VTU Question – June 2025

Biology for Engineers – BBOK407

		Module 1	M	L	C
Q.1	a	What are Nucleic acids? Mention its properties and functions.	10	L3	CO1
	b	Write a short note on all the four types of stem cells.	10	L2	CO1
		Or			
Q.2	a	Explain the similarities and differences between plant and animal cell.	10	L3	CO1
	b	Explain the properties and functions of hormones.	10	L2	CO1
		Module 2			
Q.3	a	Explain the application of carbohydrates as cellulose-based water filters, mention its advantages.	10	L3	CO2
	b	Write a short note on PLA as bioplastic.	10	L2	CO2
		Or			
Q.4	a	Explain the DNA vaccine for rabies.	10	L3	CO2
	b	Discuss the following I. Meat analog of proteins II. Lipids as cleaning agents	10	L2	CO2
		Module 3			
Q.5	a	Explain eye as a camera system.	10	L3	CO3
	b	Describe the architecture of lungs and gas exchange mechanism.	10	L2	CO3
		Or			
Q.6	a	Explain the kidney as filtration system.	10	L3	CO3
	b	Write a short note on Chronic Obstructive Pulmonary Disease (COPD).	10	L2	CO3
		Module 4			
Q.7	a	Write a short note on: (i) Lotus Leaf effect (ii) Shark skin	10	L2	CO4
	b	Illustrate the HBO's and PFC's as human blood substitutes.	10	L2	CO4
		Or			
Q.8	a	Write a short note on: (i) Photovoltaic cells (ii) Bionic leaf	10	L2	CO4
	b	Describe the engineering applications of GPS and Velcro technology.	10	L2	CO4
		Module 5			
Q.9	a	Analyze the bio-engineering solutions for muscular dystrophy and osteoporosis.	10	L2	CO5
	b	Write a short note on self-healing bio-concrete.	10	L2	CO5
		Or			
Q.10	a	Examine the bioimaging and artificial intelligence for disease diagnosis.	10	L2	CO5
	b	Explain the process of biomining via microbial surface adsorption.	10	L2	CO5

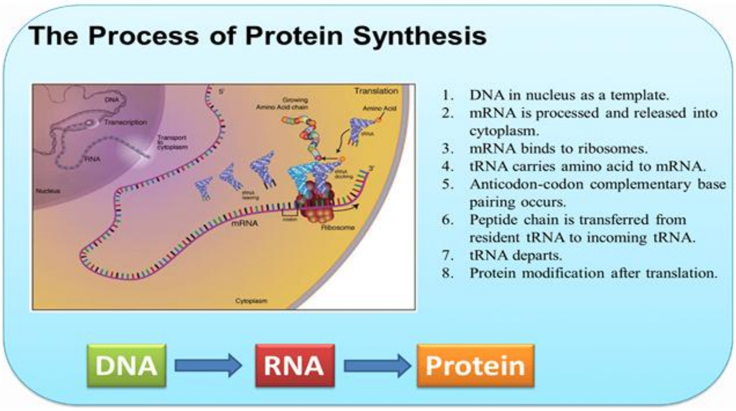
<u>**Module – 1**</u>

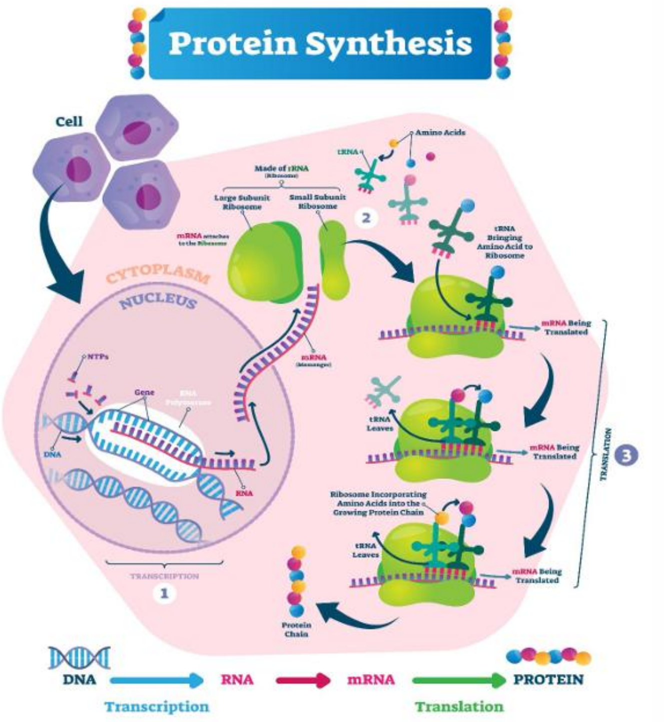
1a. What are Nucleic acids? Mention its properties and functions.

Nucleic acids

Nucleic acids are biopolymers, macromolecules, essential to all known forms of life. They are composed of nucleotides, which are the monomer components: a 5-carbon sugar, a phosphate group and a nitrogenous base.

The two main classes of nucleic acids are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). If the sugar is ribose, the polymer is RNA; if the sugar is deoxyribose, a version of ribose, the polymer is DNA.





- Nucleic acids are chemical compounds that are found in nature.
- They carry information in cells and make up genetic material.
- These acids are very common in all living things, where they create, encode, and store information in every living cell of every life form on Earth.
- In turn, they send and express that information inside and outside the cell nucleus.
- From the inner workings of the cell to the young of a living thing, they contain and provide information via the nucleic acid sequence.
- This gives the RNA and DNA their unmistakable 'ladder-step' order of nucleotides within their molecules. Both play a crucial role in directing protein synthesis.

1b. Write a short note on all the four types of stem cells.

Stem cells

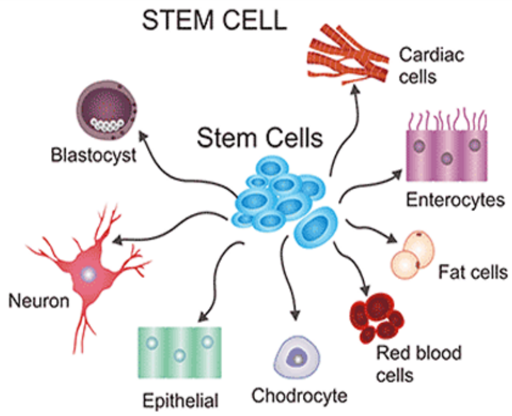
The stem cells can be used to grow a specific type of tissue or organ. This can be helpful in kidney and liver transplants.

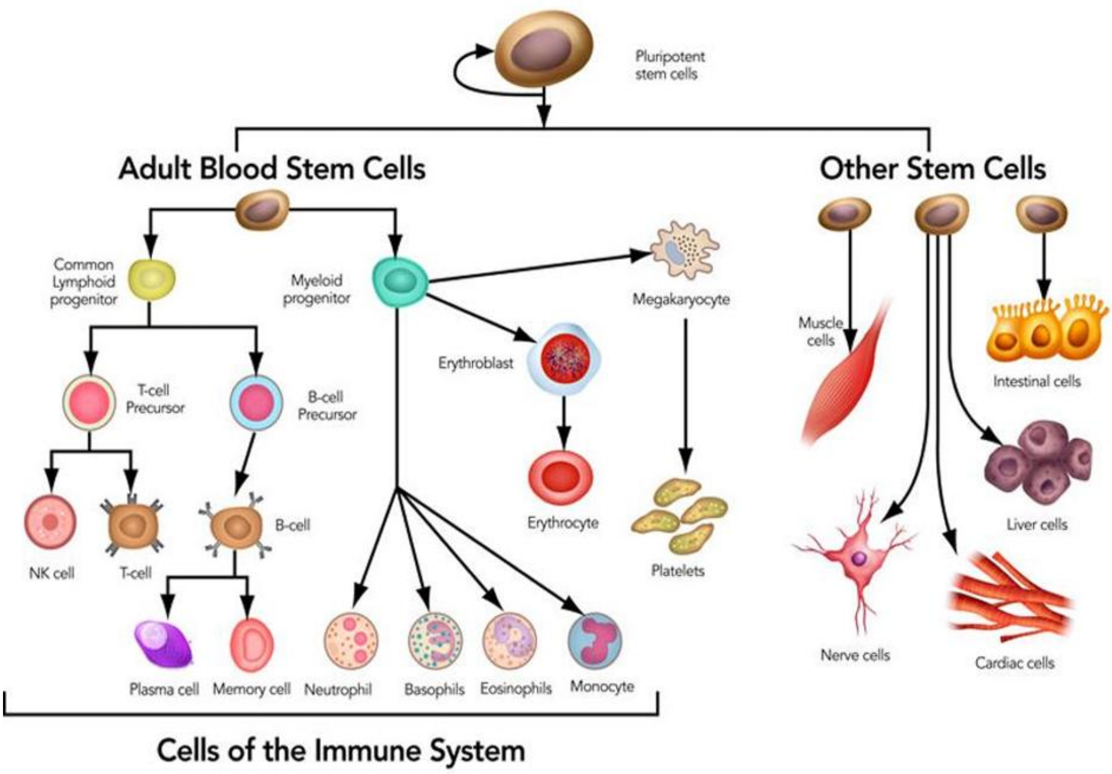
Stem cells have many potential applications in research and medicine, including treating disease, repairing damaged organs, and developing new drugs.

- ❖ **Genetic defects**: Stem cells can help researchers understand what causes genetic defects in cells.
- ❖ **Disease**: Stem cells can help researchers study how diseases develop, including cancer, cardiovascular disease, and neurodegenerative disorders.
- ❖ **Drug safety**: Stem cells can be used to test the safety and effectiveness of new drugs.

Types/ Sources of Stem Cells

1. Embryonic stem cells
2. Adult stem cells (Somatic or Tissue-specific stem cell
3. Induced pluripotent stem cells (iPSCs)
4. Perinatal stem cells
5. Mesenchymal stem cells (MSCs)





Pluripotent stem cells are a type of stem cell that have the ability to differentiate into any cell type within the three primary germ layers:

1.Ectoderm: Skin and nervous tissue
2.Mesoderm: Muscle, bone, and blood cells
3.Endoderm: Internal organs (like the liver and lungs)

This image represents the different pathways of **stem cells**, particularly focusing on **blood stem cells** and their role in immune system cell development, as well as other specialized cells.

1. Pluripotent Stem Cells

These are the master cells capable of differentiating into any cell type in the body.

They give rise to adult stem cells, including **blood stem cells** and **other tissue-specific stem cells**.

2. Adult Blood Stem Cells (Hematopoietic Stem Cells)

These are specialized stem cells responsible for generating blood and immune cells.

They differentiate into two main types of progenitor cells:

- **Common Lymphoid Progenitor**
- **Myeloid Progenitor**

3. Common Lymphoid Progenitor Pathway

Generates cells involved in adaptive immune responses:

- **T-cell Precursor:** Develops into **T-cells** (key in cell-mediated immunity).
- **B-cell Precursor:** Develops into **B-cells**, which produce antibodies.
- **Natural Killer (NK) Cells:** Provide rapid responses to infected cells.
- **Plasma and Memory Cells:** Specialized forms of B-cells.

4. Myeloid Progenitor Pathway

Generates various types of blood cells:

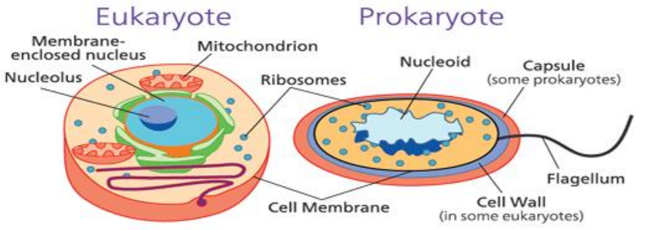
- **Erythroblast:** Develops into **Erythrocytes (Red Blood Cells)** for oxygen transport.
- **Megakaryocyte:** Produces **Platelets** for blood clotting.
- **Neutrophils, Basophils, Eosinophils, and Monocytes:** Key components of innate immune responses.

5. Other Tissue-Specific Stem Cells

Differentiate into:

- **Muscle Cells:** Contribute to muscle tissue.
- **Intestinal Cells:** Involved in nutrient absorption.
- **Liver Cells:** Perform metabolic and detox functions.
- **Nerve Cells:** Essential for neural signaling.
- **Cardiac Cells:** Maintain heart function.

2a. Explain the similarities and differences between plant and animal cell.



Prokaryotic Cells Eukaryotic Cells

Aspect	Prokaryotic Cells	Eukaryotic Cells
Feature	Simple cell structure	Complex cell structure
Size	0.1 – 5 µm	10 – 100 µm
Nucleus	No true nucleus (nucleoid region present)	Membrane-bound nucleus
Genetic Material (DNA)	Single circular chromosome; no histones	Multiple linear chromosomes; associated with histones
Membrane-bound Organelles	Absent	Present (mitochondria, endoplasmic reticulum, Golgi apparatus, etc.)
Ribosomes	70S	80S
Cell Wall	Present (peptidoglycan in bacteria)	Present in plants (cellulose), fungi (chitin); absent in animal cells
Flagella Structure	Simple; made of flagellin	Complex; made of microtubules in a 9+2 arrangement
Reproduction	Asexual (binary fission)	Sexual (meiosis) and asexual (mitosis)
Cytoskeleton	Absent or poorly developed	Well-developed (microfilaments, intermediate filaments, and microtubules)
Metabolism	Simple metabolic pathways	Complex metabolic pathways
Cell Division	Binary fission	Mitosis and meiosis
Respiration	Occurs across the cell membrane	Occurs in mitochondria
Functions	Efficient for rapid reproduction and adaptation to harsh environments	Specialized for complex and multicellular life functions
Characteristics	- No compartmentalization of cytoplasm	- Compartmentalized organelles for specialized functions

The designation **70S ribosome** refers to a type of ribosome found in **prokaryotic cells** (bacteria and archaea) as well as in the mitochondria and chloroplasts of eukaryotic cells. The term **70S** provides information about the size and sedimentation rate of the ribosome when subjected to ultracentrifugation.

Breakdown of "70S":

1."S" stands for Svedberg unit:

1. It is a unit of sedimentation rate, which reflects the size, shape, and density of particles in a centrifuge.
2. A higher Svedberg value does not simply add up linearly (e.g., 50S + 30S = 70S, not 80S) because it depends on both mass and shape.

2.Subunits of the 70S Ribosome:

1. **Large subunit (50S):**
    1. Contains 23S rRNA and 5S rRNA along with about 31 proteins.
2. **Small subunit (30S):**
    1. Contains 16S rRNA and about 21 proteins.

3.Function of the 70S Ribosome:

1. Responsible for **protein synthesis** by translating messenger RNA (mRNA) into a polypeptide chain.

2b. Explain the properties and functions of hormones.

Properties and Functions of Hormones

Properties of Hormones:

1. Chemical Messengers: Hormones are secreted by endocrine glands and act as messengers to regulate physiological activities.
2. Produced in Small Quantities: They are effective in very low concentrations.
3. Specificity: Each hormone acts on specific target organs or cells that have appropriate receptors.
4. Transported via Bloodstream: Hormones travel through the blood to reach target sites.
5. Regulated Secretion: Their secretion is tightly regulated by feedback mechanisms.
6. Short or Long-Term Effects: Some act quickly (e.g., adrenaline), while others take longer (e.g., growth hormone).
7. Do Not Supply Energy: Hormones are not used as a source of energy but regulate energy metabolism.

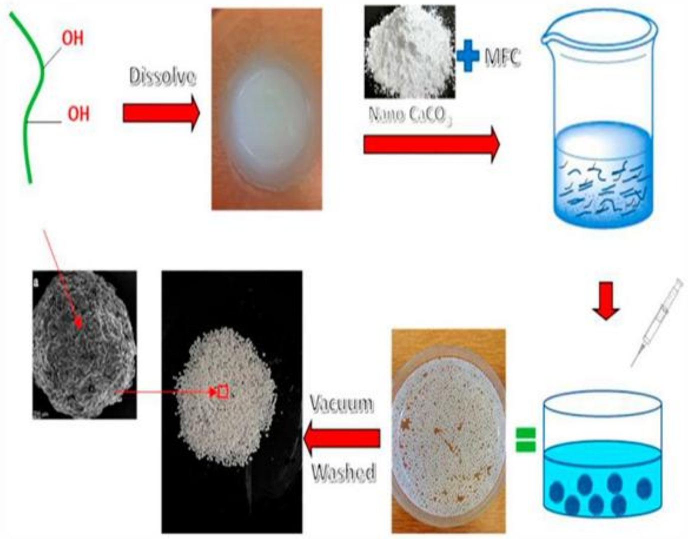
Functions of Hormones:

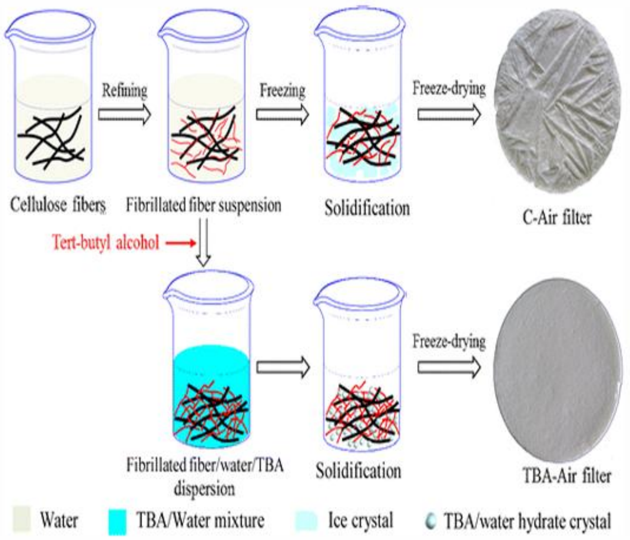
1. Regulation of Metabolism: Hormones like insulin and thyroid hormones regulate metabolic rate and glucose levels.
2. Growth and Development: Growth hormone and sex hormones control physical development and puberty.
3. Homeostasis Maintenance: Hormones like ADH and aldosterone help maintain water and electrolyte balance.
4. Reproductive Functions: Estrogen, progesterone, and testosterone regulate reproductive processes.
5. Response to Stress: Cortisol and adrenaline help the body cope with stress.
6. Mood and Behaviour: Hormones such as serotonin and dopamine influence mood and behaviour.

<u>**Module – 2**</u>

3a. Explain the application of carbohydrates as cellulose-based water filters, mention its advantages.

Cellulose-based water Filters





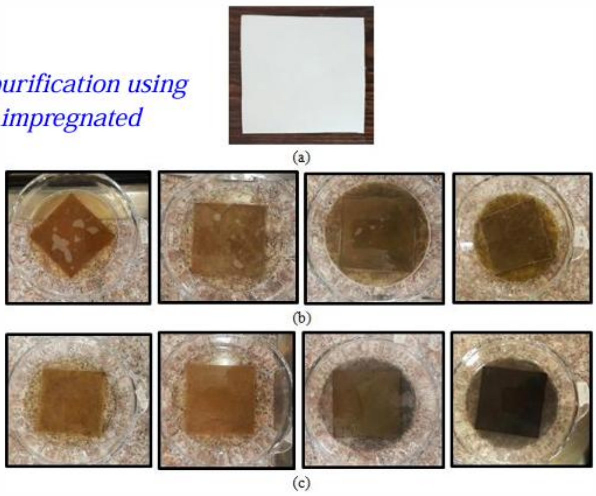
Bioproduction of Chemicals: Microbial Fuel Cells (MFCs) can be employed to synthesize valuable bio-products, including hydrogen, methane, or even specific organic compounds, through the microbial metabolism of substrates in the fuel cell.

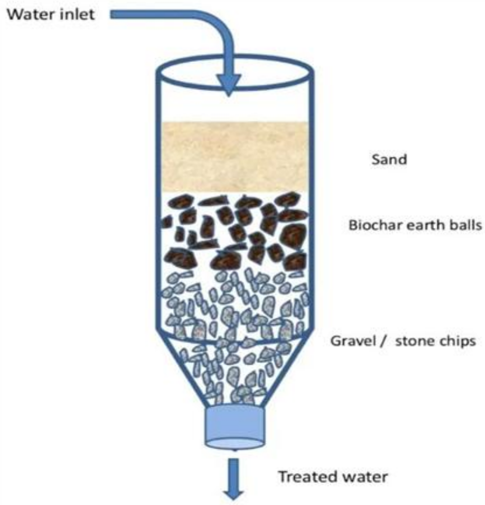
Cellulose-based water purification using paper filters modified with polyelectrolyte multilayers to remove bacteria from water through electrostatic interactions

Research Centre:

Department of Fibre and Polymer Technology, KTH Royal Institute of Technology, Teknikringen 56-58, 114 28 Stockholm, Sweden

Surface-water purification using cellulose paper impregnated





3b. Write a short note on Meat analogue and Plant protein as food.

With increasing awareness of health, sustainability, and ethical concerns associated with conventional animal farming, plant-based diets have gained popularity. Among these innovations, meat analogues and plant proteins play a pivotal role in providing nutritional substitutes for animal-based foods without compromising on taste or health benefits.

1. Meat Analogue:

Definition:

Meat analogues, also known as mock meat, plant-based meat, or meat substitutes, are food products designed to simulate the flavor, texture, appearance, and nutritional value of conventional meat using plant-derived ingredients.

Common Ingredients:

- Soy protein isolate
- Wheat gluten (seitan)
- Pea protein
- Mushroom extracts
- Legumes and pulses

Nutritional Aspects:

- High in protein and dietary fiber
- Often low in saturated fats and cholesterol-free
- Can be fortified with vitamins and minerals like B12 and iron

Advantages:

- Promotes sustainable food production
- Reduces greenhouse gas emissions
- Suitable for vegetarians and vegans
- Helps prevent animal cruelty

Limitations:

- Some products may be high in sodium or over-processed
- Allergen risks (e.g., soy, gluten)

2. Plant Protein as Food:

Definition:

Plant protein refers to protein that is sourced from plants, including legumes, whole grains, nuts, seeds, and vegetables.

Sources of Plant Protein:

- Soybeans, lentils, chickpeas
- Quinoa, brown rice
- Almonds, chia seeds, pumpkin seeds

Nutritional Benefits:

- Contains essential amino acids (especially when diversified)
- Rich in fiber, antioxidants, and micronutrients
- Supports heart health and reduces risk of chronic diseases

Applications:

- Used in protein supplements, meat alternatives, dairy substitutes (e.g., soy milk, almond milk)
- Incorporated in traditional diets and modern food tech

4a. Explain the DNA vaccine for rabies.

Rabies is a fatal viral disease caused by the Rabies virus, which affects the central nervous system. It is commonly transmitted to humans through the bite or scratch of infected animals (typically dogs). Once symptoms appear, rabies is almost always fatal, making early vaccination crucial.

What is a DNA Vaccine?

A DNA vaccine is a type of vaccine that uses genetically engineered DNA to induce an immune response. It involves injecting a small, circular piece of DNA (called a plasmid) containing genes that code for antigens (proteins) of the virus. The host cells take up this DNA, produce the viral proteins, and trigger an immune response.

Mechanism of DNA Vaccine for Rabies:

1. Plasmid Design:
   The DNA vaccine for rabies contains a gene encoding the rabies virus glycoprotein (G protein), which is essential for inducing protective immunity.

2. Delivery into Host Cells:
   The plasmid is injected into muscle or skin tissue using a needle or gene gun.
3. Antigen Expression:
   Host cells take up the DNA and produce the rabies glycoprotein.
4. Immune Response:
   The expressed antigen is recognized by the immune system, activating both:
   - Humoral immunity (antibody production)
   - Cell-mediated immunity (T-cell activation)

This helps the immune system recognize and neutralize the actual rabies virus upon future exposure.

Advantages of DNA Vaccine for Rabies:

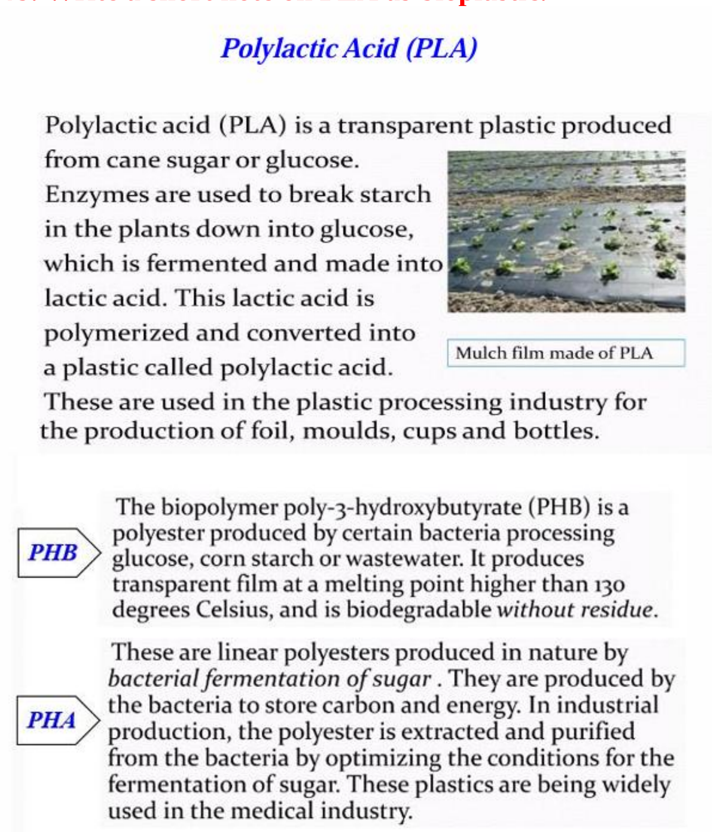
- Safe – Non-infectious and does not use live virus.
- Stable – DNA is more stable and doesn't require cold storage.
- Cost-effective – Easy to produce and scale.
- Long-lasting immunity – Stimulates both B and T cell responses.
- Rapid Development – Especially useful in pandemics or outbreaks.

Current Status and Use:

- Several DNA-based rabies vaccines have shown promising results in animal models (dogs, mice, monkeys).
- Human clinical trials are underway in different parts of the world.
- They may be used in the future as pre-exposure prophylaxis or even post-exposure treatment.

DNA vaccines represent a modern and promising approach to combat rabies, particularly in areas where cold-chain limitations and rapid response are challenges. Though still under clinical development, DNA vaccines for rabies could revolutionize how we prevent and control this deadly disease.

4b. Write a short note on PLA as bioplastic.



Polylactic Acid (PLA)

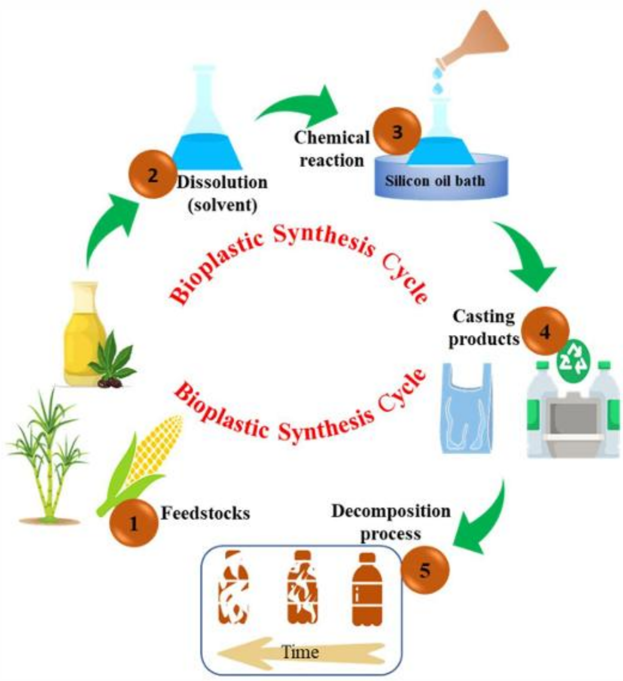
Polylactic acid (PLA) is a transparent plastic produced from cane sugar or glucose. Enzymes are used to break starch in the plants down into glucose, which is fermented and made into lactic acid. This lactic acid is polymerized and converted into a plastic called polylactic acid.

Mulch film made of PLA

These are used in the plastic processing industry for the production of foil, moulds, cups and bottles.

PHB: The biopolymer poly-3-hydroxybutyrate (PHB) is a polyester produced by certain bacteria processing glucose, corn starch or wastewater. It produces transparent film at a melting point higher than 130 degrees Celsius, and is biodegradable *without residue*.

PHA: These are linear polyesters produced in nature by *bacterial fermentation of sugar*. They are produced by the bacteria to store carbon and energy. In industrial production, the polyester is extracted and purified from the bacteria by optimizing the conditions for the fermentation of sugar. These plastics are being widely used in the medical industry.

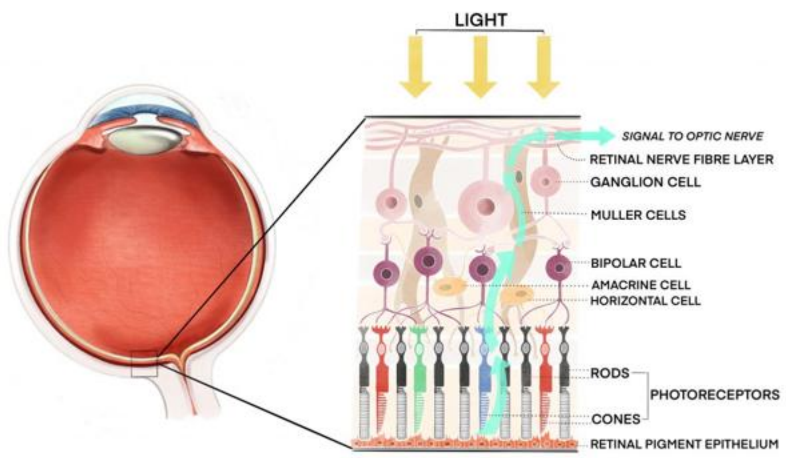


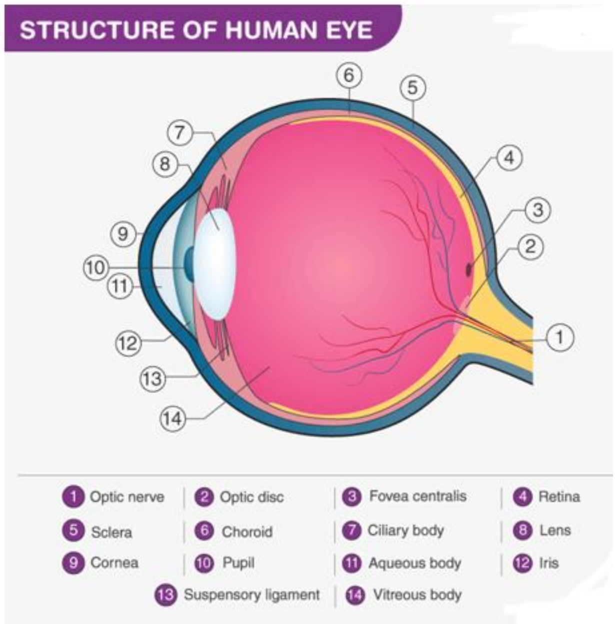
<u>**Module – 3**</u>

5a. Explain eye as a camera system.

Structure of the Human Eye

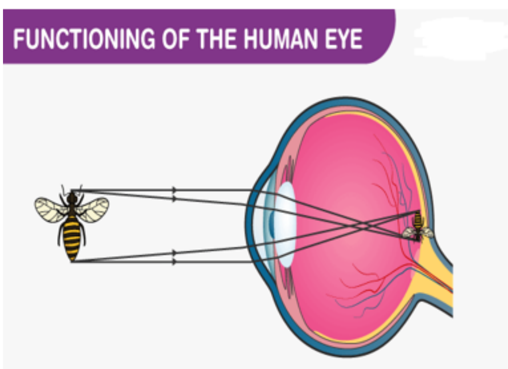
A human eye is roughly 2.3 cm in diameter and is almost a spherical ball filled with some fluid.





The function of the Human Eye

- As we mentioned earlier, the eye of a human being is like a camera. Much like the electronic device, the human eye also focuses and lets in light to produce images.
- So basically, light rays that are deflected from or by distant objects land on the retina after they pass through various mediums like the cornea, crystalline lens, aqueous humor, the lens, and vitreous humor.



Medium	Refractive Index
Air	1.000
Cornea	1.376
Aqueous Humor	1.336
Lens	1.42
Vitreous Humor	1.336

- The concept here though is that as the light rays move through the various mediums, they experience <u>refraction of light</u>. Well, to put it in simple terms, refraction is nothing but the change in direction of the rays of light as they pass between different mediums.

- *Having different refractive indexes is what bends the rays to form an image.*
- *The light rays finally are received and focused on the retina.*
- *The retina contains photoreceptor cells called rods and cones and these basically detect the intensity and the frequency of the light.*
- *Further, the image that is formed is processed by millions of these cells, and they also relay the signal or nerve impulses to the brain via the optic nerve.*
- *The image formed is usually inverted but the brain corrects this phenomenon. This process is also similar to that of a convex lens.*

5b. Describe the architecture of lungs and gas exchange mechanism.

Lungs as purification system

The lung purifies air by removing harmful substances and adding oxygen to the bloodstream. The process of purifying air in the lungs can be described as follows:

- Filtration: The nose and mouth serve as a first line of defense against harmful substances in the air, such as dust, dirt, and bacteria. The tiny hairs in the nose, called cilia, and the mucus produced by the respiratory system trap these substances and prevent them from entering the lungs.
- Moisturization: The air is also humidified as it passes over the moist lining of the respiratory tract, which helps to keep the airways moist and prevent them from drying out.
- Gas Exchange: Once the air reaches the alveoli, the gas exchange process occurs, where oxygen diffuses across the thin alveolar and capillary walls into the bloodstream, and carbon dioxide diffuses in the opposite direction, from the bloodstream into the alveoli to be exhaled.
- This process ensures that the bloodstream is supplied with fresh, oxygen-rich air, while carbon dioxide is removed from the body. Overall, the lung serves as a vital purification system, filtering out harmful substances, adding oxygen to the bloodstream, and removing carbon dioxide. It plays a critical role in maintaining the body's homeostasis and supporting life.

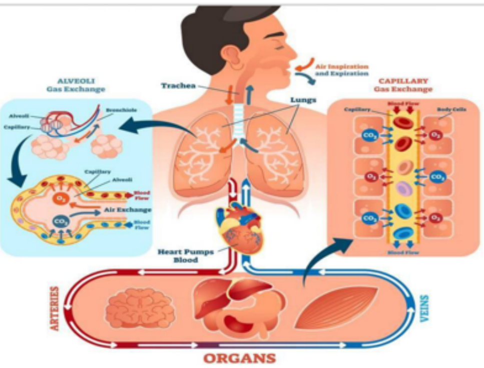


Figure: Representing the oxygen-carbon dioxide exchange in the alveoli and capillary

- Air enters the lungs through the air passage, which includes the nasal cavities, pharynx, larynx, trachea, bronchi and bronchioles.
- The lungs are elastic bags located in a closed cavity called thorax or thoracic cavity.
- The right lungs consists of three lobes(upper, middle and lower) and left lungs has two lobes (upper and lower).
- The larynx sometimes called as "voice box"(vocal cords) is connected to the bronchi through trachea, called as windpipe.
- Above the larynx is the epiglottis, a valve that closes whenever a person swallows, so that food and liquids are directed to the oesophagus.

GAS EXCHANGE MECHANISMS

- The exchange of gases in any biological process is called respiration.
- The process of taking the oxygen from the environment, transporting the oxygen to the cells, removing the carbon dioxide from the cells and exhausting this waste product into the atmosphere is called respiration.
- The exchange of gases takes place in the lungs, is termed as external respiration.
- The function of the lungs is to oxygenate the blood and to eliminate carbon dioxide in a controlled manner.
- During inspiration, fresh air enters the respiratory tract, becomes humidified and heated to body temperature, and is mixed with gases already present in the region comprising the trachea and bronchi.
- This gas is then mixed further with the gas residing in the alveoli as it enters these small sacs in the walls of the lungs.
- Oxygen diffuses from the alveoli to the pulmonary capillary blood supply, whereas carbon dioxide diffuses from the blood to the alveoli.
- The oxygen is carried from the lungs and distributed among the various cells of the body by the blood circulation system, which also returns the carbon dioxide to the lungs.
- The entire process of inspiring and expiring air, exchange of gases, distribution of oxygen to the cells and collection of CO2 from the cells is known as pulmonary function.
- The gas exchange mechanism in the lung involves the transfer of oxygen from the air in the alveoli to the bloodstream, and the transfer of carbon dioxide from the bloodstream to the air in the alveoli. This process is known as diffusion and occurs due to differences in partial pressures of oxygen and carbon dioxide.
- Oxygen Diffusion: The partial pressure of oxygen in the air in the alveoli is higher than the partial pressure of oxygen in the bloodstream. This difference creates a gradient that causes oxygen to diffuse from the alveoli into the bloodstream, where it binds to hemoglobin in red blood cells to form oxyhemoglobin. (oxygen air>bloodstream)
- Carbon Dioxide Diffusion: The partial pressure of carbon dioxide in the bloodstream is higher than the partial pressure of carbon dioxide in the air in the alveoli. This difference creates a gradient that causes carbon dioxide to diffuse from the bloodstream into the alveoli, where it is exhaled. (carbondioxide bloodstream> carbondioxide air)

6a. Explain the kidney as filtration system.

Kidney as a Filtration System

- The kidney is a complex organ that acts as a filtration system for the body.
- It removes waste and excess fluid from the bloodstream and maintains a delicate balance of electrolytes, hormones, and other substances that are critical for the body's normal functioning.
- The kidney also plays an important role in *regulating blood pressure* by secreting the *hormone renin*, which helps control the balance of fluid and electrolytes in the body.
- It also *regulates red blood cell production* and the levels of *various minerals* in the *blood, such as calcium and phosphorus*.
- Without the kidney, waste and excess fluid would accumulate in the body, leading to serious health problems.

Architecture of Kidney

- The kidney is composed of functional units called nephrons, which are the basic structural and functional units of the kidney.
- Each kidney contains approximately one million nephrons, and each nephron performs the functions of filtration, reabsorption, and secretion.
- The nephron is comprised of several key structures:
- Bowman's capsule: This is a cup-shaped structure that surrounds the glomerulus and filters waste and excess fluid from the bloodstream into the renal tubule.
- Glomerulus: A network of tiny blood vessels within the Bowman's capsule that filters waste and excess fluid from the bloodstream.
- Proximal convoluted tubule: A segment of the renal tubule that reabsorbs important substances, such as glucose, amino acids, and electrolytes, back into the bloodstream.

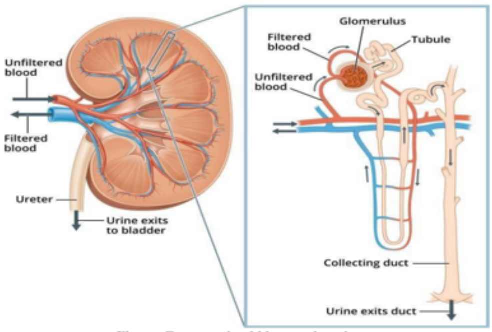


Figure: Representing kidney and nephron

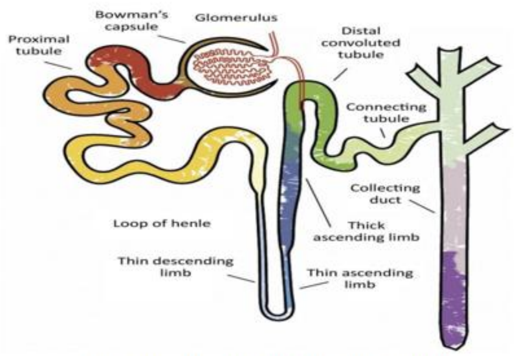


Figure: Representing the parts of nephron

Mechanism of Filtration

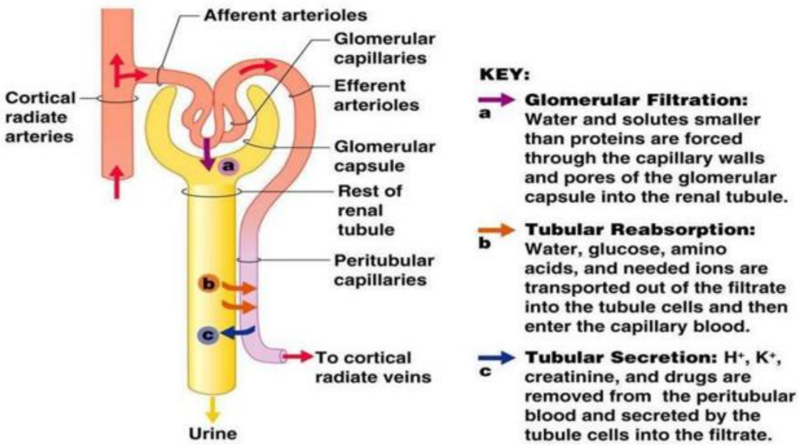


Figure: Schematic of mechanism of filtration in human kidney

6b. Write a short note on Chronic Obstructive Pulmonary Disease (COPD).

Chronic Obstructive Pulmonary Disease (COPD) is a progressive, incurable respiratory condition characterized by persistent airflow limitation and an abnormal inflammatory response of the lungs. It is a major cause of morbidity and mortality worldwide, leading to a reduced quality of life and a significant economic burden on healthcare systems.

COPD is an umbrella term encompassing two primary conditions:

- Chronic bronchitis – inflammation of the bronchial tubes with excessive mucus production.
- Emphysema – damage and enlargement of the air sacs (alveoli) in the lungs.

Causes and Risk Factors

The primary cause of COPD is long-term exposure to harmful particles or gases, most commonly from cigarette smoking. However, several other risk factors include:

- Smoking: Accounts for about 85–90% of COPD cases. Passive (second-hand) smoke also contributes.
- Environmental Exposure: Long-term inhalation of dust, chemical fumes, air pollutants, and biomass fuels.
- Occupational Hazards: Prolonged exposure to industrial dust and chemicals in the workplace.
- Genetics: A rare genetic disorder called Alpha-1 Antitrypsin Deficiency can lead to early-onset COPD.
- Respiratory Infections: Frequent childhood respiratory infections can increase the risk.
- Age and Gender: More common in people over 40, and historically more prevalent in males, though rising in females due to increased smoking.

Pathophysiology

COPD involves chronic inflammation of the airways, lung tissue, and pulmonary blood vessels. The disease process includes:

1. Airway Inflammation: Continuous exposure to irritants leads to infiltration of inflammatory cells like neutrophils, macrophages, and T-lymphocytes.
2. Bronchial Remodelling: Structural changes in airways due to chronic inflammation cause narrowing and obstruction.
3. Mucus Hypersecretion: Goblet cell hyperplasia and enlarged mucus glands produce excess sputum, obstructing airflow.
4. Alveolar Damage (Emphysema): Destruction of alveolar walls reduces the surface area for gas exchange and leads to lung hyperinflation.
5. Impaired Gas Exchange: Loss of elasticity and alveolar collapse reduce oxygen absorption and carbon dioxide elimination.

Symptoms of COPD

COPD symptoms usually develop gradually and worsen over time:

- Chronic Cough: Often the first symptom, may be dry or productive.
- Sputum Production: Frequent mucus, especially in chronic bronchitis.
- Shortness of Breath (Dyspnea): Especially during physical activity and worsens with disease progression.
- Wheezing: Due to narrowed airways.
- Fatigue and Weakness: Caused by reduced oxygen levels.
- Chest Tightness and recurrent respiratory infections.

Diagnosis

Early diagnosis is crucial for managing COPD effectively. Diagnosis is based on:

1. Clinical History:
   - Symptoms (chronic cough, sputum, breathlessness)
   - Risk factor exposure (smoking, environmental)
2. Physical Examination:
   - Wheezing, barrel chest, use of accessory muscles
3. Pulmonary Function Tests (PFTs):
   - Spirometry: Gold standard test. A post-bronchodilator FEV1/FVC ratio < 0.70 confirms persistent airflow limitation.
4. Chest X-ray/CT scan:
   - Shows hyperinflation, flattened diaphragm, or emphysematous changes.
5. Blood Tests:
   - Alpha-1 antitrypsin deficiency screening in young or non-smoking individuals.
   - Arterial blood gas analysis in severe cases.

Staging and Classification

The Global Initiative for Chronic Obstructive Lung Disease (GOLD) categorizes COPD into stages based on FEV1 (% predicted):

- GOLD 1 (Mild): FEV1 ≥ 80%
- GOLD 2 (Moderate): 50% ≤ FEV1 < 80%
- GOLD 3 (Severe): 30% ≤ FEV1 < 50%
- GOLD 4 (Very Severe): FEV1 < 30%

Management and Treatment

Although COPD is not curable, its progression can be slowed, and symptoms can be managed through a comprehensive approach:

1. Lifestyle Modifications:
    - Smoking cessation: Most effective intervention.
    - Avoidance of pollutants and occupational hazards.
    - Healthy diet and regular exercise.
2. Pharmacologic Therapy:
    - Bronchodilators (β2-agonists, anticholinergics): Relieve breathlessness.
    - Inhaled corticosteroids (ICS): For patients with frequent exacerbations.
    - Combination therapy: LABA + ICS or LABA + LAMA.
    - Phosphodiesterase-4 inhibitors: For chronic bronchitis phenotype.
    - Mucolytics: To reduce mucus thickness.
3. Vaccination:
    - Annual influenza and pneumococcal vaccines reduce infections.
4. Pulmonary Rehabilitation:
    - Exercise training, education, and nutritional advice to improve quality of life.
5. Oxygen Therapy:
    - For patients with chronic hypoxemia ($SpO_2 \leq 88\%$).
6. Surgical Options:
    - Lung volume reduction surgery or lung transplant in advanced emphysema.

Module – 4

7a. Write a short note on:
(i) Lotus Leaf effect
(ii) Shark skin

(i) Lotus Leaf Effect

The Lotus Leaf Effect refers to the self-cleaning property observed in the surface of lotus leaves. This phenomenon is due to the super hydrophobicity of the leaf surface, which is characterized by very high-water contact angles (greater than 150°).

- The surface of the lotus leaf is covered with microscopic waxy structures that minimize the adhesion of water and dirt.
- Water droplets roll off easily, picking up dust and contaminants — a process known as self-cleaning.
- This effect has inspired numerous biomimetic applications, such as self-cleaning windows, water-repellent fabrics, anti-corrosion coatings, and paints.

Key Concepts: Super hydrophobicity, micro/nano surface structure, self-cleaning surfaces, biomimetics.

(ii) Shark Skin

The Shark Skin Effect refers to the unique texture of shark skin, which reduces drag and resists biofouling (accumulation of microorganisms on surfaces).

- Shark skin is composed of tiny, overlapping scales called dermal denticles that have riblet-like patterns.
- These riblets channel water efficiently, reducing friction and turbulent flow, allowing sharks to swim faster with less effort.
- Shark skin also prevents the attachment of algae and bacteria, leading to applications in antifouling surfaces.

Biomimetic Applications:

- Drag-reducing swimsuits and aircraft coatings,
- Antibacterial and anti-fouling hospital surfaces,

- Efficient designs for ships and submarines.

Key Concepts: Riblet structure, drag reduction, antifouling, biomimicry.

7b. Illustrate the HBO's and PFC's as human blood substitutes.

Due to the increasing demand and limited availability of donor blood, blood substitutes have been developed as alternatives for transfusion in emergencies, surgeries, and battlefield scenarios. Two of the most widely studied classes of artificial blood substitutes are:

1. Hemoglobin-Based Oxygen Carriers (HBOs)

Definition:

HBOs are blood substitutes derived from purified, modified hemoglobin (Hb) — the oxygen-carrying protein found in red blood cells (RBCs).

Features & Functions:

- Designed to carry and deliver oxygen to tissues, mimicking the function of natural hemoglobin.
- Can be derived from human, bovine (cow), or recombinant sources.
- Modified chemically (e.g., polymerized or PEGylated) to increase stability, prevent renal toxicity, and avoid immune responses.

Advantages:

- No need for cross-matching (universal compatibility).
- Long shelf-life (no refrigeration needed).
- Useful in trauma, surgery, and remote battlefield conditions.

Limitations:

- Short half-life in circulation.
- Risk of vasoconstriction and oxidative stress.
- Not yet widely approved for clinical use in most countries.

Examples:

- Hemopure (bovine-derived Hb)
- PolyHeme
- HemAssist

2. Perfluorocarbons (PFCs)

Definition:

PFCs are synthetic, inert organic compounds that can dissolve large volumes of gases, particularly oxygen and carbon dioxide.

Features & Functions:

- Capable of transporting and releasing oxygen due to high gas solubility.
- Require supplemental oxygen administration to work effectively.
- Delivered in emulsion form (tiny PFC droplets suspended in a liquid).

Advantages:

- Extremely small particle size — can reach capillaries and damaged tissues that RBCs can't.
- No risk of infection transmission.
- Long shelf-life and easy storage.

Limitations:

- Oxygen delivery capacity is lower than that of natural blood.
- Requires high inspired oxygen concentration.
- Some PFCs have been associated with flu-like symptoms or liver burden.

Examples:

- Oxygent
- Fluosol-DA
- Perftoran (approved in Russia)

8a. Write a short note on:
(i) Photovoltaic cells
(ii) Bionic leaf

(i) Photovoltaic Cells
Definition:
Photovoltaic (PV) cells, commonly known as solar cells, are devices that convert sunlight directly into electricity using the photovoltaic effect.
Working Principle:
When sunlight hits a PV cell, photons from the light strike the semiconductor material (typically silicon), exciting electrons and creating electron-hole pairs. These charge carriers are separated by the electric field in the cell, generating a direct current (DC).
Key Components:

- Semiconductor layers (e.g., silicon)
- Conductive metal contacts
- Anti-reflective coating to capture more sunlight

Applications:

- Solar panels for homes and industries
- Power sources for satellites and space probes
- Portable solar chargers and traffic signs

Advantages:

- Renewable and clean energy source
- Low operating cost after installation
- Scalable for various energy needs

(ii) Bionic Leaf
Definition:
A bionic leaf is a bio-inspired artificial photosynthesis system that mimics natural leaves by converting sunlight, water, and carbon dioxide into energy-rich fuels and useful chemicals.
Working Mechanism:

- Developed using solar energy, catalysts, and microbes.
- First, solar energy splits water into hydrogen and oxygen.
- Then, engineered bacteria (e.g., Ralstonia eutropha) use the hydrogen to convert CO_2 into liquid fuels like isopropanol or biomass.

Significance:

- It merges biological and artificial systems for sustainable fuel production.
- Operates at an efficiency higher than natural photosynthesis.
- Can aid in carbon capture and renewable chemical synthesis.

Applications:

- Clean fuel generation
- Carbon-neutral energy solutions
- Agricultural fertilizer production (in newer versions)

8b. Describe the engineering applications of GPS and Velcro technology.
Global Positioning System (GPS) – Engineering Applications
Definition:
GPS is a satellite-based navigation system that provides location, velocity, and time information to users anywhere on Earth.
Engineering Applications:

1. Civil Engineering & Construction:
   - Surveying and Mapping: High-precision GPS enables accurate land surveys and digital terrain modeling.
   - Machine Guidance: GPS is used in earth-moving equipment for precise grading and excavation.
   - Site Management: Real-time location tracking helps manage construction logistics and equipment.
2. Transportation Engineering:
   - Traffic Monitoring: GPS aids in tracking traffic patterns and congestion for efficient urban planning.
   - Fleet Management: Used for real-time monitoring of public transport and logistics fleets.
   - Navigation Systems: Integrated into vehicles for route optimization and accident avoidance.

3. Geotechnical Engineering:
    - Structural Monitoring: Tracks deformation in bridges, dams, and tall structures with sub-centimeter accuracy.
    - Seismic Studies: Assists in monitoring tectonic movements and post-disaster analysis.
4. Environmental Engineering:
    - Disaster Management: Helps in evacuation planning, rescue operations, and damage assessment during natural disasters.
    - Resource Management: Used in tracking deforestation, water bodies, and pollution sources.

Velcro Technology – Engineering Applications
Definition:
Velcro is a brand name for a hook-and-loop fastening system, inspired by the way burrs stick to animal fur. Invented by George de Mestral in 1941, it mimics biomimicry in design.
Engineering Applications:

1. Aerospace Engineering:
    - Cable Management: Used to organize wiring and components in spacecraft and aircraft.
    - Tool Restraints: Keeps tools and devices secure in zero-gravity environments (e.g., NASA's space missions).
2. Automotive Engineering:
    - Interior Fastening: Secures carpets, headliners, and removable panels.
    - Accessory Attachments: Used for quick fastening of seat covers and portable electronics.
3. Textile and Wearable Engineering:
    - Adaptive Clothing: Used in medical and military uniforms for quick removal or fastening.
    - Wearable Sensors: Holds sensors or battery packs in health-monitoring wearables.
4. Robotics & Prosthetics:
    - Quick Assembly: Assists in rapid assembly or disassembly of modular robots.
    - Prosthetic Attachments: Provides comfort and secure attachment for wearable prosthetic limbs.

Module – 5

9a. Analyze the bio-engineering solutions for muscular dystrophy and osteoporosis.

1. Muscular Dystrophy (MD)
Definition:
Muscular dystrophy is a group of genetic disorders characterized by progressive weakness and degeneration of skeletal muscles. The most common type is Duchenne Muscular Dystrophy (DMD) caused by mutations in the dystrophin gene.
Bio-Engineering Solutions for MD:

1. Gene Therapy:
    - Introduction of functional copies of the dystrophin gene using viral vectors (e.g., AAV – adeno-associated virus).
    - Techniques like CRISPR/Cas9 are used to correct gene mutations at the DNA level.
2. Stem Cell Therapy:
    - Use of induced pluripotent stem cells (iPSCs) or mesenchymal stem cells (MSCs) to regenerate damaged muscle tissues.
    - Engineered muscle cells are injected into the body to restore function.
3. Exon Skipping Technology:
    - Synthetic antisense oligonucleotides (ASOs) are used to skip faulty exons during mRNA processing, producing partially functional dystrophin.
4. Tissue Engineering:
    - Creation of 3D muscle tissues using biocompatible scaffolds to study disease progression and test therapies.
    - Scaffold materials (collagen, fibrin) mimic natural extracellular matrix (ECM).
5. Bio-Sensors and Wearables:
    - Devices for muscle activity monitoring, gait analysis, and mobility tracking to assess therapy effectiveness.

2. Osteoporosis
Definition:
Osteoporosis is a metabolic bone disease where bone mineral density (BMD) decreases, leading to fragile bones and

increased fracture risk, especially in postmenopausal women and the elderly.
Bio-Engineering Solutions for Osteoporosis:

1. Biomaterials for Bone Regeneration:
    - Use of biodegradable scaffolds made of hydroxyapatite, tricalcium phosphate, or bioglass to support bone regrowth.
    - These materials are seeded with osteoblasts or stem cells.
2. Bone Tissue Engineering:
    - Incorporation of growth factors (e.g., BMPs – Bone Morphogenetic Proteins) into scaffolds to stimulate bone healing and regeneration.
3. Smart Drug Delivery Systems:
    - Nanotechnology-enabled targeted delivery of anti-resorptive or bone-forming drugs (like bisphosphonates, teriparatide) to affected bone sites.
    - Hydrogel-based systems allow controlled drug release.
4. 3D Bioprinting of Bone Constructs:
    - Customized bone grafts are created using patient-specific data from CT/MRI.
    - These bio-printed structures can integrate with native bone.
5. Bone Density Monitoring Devices:
    - Use of non-invasive imaging tools (DEXA scans integrated with AI) for early detection and tracking of osteoporosis.
    - Development of wearable devices for real-time biomechanical stress analysis.

9b. Write a short note on self-healing bio-concrete.

Self-healing bio-concrete is an advanced construction material designed to automatically repair cracks in concrete without human intervention. It integrates biological agents, mainly specific types of bacteria, into the concrete matrix, enabling it to heal itself when cracks occur.

Mechanism:

1. Bacterial Activation:
    - The most commonly used bacteria are spore-forming bacteria like Bacillus subtilis or Bacillus pasteurii.
    - These bacteria remain dormant inside the concrete until water enters through cracks.
2. Calcium Carbonate Precipitation:
    - On contact with water, the bacteria become active and consume a nutrient source (usually calcium lactate).
    - As a metabolic by-product, they precipitate calcium carbonate ($CaCO_3$), which fills and seals the crack.

Components:

- Bacterial spores
- Nutrient (e.g., calcium lactate)
- Water (activator)
- Carrier materials like silica gel or clay pellets to protect bacteria during mixing

Advantages:

- Increases lifespan of concrete structures
- Reduces maintenance costs
- Improves durability and water-tightness
- Environmentally friendly and sustainable solution

Applications:

- Tunnels, bridges, basements, marine structures, and other infrastructure exposed to stress and harsh environments.

10a. Examine the bioimaging and artificial intelligence for disease diagnosis.

Modern disease diagnosis is increasingly relying on technological advancements for greater accuracy, speed, and early detection. Two rapidly advancing fields — bioimaging and artificial intelligence (AI) — are revolutionizing diagnostic medicine by providing clinicians with deeper insights into patient health and enabling data-driven, automated decision-making. Bioimaging refers to the techniques used to visualize biological processes and structures in the human body. It plays a vital role in detecting, monitoring, and understanding diseases at anatomical, molecular, and cellular levels.
Common Bioimaging Modalities:

- X-rays: For bone fractures, chest infections, and dental analysis.
- CT (Computed Tomography): Provides 3D images for detecting tumors, internal bleeding, and organ damage.

- MRI (Magnetic Resonance Imaging): Offers detailed images of soft tissues like the brain, spine, and joints.
- Ultrasound: Used for fetal imaging, organ inspection, and guided biopsies.
- PET and SPECT Scans: Highlight metabolic activity, ideal for detecting cancer or neurological disorders.
- Fluorescence and Optical Imaging: Used in cellular and molecular biology for studying tissue interactions.

Significance:

- Non-invasive and real-time visualization
- Enables early-stage disease detection
- Guides surgical and therapeutic interventions
- Allows for longitudinal monitoring of disease progression

Artificial Intelligence in Disease Diagnosis

Artificial Intelligence (AI) uses machine learning (ML), deep learning (DL), and neural networks to process large volumes of medical data for pattern recognition, classification, and prediction.

Applications in Diagnosis:

- Image Analysis:
  - AI algorithms analyze medical images to detect abnormalities (e.g., tumors in MRIs, pneumonia in chest X-rays).
  - Tools like Google's DeepMind and IBM Watson Health support radiologists in interpreting scans.
- Predictive Diagnostics:
  - AI can predict the likelihood of disease development based on genetic data, lifestyle, or previous history.
  - Example: Predicting the onset of diabetes, Alzheimer's, or cardiovascular diseases.
- Decision Support Systems:
  - AI systems assist clinicians by suggesting diagnoses or treatment options based on electronic health records (EHRs).
- Pathology and Genomics:
  - AI enables automated analysis of biopsy slides, blood samples, and gene sequences.

Integration of Bioimaging and AI

Combining AI with bioimaging leads to smart diagnostics, where AI models enhance the interpretation of imaging data.

Key Benefits:

- Improved accuracy and consistency
- Faster processing times and automated reporting
- Detection of subtle patterns invisible to the human eye
- Enables personalized medicine through integrated analysis of imaging and clinical/genomic data

Examples:

- AI-based breast cancer screening using mammograms
- Lung nodule detection in chest CT scans
- Brain tumor segmentation from MRI using convolutional neural networks (CNNs)

Challenges and Limitations

- Data privacy and security concerns
- Need for large annotated datasets for training AI models
- Risk of bias in AI algorithms
- Integration with clinical workflow is still evolving
- Interpretability: AI's "black box" nature makes it difficult to understand decision logic

10b. Explain the process of biomining via microbial surface adsorption.

Biomining is a biotechnological method of extracting metals from ores and mine waste using microorganisms. Among the various mechanisms involved, one significant process is microbial surface adsorption, where metal ions are adsorbed onto the microbial cell surface without the need for cellular metabolism.

Microbial surface adsorption refers to the passive binding of metal ions to the surface of microbial cells. This occurs primarily due to the presence of functional groups such as:

- Carboxyl (–COOH)
- Hydroxyl (–OH)
- Amino ($–NH_2$)
- Phosphate ($–PO_4^{3-}$)

These groups are present on the cell wall of bacteria, fungi, or algae and interact with metal cations, allowing the cells to bind metals from solutions.

Microorganisms Used in Biomining

- Bacteria: Acidithiobacillus ferrooxidans, Leptospirillum ferrooxidans
- Fungi: Aspergillus niger, Penicillium spp.
- Algae: Chlorella spp., Spirogyra spp.

Steps in Biomining via Surface Adsorption

Step 1: Contact with Metal-Bearing Material

The microbes are introduced into a slurry or heap that contains the metal-rich ore or waste.

Step 2: Metal Ion Release

Metals such as Cu^{2+}, Zn^{2+}, or Ni^{2+} dissolve in the aqueous phase due to bioleaching or natural solubilization.

Step 3: Surface Binding

Metal ions in the solution bind to the negatively charged functional groups on the microbial cell walls through:

- Ion exchange
- Complexation
- Electrostatic interactions

Step 4: Bioaccumulation (optional)

In some cases, after adsorption, the metal ions may enter the cell and accumulate internally, though surface adsorption is usually extracellular and metabolism-independent.

Advantages of Surface Adsorption in Biomining

- Eco-friendly: Reduces chemical usage in metal recovery
- Cost-effective: Operates at ambient temperature and pressure
- Selective: Certain microbes show preferential binding to specific metals
- Applicable to low-grade ores and mine waste

Applications

- Recovery of heavy metals (e.g., uranium, gold, copper, zinc)
- Treatment of acidic mine drainage
- Bioremediation of contaminated soils and waters