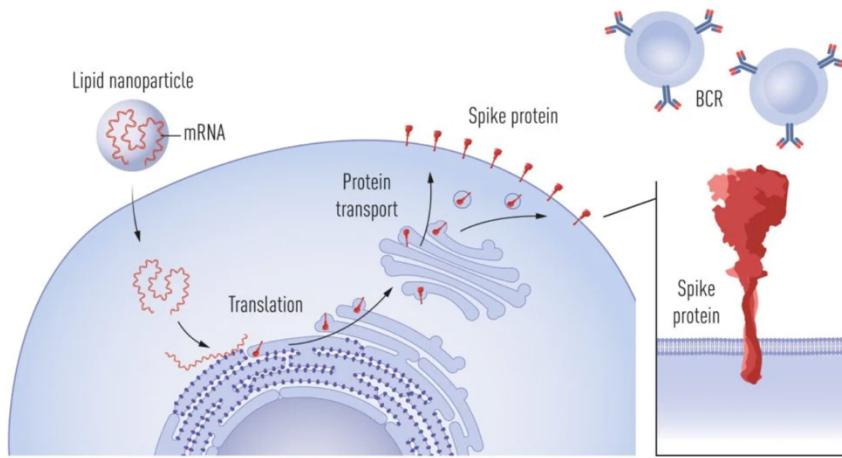


Figure 4. Spike production following mRNA vaccination and recognition of spike by B cells.
Following uptake of mRNA into cells, facilitated by lipid nanoparticles, the mRNA acts as a template for spike protein production. Spike is then transiently expressed on the cell surface, where it is recognized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

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- 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 (28th 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

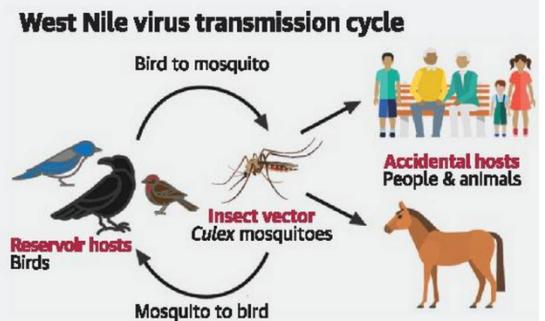
12) ACUTE ENCEPHALITIS SYNDROME (AES)

- **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.