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SENIOR FIVE TERM 1

TOPIC 1: Cell Biology

Competency: The learner evaluates cells and tissues, by analyzing and relating their structure to function, as a basis for medical research in order to improve health.

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Acids, bases and salts

Definition

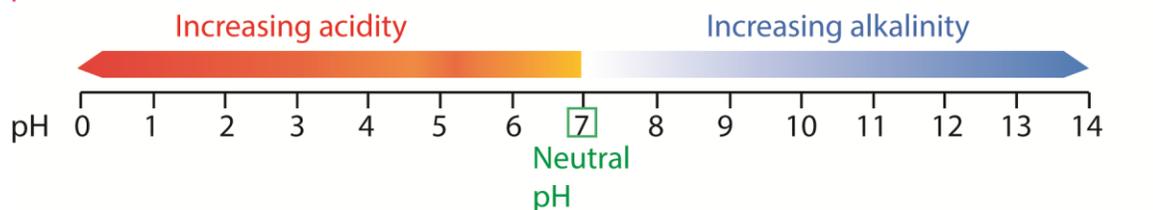
An **acid** is a molecule or ion capable of donating hydrogen ions (proton or H^+) in solution. They neutralize alkalis, dissolve some metals with liberation of hydrogen, and turn litmus red; typically, a corrosive or sour-tasting liquid of this kind:

A **base** is a substance that can accept a hydrogen ion (H^+) from another substance

pH

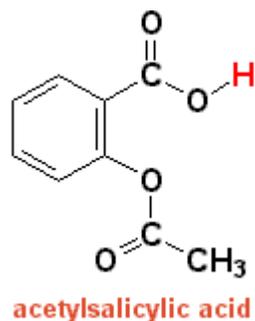
In chemistry, pH is a numeric scale used to specify the acidity or basicity (alkalinity) of an aqueous solution. It is roughly the negative of the logarithm to base 10 of the concentration, measured in units of moles per liter, of hydrogen ions. More precisely it is the negative of the logarithm to base 10 of the activity of the hydrogen ion.

pH Scale



Here are some of the places that acids and bases can be found in the human body:

1. **DNA** is a complex NUCLEIC ACID found in cells that contains four unique nitrogen-based BASES: adenine, cytosine, guanine and thymine. Differing combinations of these four bases determine the genetic characteristics of all human life.
2. **AMINO ACIDS** are the building blocks of proteins! The majority of amino acids consist of both a carboxylic acid (**-COOH**) and an amino (**-NH₂**) functional group attached to the same tetrahedral carbon atom.
3. **LACTIC ACID** is an acid produced when sugars are processed by the body. The production of too much lactic acid can cause serious health issues and even death.
4. **VITAMIN C** has the chemical name ASCORBIC ACID and Aspirin and other pain relief remedies are also organic acids. Here is the chemical structure of Aspirin:



5. BLOOD is naturally buffered to a pH of 7.35 – 7.45 in healthy humans. While our bodies naturally work to keep a healthy acid-base balance, problems can arise when acidic or basic compounds are too concentrated or not present in high enough concentrations. The blood's acid-base balance is precisely controlled, because even a minor deviation from the normal range can severely affect many organs. The body uses different mechanisms to control the blood's acid-base balance such as the release of CO₂ from the lungs, adjusted kidney function for excretion of substances and controlled buffering of blood via concentrations of the bicarbonate ion.
6. Acidosis **and** alkalosis are the two abnormalities of acid-base balance. In acidosis, the blood has too much acid (or too little base), resulting in a decrease in blood pH. In alkalosis, the blood has too much base (or too little acid), resulting in an increase in blood pH. Acidosis and alkalosis are not diseases, but rather are conditions that result for a variety of reasons.

Effects of unbalanced pH in the body

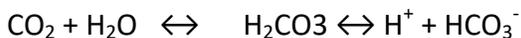
A person with mild metabolic acidosis may have no symptoms but usually experiences nausea, vomiting, and fatigue. Breathing becomes deeper and slightly faster (as the body tries to correct the acidosis by expelling more carbon dioxide). As the acidosis worsens, the person begins to feel extremely weak and drowsy and may feel confused and increasingly nauseated. Eventually, blood pressure can fall, leading to shock, coma, and death.

Systems responsible for maintenance of the acid-base balance in the body

Several systems maintain constant pH. The list below is made according to order when they act:

- 1) **Chemical buffering systems** provides immediate and short-term response to pH changes.

The **bicarbonate buffer system** is an acid-base homeostatic mechanism involving the balance of carbonic acid (H₂CO₃), *bicarbonate* (HCO₃⁻), and carbon dioxide (CO₂) in order to maintain pH in the blood. In presence carbonic anhydrase, carbon dioxide (CO₂) reacts with water (H₂O) to form carbonic acid (H₂CO₃), which in turn rapidly dissociates to form a bicarbonate ion (HCO₃⁻) and a hydrogen ion (H⁺) as shown in the following reaction:



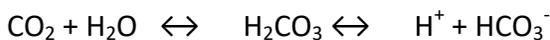
When the pH of the body falls, H^+ and HCO_3^- react to form H_2CO_3 and when pH rise H^+ react with OH^- to form water leading to further ionization of H_2CO_3

2) Respiratory system

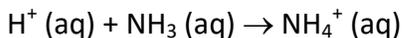
Respiration reacts in **1-3 minutes**. Respiratory system regulates **carbon dioxide**. Respiration is able to change pCO_2 by its elimination or retention. Respiratory centre is in **brainstem**.

3) Kidneys

Kidneys react in **hours-days**. In the kidney carbon dioxide react with water to form hydrogen ions (H^+) and hydrogen carbonate (HCO_3^-)



When the pH is low the collecting duct and distal convoluted tubules secrete hydrogen ions and retain hydrogen carbonate ions producing urine with low pH. H^+ are eliminated as ammonium ions.



Conversely, if blood too alkaline, then the collecting duct can secrete bicarbonate into urine and retain H^+ lowering the pH of blood leading to alkaline urine.

4) Liver

Liver is pivotal organ of the energetic metabolism it also has important influence on the acid-base balance. Liver is the most important tissue where ammonium is detoxified in both urea cycle, and glutamine synthesis. Which one of these fates of ammonium is favored closely depends on status of the acid-base balance:

a) $NH_4^+ \rightarrow$ **urea** + $2 H^+ \rightarrow$ acidification of the body



b) $NH_4^+ \rightarrow$ **glutamine synthesis** $\rightarrow H^+$ is not produced, glutamine is taken up by the kidneys. In the kidney is H^+ **excreted as NH_4^+**

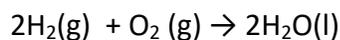
Water

This is the most abundant compound, typically making up of 60-95% fresh mass of an organism.

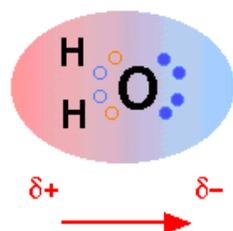
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Structure of water

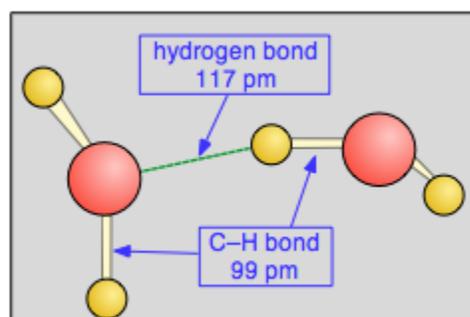
Water is made of hydrogen and oxygen.



The H_2O molecule is electrically neutral, but polar because the positive and negative charges are not distributed uniformly. This leads to partial positive charges on hydrogen atoms and a partial negative charge on oxygen atom



In liquid and solids these partial charges attract to form hydrogen bonds



The hydrogen bonds are responsible for high melting and boiling points and strong surface tension of water.

Uses of water in living organisms

- (i) It makes up structures of organisms
- (ii) It is a solvent
- (iii) It is a reagent in hydrolysis
- (iv) Provide support for aquatic organisms.
- (v) Is a medium of fertilization through which gametes swim.
- (vi) Medium for removal of waste products
- (vii) Temperature control
- (viii) Hearing and balance as endolymph

Uses of water to the plants

- (i) Aid seed dispersal
- (ii) Provide support to herbaceous plants
- (iii) Breaks up the testa of a seed during germination
- (iv) Reagent in photosynthesis
- (v) Loss of water through the leaves cools the plant.
- (vi) Medium of fertilization

Uses of water to the animal

- (i) A medium of transport
- (ii) Evaporation cools the animal
- (iii) Lubricates joints, eyes, lungs
- (iv) Constituent of protecting fluids such as tears, mucus.

Adaptation of Water to its function to organisms

- (i) Water is the **universal solvent**:

Polar and ionic substances have an electrostatic charge, so they are attracted to the charges on water molecules and dissolve readily. Non-polar substances, such as oil, do not dissolve in water, as they do not have charged molecules. When a salt dissolves in water, the ions separate and a layer of water molecules form around the ions. These layers prevent ions or polar molecules from clumping together, keeping the particles in solution.

- (ii) Water has a high **surface tension**:

At an interface between air and water, a water molecule on the surface forms hydrogen bonds with other molecules around and below it, but not with air molecules above it. The unequal distribution of bonds produces a force called surface tension; this causes the water surface to contract and form a surprisingly tough film or 'skin' enabling small animals like insects to walk over. It also protects blood capillaries of gill filaments from bursting.

- (iii) Ice **floats** on water:

Water is at its most dense at 4°C. When water freezes the hydrogen bonds between the molecules forms a rigid lattice, that holds the molecules further apart than in liquid water. Ice, having expanded when freezing, is less dense than its liquid counterpart and so floats on water. This protects water from further freezing because ice insulates the surface of water.

(iv) Water is **adhesive** and **cohesive**:

Water is 'wet' because it sticks to things. This is because its molecules can form hydrogen bonds with other polar substances. This is called adhesion. The attraction between molecules of similar substances is called cohesion. In this way water molecules stick together which allows water to enter and move along very narrow spaces, in a process called capillarity. This enables water ascend in the xylem of a tall tree.

(v) Important **thermal** properties:

Water has a high **specific heat capacity** meaning that it needs to gain a lot of energy to raise its temperature. Conversely it also needs to lose a lot of energy to lower its temperature. Water's specific heat capacity is $4.2 \text{ kJ/g}^\circ\text{C}$. Thus, this minimizes increase in temperature on hot days.

Water has a high **latent heat of vaporization** which means a lot of energy is required to evaporate it. When it evaporates, water draws thermal energy out of the surface it's on, which can be observed in sweating. Thus, sweating cools, the body.

Water also has a high **latent heat of fusion** meaning that at 0°C water must lose a lot of thermal energy before it freezes, thus liquid water can reach temperatures of down to -10°C before it forms ice. This implies too much heat loss is required to freeze water body.

(vi) Other physical properties of water:

It is transparent to sunlight. This allows animals to see in water also photosynthesis in aquatic plants.

It has a relatively high density compared to air, this support aquatic animals while swimming.

It is difficult to compress. Thus, support aquatic animals while swimming.

It conducts electricity (when it contains dissolved ions) enable conduction of heat, keeping water hot.

Inorganic compounds/mineral salts

Inorganic salts include those needed in large amounts such as salts of Na^+ , Mg^{2+} , Cl^- , K^+ and those needed in trace amounts such as manganese, iron, cobalt, copper, zinc, boron, aluminium, silicon, vanadium, molybdenum and iodine

Functions of inorganic salts

- (i) They are components of proteins, e.g. nitrogen, phosphorus and Sulphur.
- (ii) They are components of tissues; e.g. calcium and phosphorus are components of bones
- (iii) They are constituents of enzymes; e.g. copper and iron.
- (iv) They are metabolic activators for example; magnesium activates enzymes in phosphate metabolism.
- (v) They are constituent of pigments for example, iron in hemoglobin and magnesium in chlorophyll.
- (vi) They are determinants of anion-cationic balance in the cell example Na^+ , Cl^- , and K^+ .
- (vii) They are determinants of osmotic pressure, e.g. Na^+ , Cl^- , and K^+ .

Carbohydrates

Carbohydrates are food substances with a general formula $(\text{CH}_2\text{O})_n$ where n is natural number.

Classification

- (i) Monosaccharides e.g. glucose, galactose and fructose

Sources: honey, fruits

Properties

- They are sweet
- Are soluble in water
- They reduce blue copper II ions to red precipitates in alkaline medium.

Testing for reducing sugars

When boiled with Benedict's or Fehling's solutions the color changes from blue to green to yellow to oranges ppt.

- (ii) **Disaccharides**

They are made of two simple sugars by condensation. Examples are given in the table below

Disaccharides	Composition	Source
Maltose	glucose + glucose	malt
Lactose	Glucose + galactose	milk
Sucrose	Glucose + fructose	Sugar cane Sugar beets
Cellubiose	Glucose + glucose	wood

Maltose, lactose and sucrose are sweet and are referred to as sugars. Maltose and lactose are reducing sugars whereas sucrose is not and referred to as non-reducing sugar.

Testing for non-reducing sugars

- When boiled with Benedict's solution or Fehling's' solution, the color remains blue.
 - When boiled with HCl, the solution cooled, neutralized by NaOH, boiled with Benedict's or Fehling's solution, the color changes from green, to yellow to orange.
- HCl hydrolyses non-reducing sugars to reducing sugars.
NaOH neutralizes the excess acid because Benedict's or Fehling's solution does not work in acidic medium.

(iii) Polysaccharide (CH₂O)_n

These are made of very many mono saccharides per unit molecule e.g. starch and cellulose

Testing for starch

It changes the color of iodine black or blue.

Functions of carbohydrates in the body

- (i) Glucose, galactose and fructose are oxidized to release energy in the body
- (ii) Glyceraldehyde is an intermediate molecule in photosynthesis.
- (iii) Ribose is component nucleotides.
- (iv) Sucrose is a form in which carbohydrates are transported in plants
- (v) Lactose is a source of energy in milk
- (vi) Storage of energy (starch in plants, glycogen in animals, inulin in some plants like Dahlia)
- (vii) Formation of cellular structures (cellulose in plant cell walls, chitin in insects)

Lipids

These include natural fats and oil. Fats are solids at room temperature while oils are liquids

Structure of lipids

Lipids are ester of glycerol and fatty acids

Formation of triglyceride from glycerol and fatty acids

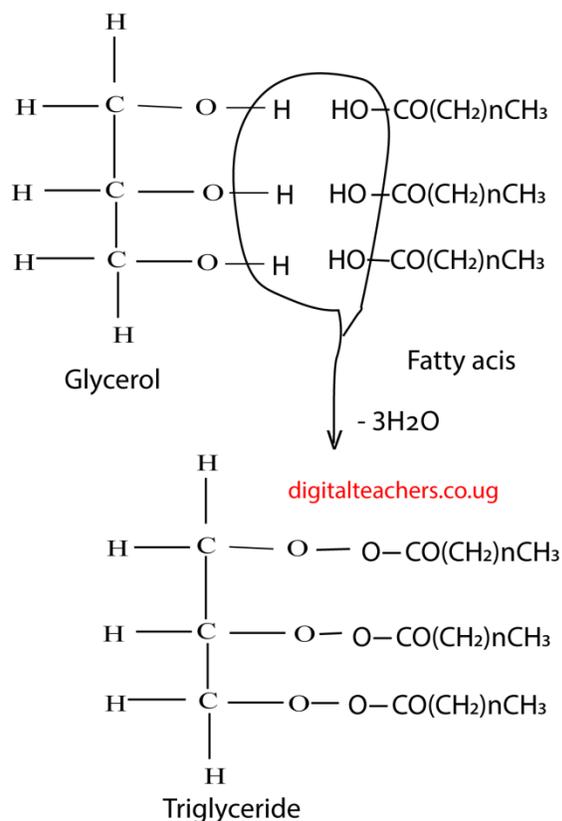


Table of nature and occurrence of some fatty acid

Name of fatty acid	formula	Saturated/unsaturated	occurrence
Butyric acid	C ₃ H ₇ COOH	Saturated	Butter fat
Linoleic	C ₁₇ H ₃₁ COOH	unsaturated	Linseed oil
Oleic	C ₁₇ H ₃₃ COOH	unsaturated	All fats
Palmitic	C ₁₅ H ₃₁ COOH	Saturated	Animal and vegetable fats
Stearic	C ₁₇ H ₃₅ COOH	Saturated	Animal and vegetable fats
arachidic	C ₁₉ H ₃₉ COOH	Saturated	Peanut
Ceritic	C ₂₅ H ₅₁ COOH	Saturated	Wool oil

Simple and conjugated lipids

Simple lipids

Simple lipids are composed only of fatty acids and an alcohol, and yield only fatty acids and an alcohol upon hydrolysis.

Composition of simple lipids

- **Fatty acids:** One to three fatty acid molecules.
- **Alcohol:** An alcohol molecule, such as glycerol (a trihydroxy alcohol) or a high-molecular-weight monohydric alcohol.

Types and examples of simple lipids

- **Fats and oils (Triacylglycerols or Triglycerides):** These are esters formed from glycerol and three fatty acids. The difference between a fat and an oil is their state at room temperature; fats are solid, and oils are liquid. Examples include butter, lard, and olive oil.
- **Waxes:** These are esters of long-chain fatty acids with long-chain monohydric alcohols. They are highly water-repellent. Examples include beeswax and carnauba wax, a plant wax.

Function of simple lipids

- **Energy storage:** Triglycerides are the most abundant lipids and the primary form of energy storage in both plants and animals.
- **Insulation:** In animals, stored fat (adipose tissue) serves as a thermal insulator.
- **Protective coating:** Waxes provide a waterproof layer on the feathers of birds, the fur of animals, and the leaves of plants to prevent water loss.

Conjugated (compound) lipids

Also known as complex lipids, conjugated lipids are formed from fatty acids and an alcohol, but also contain other chemical groups, such as a phosphate, carbohydrate, or protein.

Composition

- **Fatty acids**
- **Alcohol**
- **Additional group:** A phosphate group, carbohydrate, protein, or other nitrogen-containing molecule.

Types and examples conjugated lipids

- (i) **Phospholipids:** These contain a phosphate group and a nitrogen-containing alcohol attached to a glycerol backbone. They have a hydrophilic (water-loving) head and a

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hydrophobic (water-repelling) tail, making them amphipathic. **Examples:** Lecithin and cephalins, which are key components of cell membranes.

- (ii) **Glycolipids:** These lipids contain a carbohydrate group attached to either a glycerol or sphingosine molecule. **Examples:** Cerebrosides and gangliosides, which are found in nerve and brain tissue.
- (iii) **Lipoproteins:** These are complexes of lipids and proteins that enable the transport of fats through water-based fluids like blood. **Examples:** High-density lipoproteins (HDL) and low-density lipoproteins (LDL).

Function conjugated (compound) lipids

- (i) **Structural components:** Phospholipids and glycolipids are crucial components of cell membranes, forming the lipid bilayer that encloses every living cell.
- (ii) **Signal transduction:** Some conjugated lipids act as second messengers in cell signaling pathways.
- (iii) **Molecular transport:** Lipoproteins are responsible for transporting lipids, such as cholesterol and triglycerides, in the bloodstream.
- (iv) **Nerve protection:** Sphingolipids are a major component of the myelin sheath that insulates nerve fibers and increases the speed of nerve impulse transmission.

Summary of the uses of lipids

Structural functions of lipids

- Make up cell membrane and membranes of cell organelles
- Protection: lipids are constituents of the waxy cuticle of plants and insects. Also Myelin sheath that protects the axon is rich in lipids
- Lipids are water repellent thus prevent water loss from or entry into an animal skin
- Their spongy nature protects delicate organs as shock absorbers.
- Being bad conductors, they reduce water loss from the body when deposited beneath the skin for insulation
- Storage ; they are better storage compounds than carbohydrates due to high calories value, due to high hydrogen content, they are light, insoluble in water, compact to fit in a small volume and are easily used when required.
- Cell identity markers: Glycolipids on the outer surface of the cell membrane have carbohydrate chains that act as recognition markers for cell-to-cell communication. A well-known example is the set of glycolipids that determine the human blood types (A, B, O).
- Receptor functions: Glycolipids and specialized lipid rafts can also serve as receptors for certain signaling molecules and pathogens.

Physiological functions of lipids

- Source of metabolic water
- Store fat soluble vitamins (ADEK)
- Source of metabolic water
- Raw materials for hormones

Testing for lipids

- They form a translucent mark on paper that does not disappear when the paper is dried on a flame.
- Emulsion test
When 2cm^3 of fats or oil are dissolved in 2cm^3 of absolute ethanol followed by water, a white cloudy suspension is formed.
- Sudan III
When a few drops of Sudan III are added to a mixture of 2cm^3 of water and 2cm^3 of oil and shaken, a red stained oil layer separates out.

Advantage of storing fats over carbohydrate

- Has high energy content than carbohydrates per unit mass
- It is lighter. The lightness of fat storage (relative to its energy content) was crucial for nomadic human ancestors who needed to travel and hunt without being weighed down by bulky carbohydrate reserves
- It is compact and requires less space because fats are anhydrous since they are hydrophobic while carbohydrates are hydrated
- It is a raw material for hormones
- Insoluble in water that they have low osmotic value
- Unlimited storage capacity: Adipocytes can expand indefinitely to store triglycerides, allowing for the accumulation of a large, long-term energy reserve. Unlike the body's glycogen stores, located primarily in the liver and muscles, are limited and can become saturated fairly quickly

Proteins

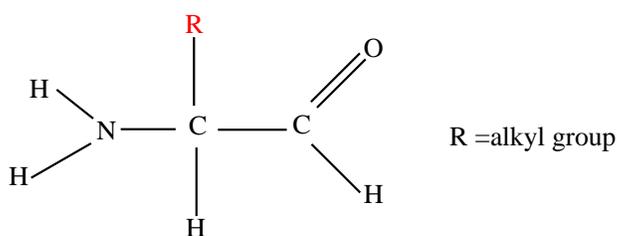
Proteins are polymers of amino acids

These are classified into two groups

- Structural proteins:** insoluble proteins that make up body structures like bones and muscles. Fibrinogen is a soluble structure protein used in blood clotting.
- Globular proteins** are soluble proteins such as enzymes, antibodies, hormones and so on.

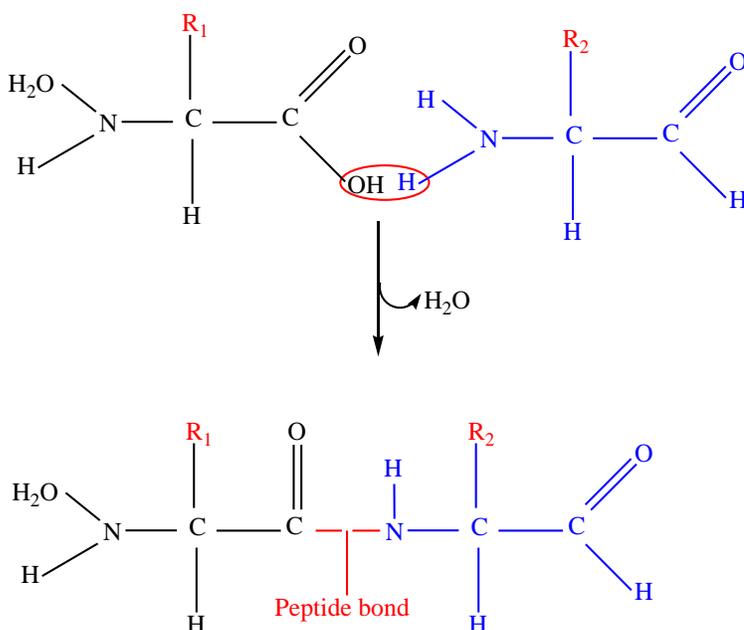
Composition of proteins

The basic unit of proteins are amino acids



There are about 22 different amino acids in the body of which isoleucine, leucine, methionine, phenylamine, proline, threonine and valine cannot be synthesized in human body and they are referred to as **essential amino acids**.

Amino acids unite to form proteins through formation of peptide bonds by a condensation reaction in which a water molecule is eliminated.



Classification of proteins

Proteins are classified into three main structural categories based on their overall shape and physical properties: **fibrous, globular, and membrane proteins**. Their distinct structures dictate their specific properties and functions within an organism.

Fibrous proteins

Fibrous proteins are elongated, robust, and insoluble, primarily serving structural, protective, and connective roles.

Properties

- **Shape:** Long and narrow, with polypeptide chains running parallel to each other.
- **Solubility:** Generally insoluble in water, which makes them ideal for providing structural support in a watery environment.
- **Amino acid sequence:** Often consist of repetitive amino acid sequences.
- **Stability:** Highly stable due to strong intermolecular forces like hydrogen bonds and disulfide bridges.
- **Flexibility:** While some, like elastin, are very flexible, many fibrous proteins are rigid and strong, contributing to their supportive function.

Functions of fibrous proteins

- **Structural support:** Form connective tissues, hair, nails, and other extracellular structures.
- **Mechanical strength:** Provide strength, elasticity, and protection to tissues.

Examples:

- **Collagen:** The most abundant protein in mammals, it is a key component of skin, tendons, cartilage, and bone.
- **Keratin:** Forms hair, nails, claws, and the outer layer of skin.
- **Elastin:** Found in tissues that require elasticity, such as ligaments and blood vessel walls.

Globular proteins

Globular proteins are compact, spherical, and generally soluble in water, allowing them to carry out dynamic functions.

Properties

- **Shape:** Compact, globe-like, or roughly spherical due to intricate folding of the polypeptide chain.
- **Solubility:** Soluble in aqueous solutions because their hydrophilic (water-attracting) amino acids are on the surface, while hydrophobic (water-repelling) amino acids are buried in the core.

- **Amino acid sequence:** Have a highly specific and often irregular amino acid sequence, crucial for their unique three-dimensional shape.
- **Stability:** Less stable than fibrous proteins and sensitive to changes in temperature and pH, which can cause denaturation (unfolding).
- **Flexibility:** Possess conformational flexibility that is often necessary for their biological activity.

Functions of globular proteins

- **Enzymatic catalysis:** All enzymes are globular proteins that speed up metabolic reactions.
- **Transport:** Carry molecules through the bloodstream or across cell membranes.
- **Signaling and regulation:** Act as hormones and cell messengers to coordinate bodily functions.
- **Immune response:** Form antibodies that protect the body from pathogens.

Examples of globular proteins

- **Hemoglobin:** Transports oxygen in red blood cells.
- **Enzymes (e.g., amylase, lipase):** Catalyze biochemical reactions.
- **Insulin:** A hormone that regulates blood sugar levels.
- **Antibodies (immunoglobulins):** Part of the immune system.

Membrane proteins

Membrane proteins are associated with or embedded within biological membranes and perform vital cellular processes at the cell's boundary

Properties

- **Shape:** Highly diverse and adapted to their location, with sections folded to interact with the hydrophobic lipid core and others with the aqueous exterior.
- **Solubility:** Often require detergents for isolation from the lipid bilayer because they are insoluble in water.

- **Location:** Can be integral (permanently embedded), or peripheral (transiently associated with one side of the membrane).
- **Structure:** Integral membrane proteins often have transmembrane domains consisting of alpha-helices or beta-barrels.

Functions of membrane proteins

- **Transport:** Act as channels, pumps, and transporters to move ions and molecules across membranes.
- **Signaling:** Function as receptors that bind to external molecules, initiating intracellular signaling cascades.
- **Anchoring:** Connect the cytoskeleton to the extracellular matrix, helping to maintain cell shape.
- **Cell-cell communication:** Facilitate communication and adhesion between cells.

Examples of membrane proteins

- **Aquaporins:** Form channels for water transport.
- **G-protein coupled receptors (GPCRs):** Mediate cell signaling.
- **Voltage-gated sodium channels:** Important for nerve impulse transmission.

Summary of the uses of proteins

- (i) Make up structures, e.g., collagen make up connective tissues.
- (ii) Make up enzymes such as catalyze and amylase.
- (iii) Are constituent of hormone such as insulin
- (iv) Are constituents of antibodies that protect the body from foreign particles.
- (v) Make up muscles such as myosin and actin
- (vi) They are storage food e.g. egg white
- (vii) Constitute toxins such as snake venom for protection.

Protein denaturation

Protein denaturation is the destruction of the highly ordered structure of the protein in its natural (native) state leading to loss of its function by breaking bonds (e.g., hydrogen bonds), within a protein .

Factors that cause protein denaturation

- Heat, which can disrupt hydrogen bonds and non-polar hydrophobic interactions.
- Freezing, which can cause ice crystals to form and damage the protein structure.
- pH change, which can alter the charge and polarity of amino acids and affect their interactions.
- Ionic strength change, which can affect the electrostatic forces between amino acids and their surroundings.
- Surface changes, which can expose the protein to different environments and solvents.
- exposure to UV light and radiation breaks bond in the proteins
- chemicals such as alcohol and heavy metals precipitate proteins from solution
- mechanical agitation can distort protein structures leading to denaturation

Testing for proteins

- a. They coagulate on heating
- b. They coagulate on addition of Melon's reagent and on heating they form a pink precipitate.
- c. They form a purple solution when mixed with equal amount of NaOH followed by 3 drops of copper sulphate solution.

Vitamins

Vitamins are complex organic compounds present in very small quantities in natural food which are essential for good healthy body and maintains its normal metabolic activities. Some vitamins are fat soluble (A, D, E, K) while others are not.

Vitamin C / ascorbic acid

Sources: citrus fruits, green vegetables, potatoes, tomatoes, etc.

Functions: Concerned with the metabolism of connective tissues and the production of strong skin.

Deficient disease: anemia and scurvy: the gums bleed, wounds fail to heal.

Testing for Vitamin C: It decolorizes DCPIP.

Other vitamins and their deficient diseases

Vitamin

A	Night blindness
K	Delayed clotting
E	Reduced fertility in rats

Functions of vitamins

- protect the body against diseases
- formation of coenzyme that facilitate enzyme reactions
- blood clotting
- components of visual pigment

Enzymes

Enzymes are biological catalyst usually protein in nature

Difference between enzyme and catalysts.

	Enzymes	Catalysts
1.	proteins in nature	inorganic chemicals e.g. Pt
2.	catalyze specific reactions Such as hydrolysis of starch	may catalyze more than one reaction e.g. platinum catalyze decomposition of H_2O_2 and reduction of benzene
3.	Denatured by heat above $45^{\circ}C$	Usually are not affected by heat
4.	Very sensitive to pH	Not sensitive to pH
5.	Initiate reaction	Do not initiate reaction

Enzyme classification

Enzymes are placed into six groups according to the general type of reaction which they catalyze

Each enzyme is given a systematic name, accurately describing the reaction it catalysis.

However, since many of these names are very long and complicated, each enzyme as allocated a trivial name of the substrate acted on by the enzyme

- (i) the name of the substrate acted on by the enzyme
- (ii) the type of reaction catalyzed.
- (iii) the suffix-ase.

The categories of enzyme are;

1. **Oxidoreductase**; are involved in biological oxidation and reduction reaction. They include dehydrogenase which catalyze removal of hydrogen atoms from a substrate and oxidase which formation of water e.g., in respiration.
2. **Hydrolase**; catalyze the addition of water to or the removal from a substrate.eg protease.
3. **Transferase**; These catalyze transfer of chemical groups or atoms from one substrate to another. Those that transfer amino groups $[NH_2]$ are called transaminase.

4. **Lyase**; break chemical bonds other than hydrolysis this creating double bond. They include carboxylase which remove carboxyl group [COOH] from intermediates in respiratory pathways.
5. **Isomerase**; These enzymes catalyze the transfer of an atom from one part of a molecule to another.
6. **Ligase** or synthetase; catalyze joining together of two molecules coupled with the breakdown of ATP e.g., phosphokinase which catalyze the addition of phosphate group to a compound.

The properties of enzymes

1. They catalyze the rate of biological reactions.
2. They are not destroyed by the reaction in which they catalyze.
3. They work in either direction i.e., catalyze both forward and backward reaction.
4. They are inactivated by high temperatures
5. They are sensitive to pH changes
6. They are usually specific to particular reactions

An experiment to investigate Investigating specificity of Enzyme

- (i) Prepare 4; to test tubes 1 and 2 add 1cm^3 of 1% starch solution; to test tube 3 and 4 add 1cm^3 of hydrogen peroxide
- (ii) To test tubes 1 and 3 add 1cm^3 of catalyze enzyme.
- (iii) To test tube 2 and 4 add amylase enzyme solution
- (iv) Incubate test tubes 1, 2, 3, and 4 between $35^{\circ}\text{C} - 40^{\circ}\text{C}$ for 30minutes
- (v) After 30 minutes test for presence of reducing sugar

Observations

Test tube 1: no reducing sugars

Test tube 2: reducing sugars presence

Test tube 3: effervescence, no reducing sugars

Test tube 4: no effervescence, no reducing sugars

Explanation

Test tube 1: no reducing sugar because catalyze enzyme does not act on starch

Test tube 2: reducing sugars formed because amylase enzyme broke down starch to reducing sugars.

Test tube 3: effervescence because catalyze enzyme broke down hydrogen peroxide to oxygen and water and not reducing sugars

Test tube 4: no effervescence and no reducing sugars because amylase enzyme does not act on hydrogen peroxide

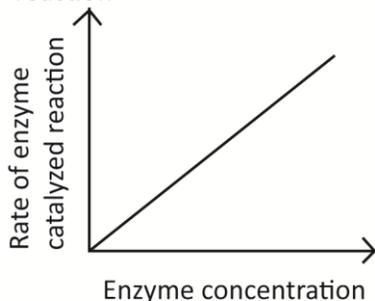
Conclusion

Enzymes are specific to the substrate for instance, amylase enzyme is specific on starch while catalyze enzyme is specific on hydrogen peroxide

Factors affecting the rate of enzyme reaction

- a) **Enzymes concentration;** provided that the substrate concentration is maintained at a high level, and other conditions such as pH and temperature are kept constant, the rate of reaction is proportional to enzyme concentration.

A graph showing relationship between enzyme concentration and the rate of enzyme- controlled reaction



Question; How would you design an experiment to show this?

Experiment to investigate concentration of amylase enzyme on the rate of reaction

- (i) Prepare 1% starch solution, 1% amylase solution and 5% amylase solution
- (ii) Label test tubes 1 and 2
- (iii) Test tube 1: add 2cm³ of starch solution and 1cm³ of 1% starch solution.
- (iv) Test tube 2: add 2cm³ of starch solution and 1cm³ of 5% starch solution.
- (v) Place test tubes 1 and 2 in a water bath maintained at 35⁰C – 40⁰C shaking periodically.
- (vi) Every after 1 minute withdraw a few drops from every test tube, place them on a white tile and add a drop of iodine solution.
- (vii) Note the time taken for starch to disappear from each test tube.

Observations:

Test tube 2 starch disappeared before test tube 1

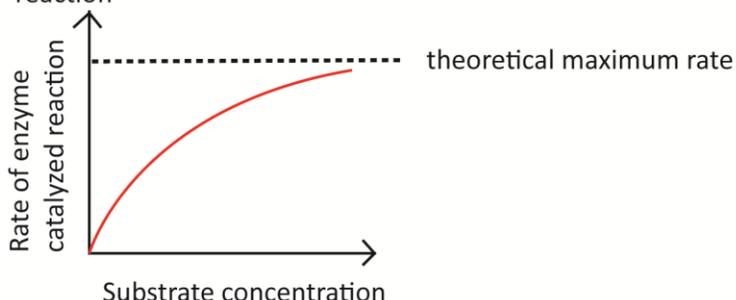
Explanation

Test tube 2 contains high concentration of enzyme that digests starch completely faster than the lower concentration of the enzyme in test tube 1

b) Substrate concentration.

For a given enzyme concentration, the rate of an enzyme reaction increases with increasing substrate concentration. The theoretical maximum rate [V_{max}] is never quite obtained, but there comes a point when any further increase in substrate concentration produces no significant change in reaction rate. This is because at high substrate concentration the active sites of the enzyme molecules at any given moment are virtually saturated with substrate. Thus, any extra substrate has to wait until the enzyme/ substrate complex has dissociated into product and free enzyme before it may itself complex with the enzyme.

A graph showing relationship between substrate concentration and the rate of enzyme- controlled reaction



Question; How would you design an experiment to show this?

Experiment to investigate concentration of substrate on the rate of enzyme reaction

- (i) Prepare 1% starch solution, 5% starch solution and 5% amylase solution
- (ii) Label test tubes 1 and 2
- (iii) Test tube 1: add 5cm^3 of 1% starch solution and 1cm^3 of 5% amylase solution.
- (iv) Test tube 2: add 5cm^3 of 5% starch solution and 1cm^3 of 5% starch solution.
- (v) Place test tubes 1 and 2 in a water bath maintained at $35^{\circ}\text{C} - 40^{\circ}\text{C}$ shaking periodically.
- (vi) Every after 3 minutes, remove 0.5cm^3 from each test tube test for presence of reducing sugar until a positive results are obtained for each test tube contents.

Observations:

Test tube 2 reducing sugar earlier than test tube 1

Explanation

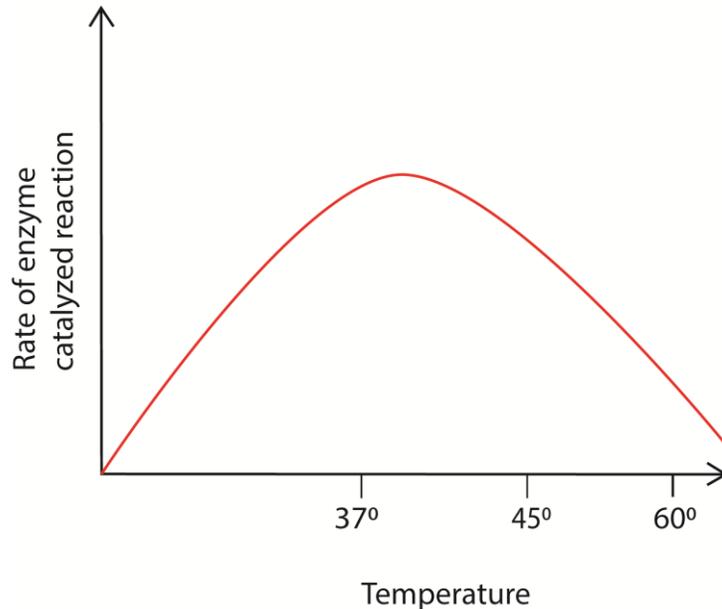
Test tube 2 contains high concentration of substrate (starch) that is acted on quickly to produce reducing sugars earlier than in test tube 1 where the concentration of starch was low.

c) Temperature

Up to 40°C , the rate of enzyme -controlled reaction increase smoothly with temperature, a ten degree rise in temperature being accompanied by approximately doubling the of

reaction. Above that 40°C the rate begins to fall off and then decline rapidly, ceasing at about 60°C, because the enzyme is denatured.

Graph showing the effect of temperature on the activating of enzyme as salivary amylase



An experiment to investigate the effect of temperature on rate of action of amylase

Materials.

- 1% starch solution
- 40 water bath
- White tile
- Test tubes
- Glass rod
- Iodine solution

Method

- Prepare 3 test tubes each with 2cm³ of 1% starch solution and 2cm³ of 1% amylase solution. Place
Test tube 1; in beaker containing ice
Test tube2; in a water bath at 40°C water bath.
Test tube3; in a beaker of boiling water
And simultaneously start the stop clock.
- Every after 1 minute withdraw a few drops from every test tube, place them on a white tile and add a drop of iodine solution.
- Note the time taken for starch to disappear from each test tube.

Observations and explanations

Test tube 2: starch disappeared because the amylase enzyme worked faster in a water bath at 40°C.

Test tube 1: starch did not disappear because the enzyme was inactive at low temperature but when the test tube is transferred to a water bath at 40°C, starch finally disappeared because the enzyme was activated.

Test tube 3: starch did not disappear even when the test tube was transferred to a water bath at 40°C because the enzyme was denatured at high temperature

d) pH

Under conditions of constant temperature, every enzyme function most efficiently over a narrow pH range e.g. pepsin at pH= 2, Amylase (salivary) at pH 6.8.

Experimentally, the pH is usually adjusted by adding HCl or NaOH to the mixture

Experiment to show the effect of pH on the action of catalyze enzyme.

- (i) Label two test tubes 1 and 2
- (ii) To test tube 1 add 1cm³ of hydrogen peroxide, followed by 1cm³ of NaOH solution and 1cm³ of catalyze enzyme/a piece of Irish potato may do.
- (iii) To test tube 2 add 1cm³ of hydrogen peroxide, followed by 1cm³ of NaOH solution and 1cm³ of catalyze enzyme/a piece of Irish potato may do.

Observations and explanations

Test tube 1: high rate of effervescence because NaOH provided favorable pH for catalyze enzyme.

Test tube 2: No/very low rate of effervescence because HCl provided unfavorable pH for catalyze enzyme.

Mechanism of enzyme action.

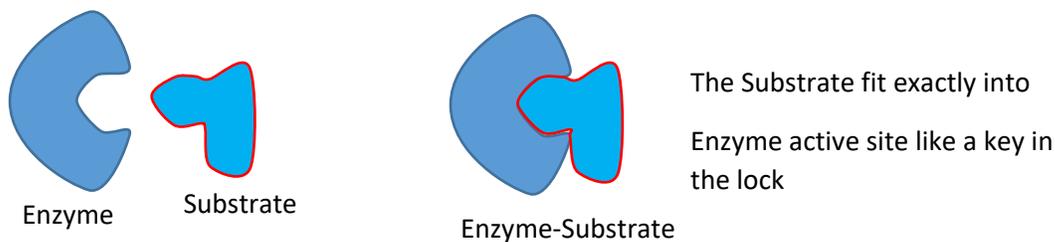
The action of an enzymes is specific to a given substrate and this specificity can be explained by two hypothesis.

Lock and key hypothesis

Enzyme are very specific to the substrates they act on because they have particular shape / configuration into which substrate with complementary shape fit in exactly as the key fit into the lock, thus the lock (enzyme) and key (substrate) hypothesis.

When an enzyme - substrate complex is formed; the substrate activated into forming the product of the reaction. Once formed, the product no longer fits into the active site and

hence escapes into the surrounding medium leaving the active site free to receive other substrate molecule.



Induced fit hypothesis.

This hypothesis claim that enzyme and their active site are physically rather more flexible structure than this described by the lock and key hypothesis, and that the active site of the enzyme is molded into a precise configuration in presence of a substrate to enable it perform its catalytic functions more effectively.

Inhibitors of enzymes

Certain substrate inhibit enzyme, thereby slowing down or stopping enzyme – controlled reactions.

These enzyme inhibitors are of specific interest for the following reasons.

- They give us important information about the shape and properties of active site of enzyme.
- They can be used to block particular reactions thereby enabling biochemist to reconstruct metabolic pathways.
- They have important medical and agricultural use as for example drugs and pesticides.

Type of inhibitors

(i) **Competitive reversible inhibitor;**

Here a compound is structurally similar to that of the usual substrate associates with the enzymes active site but it's unable to react with it. While it remains there, it prevents access of any molecules of the substrate. This type of inhibition depends on the concentration of the substrate and that of an inhibitor. At high concentration of the substrate, inhibition is overcome.

This knowledge of competitive inhibitors has been utilized in chemotherapy. Sulphonamides drugs and antibiotic such as penicillin are competitive inhibitors of essential metabolites for enzymes in bacteria.

(ii) Noncompetitive reversible inhibitors.

This is a type of inhibition in which the inhibitors attach themselves outside the active site thereby preventing the enzyme normal catalytic reaction by changing the shape of the enzyme or allosteric effect. It may be reversible when the inhibitor forms loose attachment to the enzyme that may be detached when circumstances permit e.g. cyanide or irreversible noncompetitive inhibition when the inhibitor permanently disorganizes the structure of the enzyme that it may no longer react with the substrate, e.g., mercury.

Allosteric enzymes and their inhibition

Allosteric enzymes are enzymes which exist in two different form, one active and the other inactive. The activity of these enzyme is regulated by compounds which are not their substrate and these substances (**allosteric effectors**) binds the enzyme at specific sites well away from the active site. They modify enzyme activity by causing a reversible change in the structure of the enzyme active site. Allosteric activators speed up enzyme catalyze reaction whereas or allosteric inhibitor slow down the action of allosteric enzymes.

An experiment to investigate the effect of an inhibitor on the action of an enzyme

This is a simple biological experiment to investigate the effect of an enzyme inhibitor on the activity of the enzyme amylase. The experiment uses readily available materials and provides a clear, observable result.

The concept

Amylase is an enzyme that breaks down starch into simple sugars (e.g., maltose). Iodine solution is used as an indicator to test for the presence of starch. Iodine turns blue-black in the presence of starch but remains yellow-brown when starch is absent. This color change can be used to monitor the progress of the reaction.

An inhibitor, such as a strong acid, will slow down or stop the amylase from functioning effectively.

Materials

- Starch solution (e.g., 1%)
- Amylase solution (e.g., saliva diluted in water)
- Dilute hydrochloric acid (HCl) solution (inhibitor)
- Iodine solution (starch indicator)

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- Buffer solution (to maintain optimal pH for the enzyme)
- Test tubes or small beakers
- A spot plate
- Pipettes
- Measuring cylinder
- Stopwatch
- Test tube rack
- Water bath or beaker with water at a constant temperature (around 37°C is ideal for salivary amylase)

Procedure

- (i) Label three test tubes: "Control," "Experiment," and "Inhibitor Control."
- (ii) To the control add 5 mL of starch solution, 5 mL of amylase solution and 5 mL of the buffer solution.
- (iii) To **experiment tube** add 5 mL of starch solution, 5 mL of amylase solution and 5 mL of the dilute HCl (inhibitor).
- (iv) To **the Inhibitor Control tube** add 5 mL of starch solution. 5 mL of the dilute HCl (inhibitor) and 5 mL of the buffer solution (no enzyme).
- (v) Place the test tubes into a water bath maintained between 35°C – 40°C.
- (vi) Every after 1 minute withdraw a few drops from every test tube, place them on a white tile and add a drop of iodine solution.
- (vii) Note the time taken for starch to disappear from each test tube.

Expected results

- **Control tube:** The mixture contains amylase and starch under optimal conditions. The iodine test will quickly turn from blue-black to yellow-brown, indicating rapid starch breakdown.

- **Experiment tube:** This mixture contains amylase, starch, and the inhibitor (HCl). The iodine will remain blue-black for a longer time or permanently, showing that the inhibitor has slowed down or completely stopped the enzyme's activity.
- **Inhibitor Control tube:** This mixture contains starch and HCl but no amylase. The iodine test will remain blue-black throughout the experiment, confirming that the starch is not being broken down and that the inhibitor itself does not affect the starch-iodine reaction.

Conclusion

By comparing the reaction rate in the Control tube with the rate in the Experiment tube, you can draw a conclusion about the effect of the inhibitor on the enzyme's activity. The Inhibitor Control tube acts as a crucial negative control, proving that the observed effect is due to enzyme inhibition and not some other chemical reaction.

Enzyme cofactors

These are non-protein components required by enzymes to function efficiently. Cofactor may vary from simple inorganic ions to complex organic molecules, and may either remain unchanged to the end of a reaction or be regenerated by the later processes. The enzyme-cofactor complex is called a **holo enzyme** whilst the enzyme portion without its cofactor is called an **apoenzyme**.

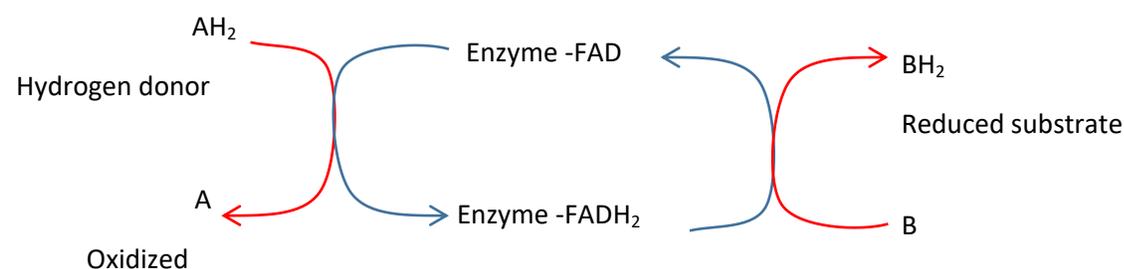
There are three recognized cofactors.

Inorganic ions (activator)

These are thought to modify either the enzyme or the substrate such that an enzyme-substrate complex can be formed, hence increasing the rate of reaction catalyzed by that particular enzyme, salivary amylase activity is increased in the presence of chloride ions.

(i) Prosthetic group (for example FAD, Biotin, Haem)

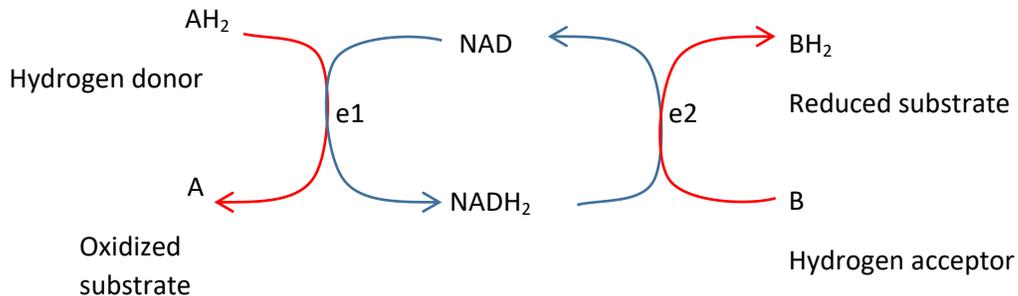
The organic molecule is integrated in such a way that it effectively assists the catalytic function of its enzyme, as in Flavin adenine dinucleotide [FAD]. This contains riboflavin [vitamin B₂] which is the hydrogen accepting part of FAD. It's concerned with cell oxidative pathways such as part of the respiratory chain in respiration.



Net effect; 2H are transferred from A to B. one halo enzyme acts as a link between A and B.

(ii) Co enzyme (NAD, NADP, Co enzyme A, ATP]

Nicotinamide adenine dinucleotide (NAD) is derived from the vitamin nicotinic acid and can exist in both a reduced and an oxidized form. In the oxidized state, it functions in catalysis as a hydrogen acceptor.

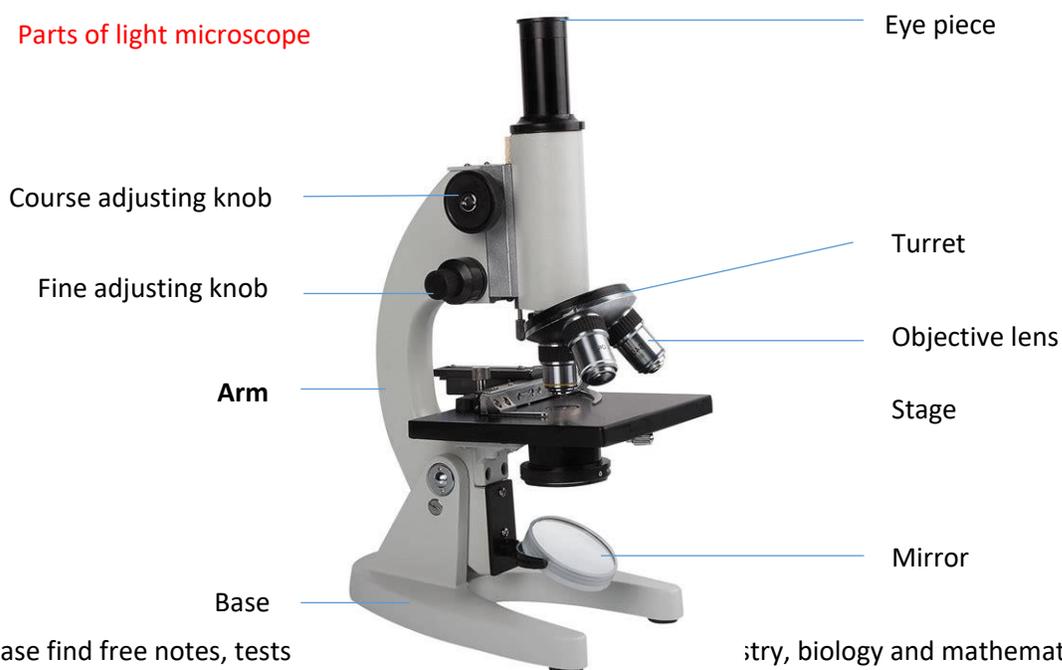


Where e1 and e2 are two different dehydrogenase enzyme.

Microscope

A microscope is a machine or equipment that magnifies specimens and enables us to view parts of the specimen that cannot be seen by naked eye. There are different types of a microscope but most school laboratories use a light microscope.

Parts of light microscope



Functions of parts of a microscope

Eye piece: magnifies the image of the specimen

Course adjusting knob: focuses the image of the specimen

Fine adjusting knob: fine tune the focus of the specimen

Turret: rotates and changes the objective lenses

Objective lenses: magnify specimens

Stage: is where the specimen is placed

Mirror: reflects light through the specimen

Base: supports the microscope.

Terminologies of microscope

- **Resolution is the ability of a microscope** to see the fine details of a specimen. **It is defined as the minimum distance between two distinct points** that can still be seen as separate. If two points are closer than this limit, they'll appear as one blurry spot.
- **Focusing of a microscope** is the ability to adjust the lenses and stage to get a sharp, clear image of the specimen you're observing.

Note that most Microscope models on Uganda market do not focus properly. Therefore, good microscopes should be purchased by a technical person who tests the microscope before otherwise the school may end with counterfeit/bicupuli useless microscopes that will make teaching theoretical.

Steps for Proper Focusing of a Microscope

- (i) **Prepare the specimen on the slide. Stain where necessary.**
- (ii) **Place and Center the Slide:** Secure your slide on the stage using stage clips. Use the stage controls to center the specimen under the lens.
- (iii) **Start with Low Magnification:** Rotate the nosepiece to the lowest objective lens (usually 4x or 10x). This gives a wider field of view and makes it easier to locate your specimen.
- (iv) **Use the Coarse Adjustment Knob:** Slowly turn the Coarse Adjusting knob to move the stage up or down. This brings the specimen roughly into focus. **Only use this knob with low-power objectives.**
- (v) **Switch to Fine Adjustment:** Once the image is nearly clear, use the fine adjustment knob to sharpen it. This is especially important at higher magnifications (40x, 100x).
- (vi) **Increase Magnification (Optional):** If needed, rotate to a higher-power objective. You may need to slightly adjust the fine focus again to maintain clarity.
- (vii) **Adjust Lighting and Diaphragm:** Modify the light intensity and diaphragm to improve contrast and resolution. Proper lighting helps reveal fine details.

Magnification using a microscope

Magnification is the number of times an image is bigger than the specimen.

How to Calculate Total Magnification of a microscope

- **Eyepiece (ocular lens):** Usually has a magnification of **10x**
- **Objective lens:** Comes in various powers like **4x, 10x, 40x, or 100x**

To find the **total magnification of the specimen**, simply multiply the eyepiece magnification by the objective lens magnification:

Total Magnification of specimen = Eyepiece × Objective

Examples:

- 10x eyepiece × 4x objective = **40x total magnification**
- 10x eyepiece × 40x objective = **400x total magnification**
- 10x eyepiece × 100x objective = **1000x total magnification**

Determining the magnification of a drawing using a microscope

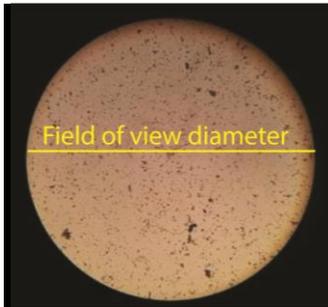
Method I

Compare the size of the drawing to that of the size of specimen as seen through the microscope and then multiply it with the total magnification of the objective and the eye piece.

For example if the drawing is twice the specimen as seen through the microscope is 2 using x10 objective and x 10 eye piece; then the magnification = $2 \times 10 \times 10 = \times 200$.

Method II

- (i) Field diameter is diameter of the circle observed when looking through a microscope.



The field diameters using different objectives are given below

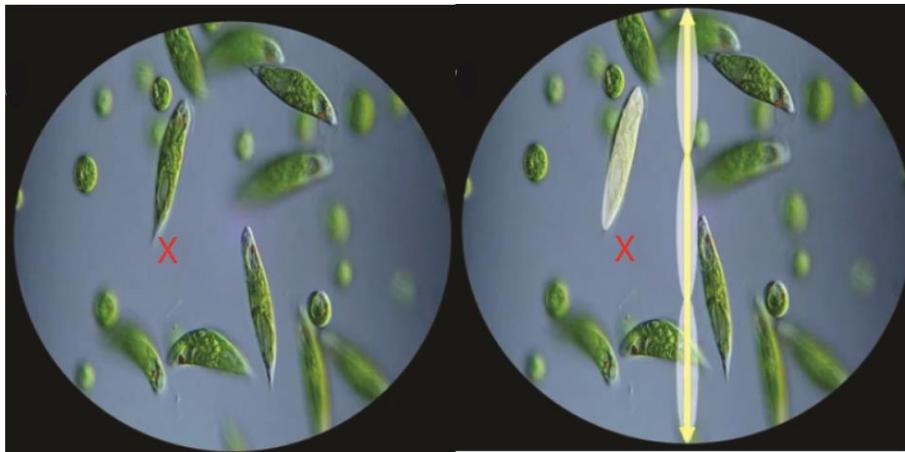
4x = 4.5mm

10x = 1.8mm

40x = 0.45mm

100x = 0.18mm

- (ii) Using the field of view, estimate the size of the specimen
For example, Euglena X



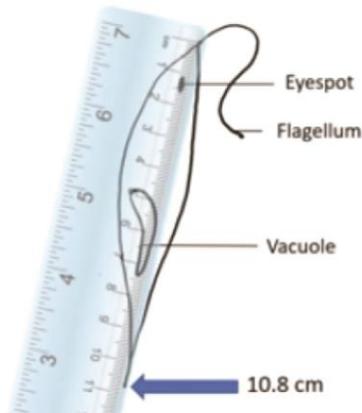
Pond water wet mount
Euglena sp. As seen under
40x objective

Estimating the size of X
that can fit in the diameter
of field of view = 3
Length of X = $\frac{1}{3} \times 0.45$ No.
= 0.15mm

Note that the title of the drawing should inform us the name of the organism, how the specimen was prepared and under what magnification it was observed:

A drawing of pond water wet mount Euglena sp. as seen under 40x objective

(Label only those structures you can identify)



$$\begin{aligned}\text{Magnification} &= \frac{\text{Drawing size}}{\text{Actual size}} \\ &= \frac{10.8\text{cm}}{0.15\text{mm}} \\ &= \frac{108\text{mm}}{0.15\text{mm}} \\ &= 720\text{x}\end{aligned}$$

Take every opportunity to practice drawing from micrographs or microscope slides and stating the magnification, get your teacher to mark them for you. Find out what you need to do to improve, and keep working at it until you feel really confident.

Plant tissues that may be investigated master microscopic analysis

Features of pollen grain.

Procedure

(i) Dry Mount Method

- Place a small amount of dry pollen directly on the centre of a clean glass slide.
- Carefully place a cover slip over the sample without trapping air bubbles.
- Observe immediately under the microscope.

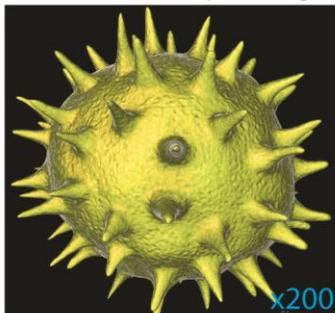
(ii) Wet Mount Method

For better visualization:

- Place a drop of distilled water or glycerine jelly on the slide.
- Add a small quantity of pollen grains into the drop using forceps or brush.
- Gently lower a cover slip onto the drop at an angle to avoid bubbles.

Observation

Hibiscus flower pollen grain under 10x objective



Hooks attach pollen grains on to the stigma

Activity 1

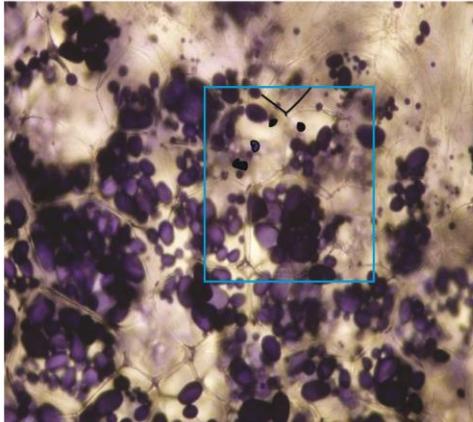
- (i) Place a drop of distilled water or glycerine jelly on the slide.
- (ii) Add a small quantity of pollen grains from the anthers of hibiscus flower into the drop using forceps or brush.
- (iii) Gently lower a cover slip onto the drop at an angle to avoid bubbles.
- (iv) Observe to see the structure of the pollen grain using a medium power objective and draw.
- (v) State the microscopic adaptive features of the pollen grains.

Features of parenchyma cells an Irish potato stained by iodine

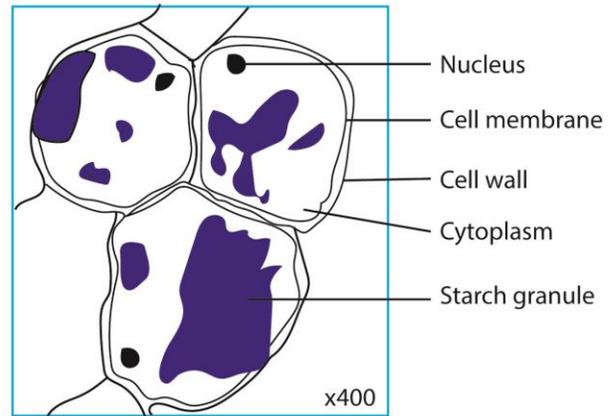
Procedure

- Use a scalpel to cut a **very thin section** of the potato. **Thin slices** are crucial so light can pass through for clear viewing.
- Transfer the thin slice onto the center of a clean glass slide using tweezers.
- Using a dropper, place 1–2 drops of iodine solution directly onto the specimen. Iodine stains starch and helps highlight cell structures like the nucleus and cytoplasm.
- Gently lower a cover slip over the specimen at an angle to avoid air bubbles. This protects the sample and flattens it for better viewing.
- Use blotting paper to absorb any excess iodine around the edges of the cover slip.
- Place the slide on the microscope stage and start with low magnification. Adjust focus and lighting as needed to view the stained parenchyma cells clearly.

Observation



A drawing of three neighbouring cells



Function of Irish potato parenchymal cells:

- (i) store starch – due to presence of starch granule
- (ii) provide support when turgid- closely packed, resistant to pressure.

Activity 2

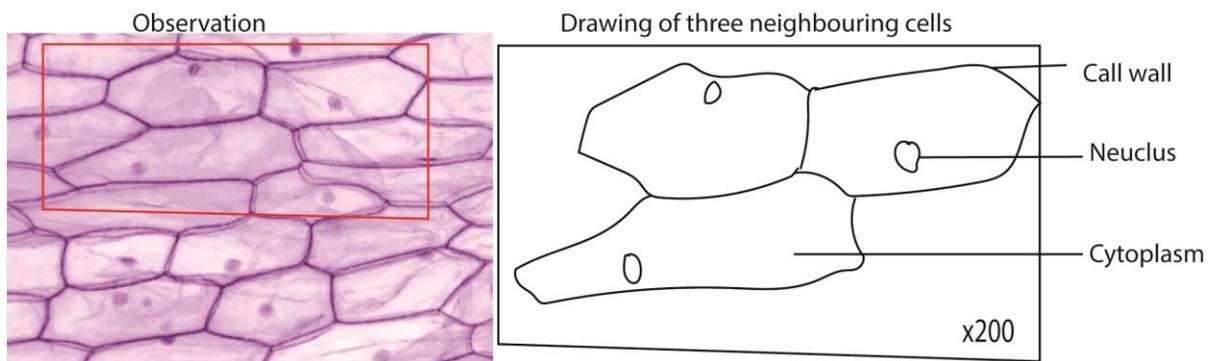
You are provided with specimen X that is an Iris potato

- (i) Draw and label external features of X
- (ii) Make a thin section of X and place on a clean glass slide provided, add a drop of iodine solution and place a cover slip on top.
- (iii) Use a filter paper to drain off excess solution
- (iv) Observe through a microscope using medium power objective.
- (v) Draw any three clear adjacent cells and state the magnification
- (vi) Identify the type of plant cells drawn in (e).
- (vii) Giving evidence, what are the function(s) of the cell identified in in (f).

Features of inner epidermal cells of an onion

Procedure

- (i) Carefully remove the epidermis – utilize forceps to delicately separate a thin, transparent layer of epidermis from the inner surface of the onion bulb.
- (ii) Position the thin onion epidermis flatly at the center of a pristine glass slide with precision.
- (iii) Enhance contrast by adding a stain—simply use a dropper to apply one or two drops of iodine solution onto the onion peel.
- (iv) Carefully position the cover slip by lowering it at an angle onto the stained onion peel, ensuring that air bubbles are avoided.
- (v) Eliminate any excess liquid by gently blotting the extra stain around the edges with a tissue or paper towel, ensuring the slide remains undisturbed.
- (vi) Position the slide on the microscope stage and secure it firmly using the stage clips.
- (vii) Begin with minimal power—concentrate on the lowest magnification (typically 4x or 10x) to identify the cells



Epidermal cells are used for protection because they are hard to tear apart.

Activity 3

You are provided with specimen X that is an onion

- Make and draw a longitudinal section of X
- Get a peel from the internal part of the leaf of X and place on a clean glass slide provided, add a drop of iodine solution and place a cover slip on top.
- Use a filter paper to drain off excess solution
- Observe through a microscope using medium power objective.
- Draw any three clear adjacent cells and state the magnification
- With evidence, what are the function(s) of the epidermal cells of an onion

Features of plasmolysed epidermal cells of an onion

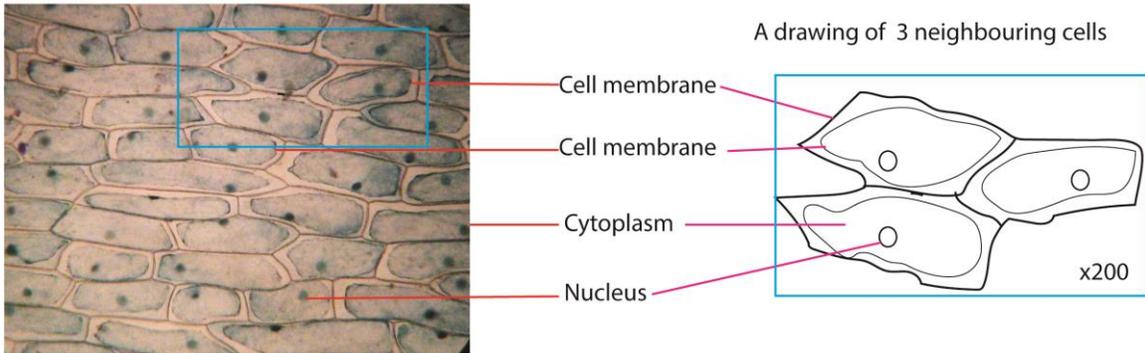
Procedure

- Use forceps to gently peel a thin, transparent layer (epidermis) from the lower surface (concave side) of an onion scale (bulb).
- Place the epidermal peel flat on a clean microscope slide.
- Add a drop or two of 10% sodium chloride solution onto the peel. This solution will cause water to move out of cells by osmosis, leading to plasmolysis.
- (Optional) Add a drop of iodine solution for better contrast.
- Carefully place a cover slip over the peel to avoid air bubbles.
- Allow the slide to sit for about 5–7 minutes. During this time, plasmolysis will occur.
- Observe under the microscope: Start viewing under the low power objective (10x). Switch to high power (40x) for a clearer, more detailed view.
- Look for cells in which the contents (protoplast) have shrunk away from the cell wall, creating a gap. This is plasmolysis.

Tips

- Ensure the peel is free of folds and is as thin as possible for clearer observation.
- The plasmolysed cells will show the cell membrane pulled away from the cell wall due to water loss, while turgid cells will not have this gap.

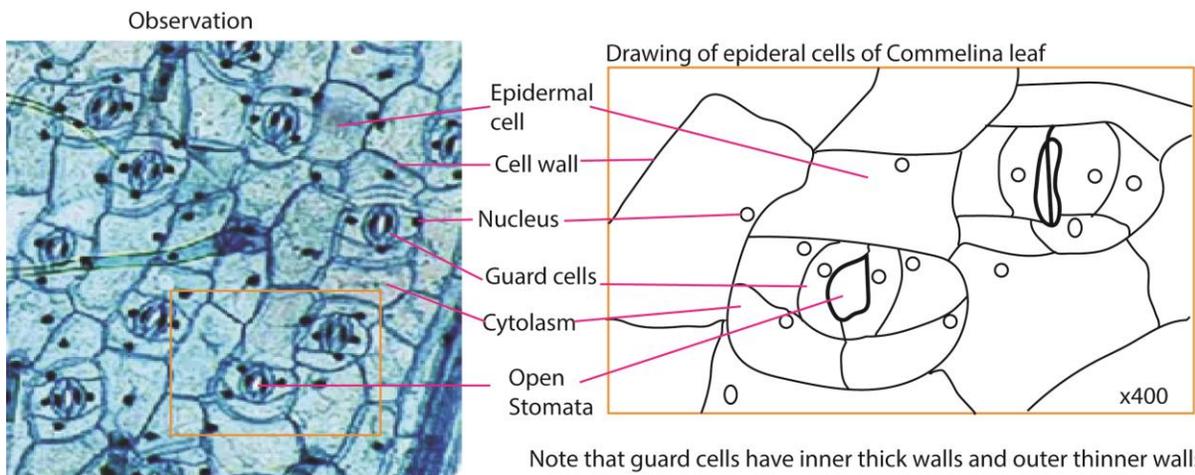
Observation



Note that under plasmolysis, cell membrane separates from cell wall as cell loses water by osmosis

Note that: Plasmolysis compromises the barrier protection and structural support of epidermal cells due to water loss, which reduces internal pressure and causes membrane detachment, weakening cell firmness.

Features of epidermal cells of Commelina leaf



Note that guard cells have inner thick walls and outer thinner walls

Activity 4

You are provided with specimen R1 and R2 from two different habitats.

R1	Commelina (Nanda) leaf (open environment)
R2	Commelina (Nanda) leaf (permanent shade)

- Peel of a cortical from the upper and lower surface of each leaf.
- Mount the upper cuticle of the specimen R1, add a drop of water, wait for 3 minutes and draw and label a stoma with a few a few adjacent cells. State your magnification.
- Repeat (a) and(b) with solution S

- d) Comment the tonicity of solution S and develop and hypothesis for the opening of the stomata.
- e) Mount separately the peels of the upper and lower cuticle of each of specimen R1 and R2.
- f) Apply a drop of water to each. Count the number of stomata per field of view on the cuticle under medium power objective.
- g) Enter your results in the table below (enter and find the average of 2 field of view)

	R1			R2		
Surface	1	1	average	1	2	average
Upper cuticle						
Lower cuticle						

- h) Comment on the result in the table in d) above
- i) With reason suggest the habitat of the plant from where the leaves were obtained.

Answer

Given that both leaves have fewer stomata on the upper surface than on the lower surfaces; they should be got from a dry habitat. But R1 has very few stomata on the upper surface compared to R2 which implies that it was obtained from a drier place than R2

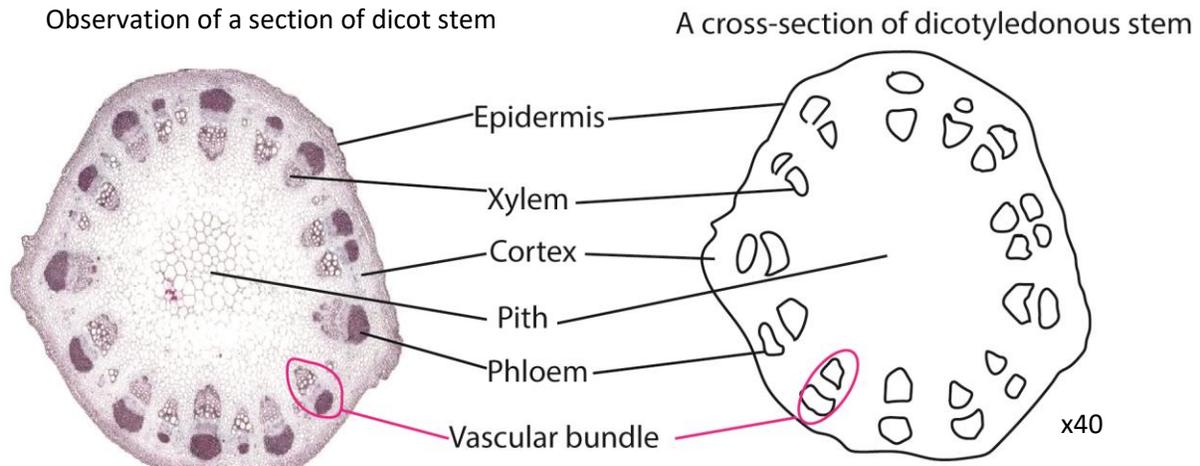
The fewer stomata on upper surface of the leaves is meant to reduce transpiration.

Microscopic features of cross-section of dicotyledonous and mono stem and root

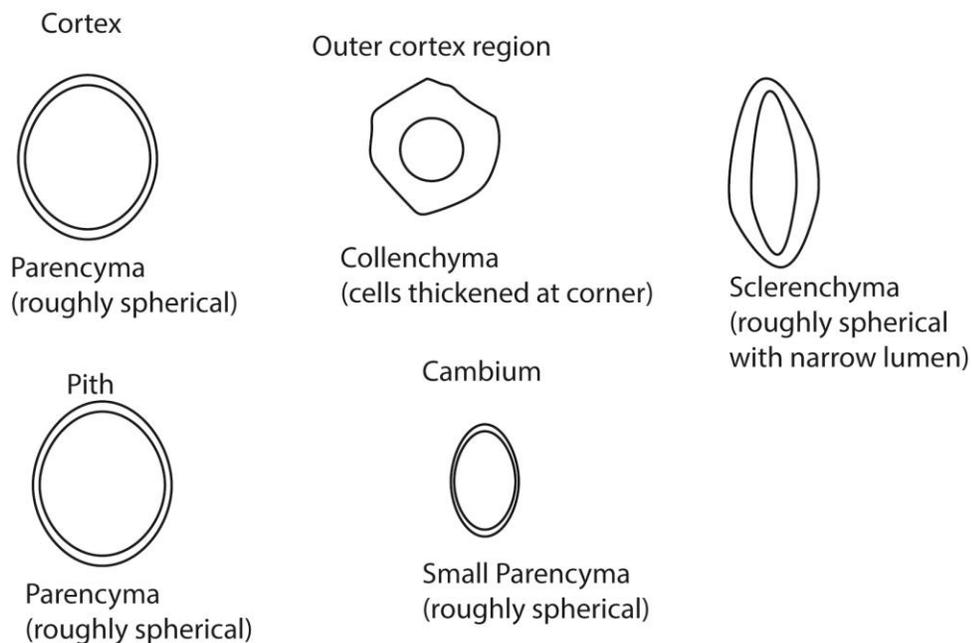
Procedure

- Study dicot stem and roots using bean seedling stem and radical while for monocot stem use maize, canna or grass spp while for monocot root use maize prop root, onion and wheat roots
- Use a scalpel to cut a **very thin cross-section** of the stem or root. **Thin slices** are crucial so light can pass through for clear viewing.
- Transfer the thin slice onto the center of a clean glass slide using tweezers.
- Using a dropper, place 1–2 drops of acidic phloroglucinol solution directly onto the specimen. Phloroglucinol stain xylem red due to its high content of lignin.
- Gently lower a cover slip over the specimen at an angle to avoid air bubbles. This protects the sample and flattens it for better viewing.
- Use blotting paper to absorb any solution around the edges of the cover slip.
- Place the slide on the microscope stage and start with low magnification.

Transverse section of dicotyledonous plant stem (bean seedling)



The structure of cells from each tissue type found in the section



Parts of a Stem Cross Section & Their Functions

Epidermis: Outermost layer; protects against water loss, pathogens, and mechanical injury. It may have a waxy cuticle.

Cortex: Composed mainly of parenchyma cells; stores food and may assist in transport.

Endodermis (*in some stems*): Regulates flow of substances into the vascular tissue; more prominent in roots.

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Xylem: Transports water and minerals from roots to leaves; provides structural support.

Phloem: Transports sugars and other organic nutrients from leaves to other parts.

Pericycle (*in dicots*): May give rise to lateral roots or contribute to secondary growth.

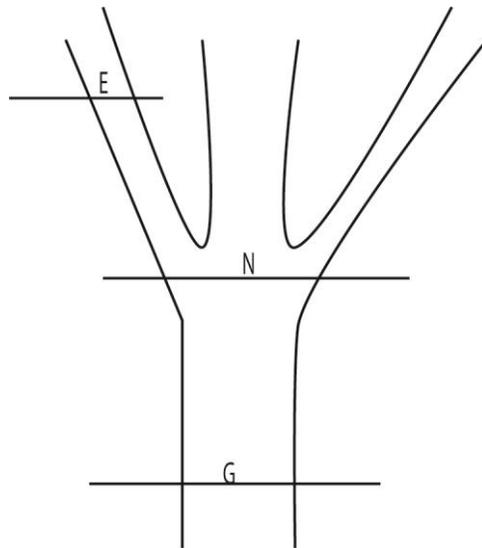
Pith (Medulla): Central region of parenchyma cells; stores nutrients and may help in transport.

Activity 5

You are provided with specimen K (bryophyllum shoot) which is a shoot. (1 hr)

- Cut a series of thin transverse sections through the stem and leaf petiole (at the 4th or 5th node from the apex) with the aim of finding out the structure of the stem at levels N and G and of the leaf at level E as illustrated below for your guidance.
- Stain the sections with Phloroglucinol and concentrated Hydrochloric Acid (corrosive and fumes).
- Draw plans to show the distribution of lignified tissue at N, G and E. make your drawings in the spaces provided below the illustration.

Illustration for your guidance and spaces below for your drawings.



E	G	N

- d) How does the structure of the stem at N differ from that at G? Suggest one reason to account for this difference (if any).

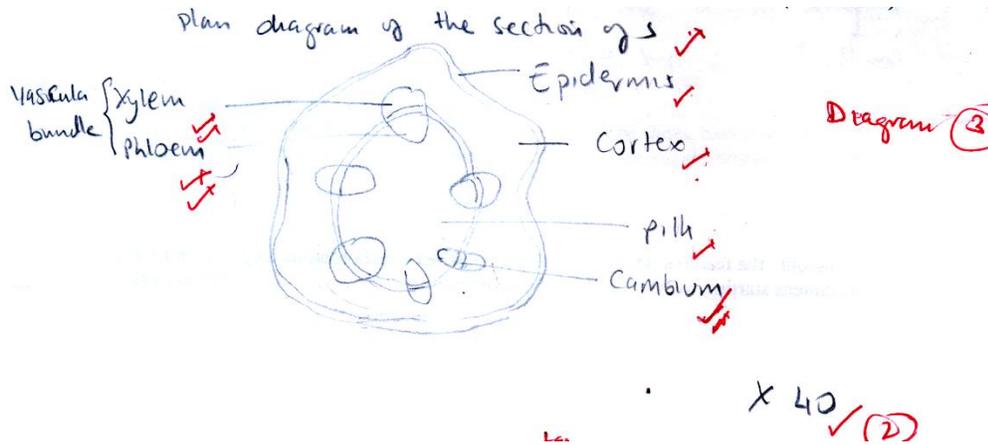
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Activity 6

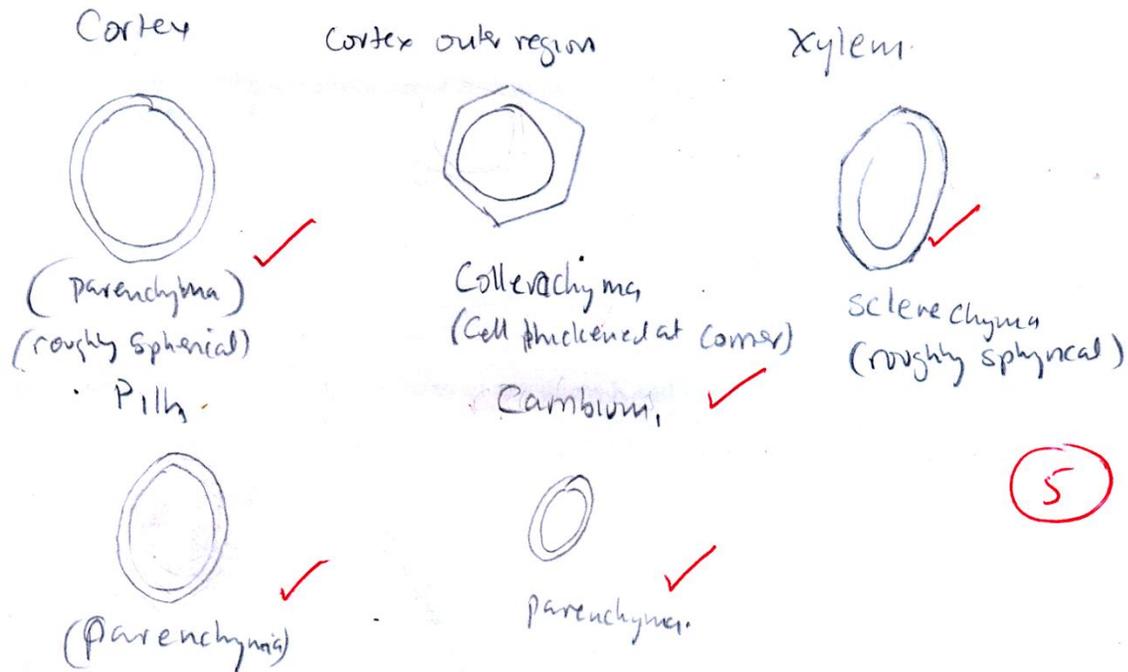
You are provided with specimen S (stem of bean seedling).

- (a) Cut three thin cross-sections from it and immediately transfer them into a Petri dish of water
 (b) Mount one section in a drop of acidified phloroglucinol on a slide and cover with a cover slip. Observe under the low power of a microscope.

- (a)(i) Draw and label the tissue plan section of specimen S (10 ½ marks)



- (ii) Draw the structure of one cell from each tissue type found in the section (05 marks)



(b) Identify the stained tissue in the section of specimen S (01 mark)

Xylem (1)

(i) Give reasons, state the major group of plants to which specimen S belong (03 marks)

Dicotyledonous plant (1)

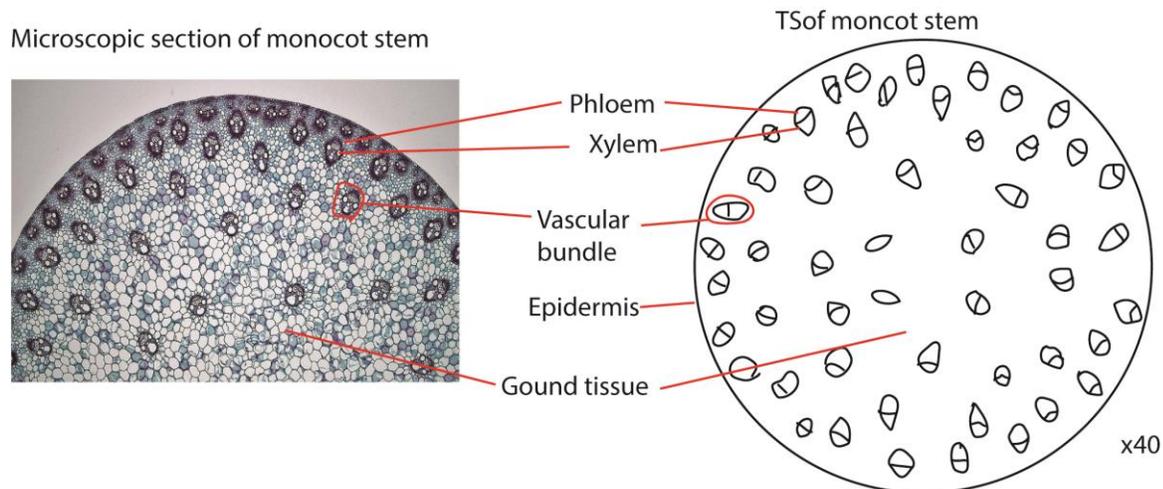
Because it has a pith with vascular bundles in a ring (2)

(ii) Give Structural adaptations of the coloured tissue for its functions (02 marks)

Lignified for support (1)

Has open tube for conducting water (1)

Transverse section of monocotyledonous plant stem (stem grass or maize seedling)



Differences between dicotyledonous and monocotyledonous section of the stem

Dicot root

Vascular bundles in a ring

4 to 8 vascular bundle

Has pith

Xylem elements polygonal

Monocot stem

Vascular bundle scattered

Numerous vascular bundles

Has no pith

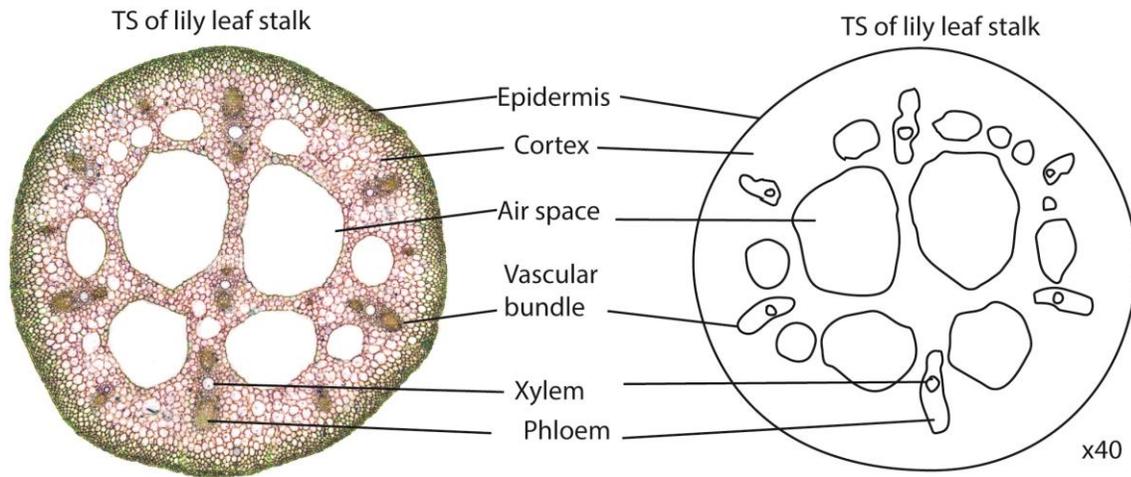
Circular xylem elements

Activity 7

You are provided with specimen P (canalily stem).

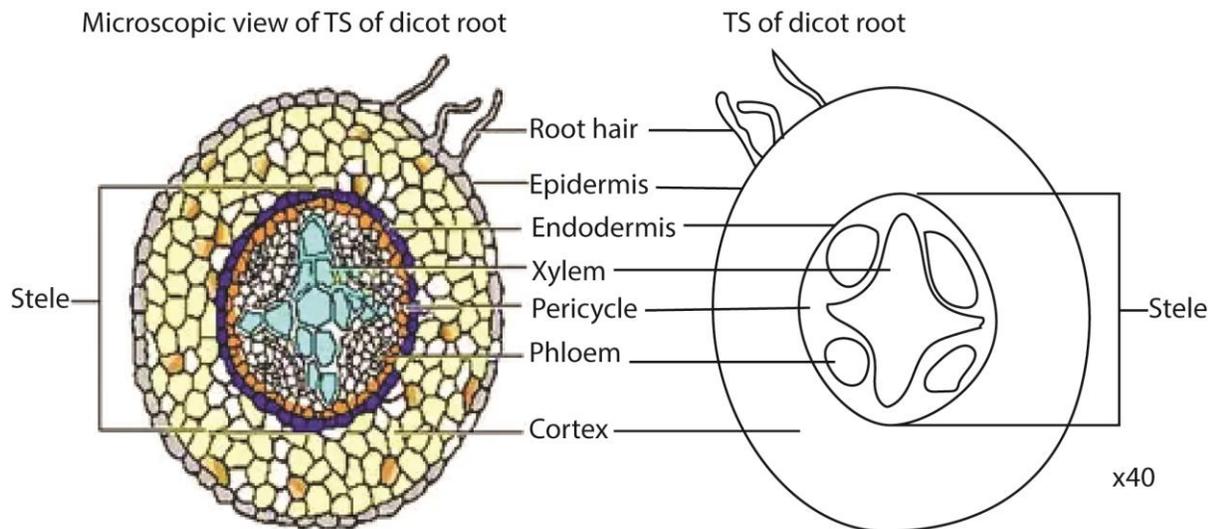
- Cut three thin cross-sections from it and immediately transfer them into a Petri dish of water
- Mount one section in a drop of acidified phloroglucinol on a slide and cover with a cover slip. Observe under the low power of a microscope.
- Observe under low power objective and draw.
- Identify specimen P

Transverse section of floating plant stem(Water lily leaf stalk)



In aerenchyma plants like water lily and rice, air spaces reduce weight of the plant and also facilitate gaseous exchange between aerial and submerged parts.

Transverse section of dicotyledonous plant root (3-4 days bean radicle)



Activity 8

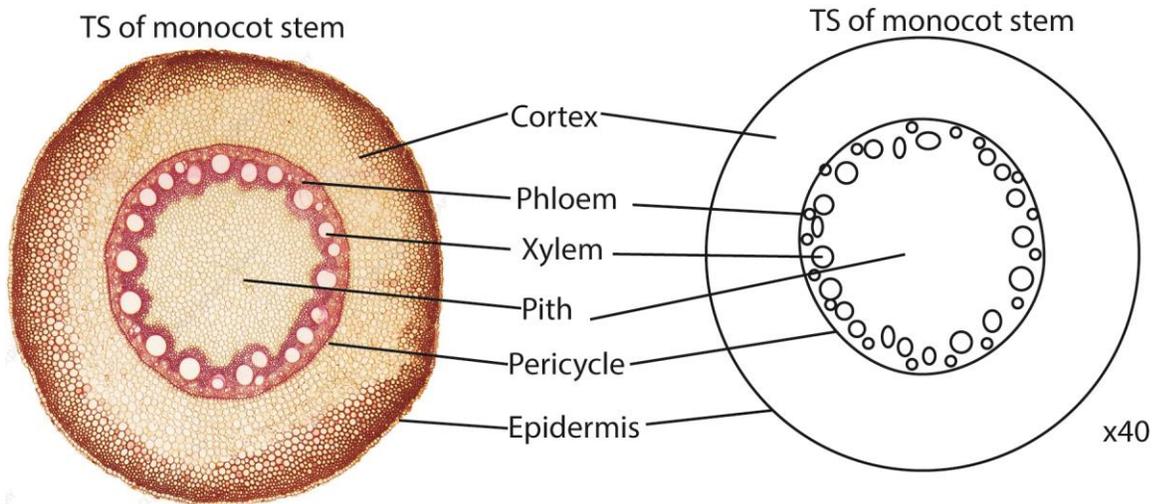
You are provided with specimen Q (*gyanodra gyanondrapsis (Jobyo) taproot /3-4 day bean seedling taproot*). Cut thin transverse section through Q. Place the section on a glass slides and add a drop of phloroglucinol followed by a drop of concentrated Hydrochloric acid. Leave to stand for one minute. Drain excess liquid and place a cover slip. Examine under low power magnification of the microscope. A hand lens may be used.

- Draw a plan diagram to show the distribution of the coloured substance in Q
- Identify the type of the plant from which Q was obtained.
- What substance in the tissue takes up the colour?

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- d) What is the role of the coloured substance in the plant?
 e) Which tissue of the plant is the coloured substance likely to be found?

Transverse section of monocotyledonous plant root (3-4 days bean radicle)



Differences between dicotyledonous and monocotyledonous root

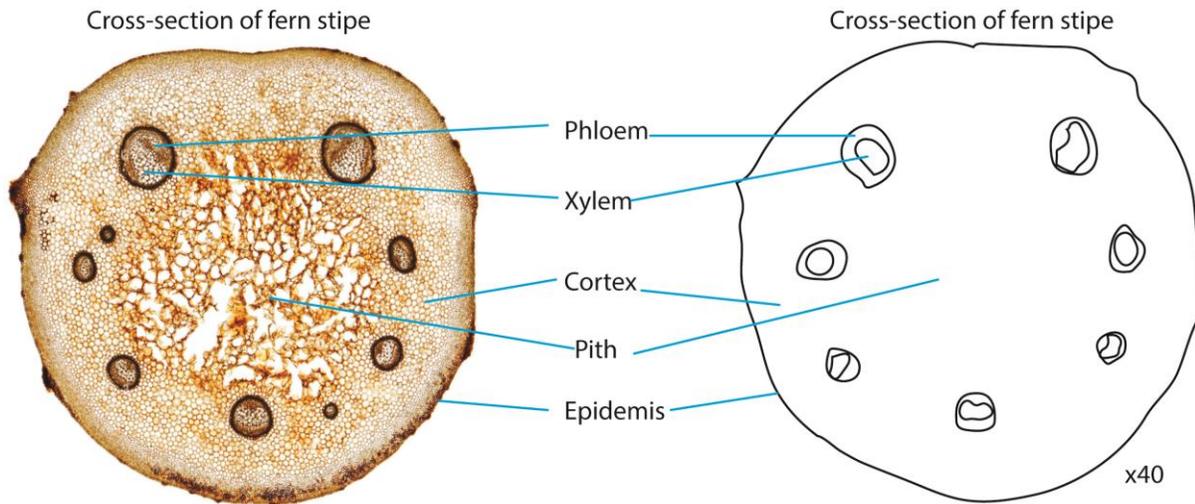
Dicot Root	Monocot root
Pericycle gives rise to cork cambium, parts of the vascular cambium, and lateral roots	Pericycle gives rise to lateral roots only
Has a limited number of Xylem and Phloem	Has a higher number of Xylem and Phloem
Angular or Polygonal xylem	Round or Oval round
Has no pith	Larger and well developed pith

Activity 9

You are provided with specimen T (Maize prop root).

- Cut three thin cross-sections from it and immediately transfer them into a Petri dish of water
- Mount one section in a drop of acidified phloroglucinol on a slide and cover with a cover slip. Observe under the low power of a microscope.
- Observe under low power objective and draw.
- Identify specimen T.

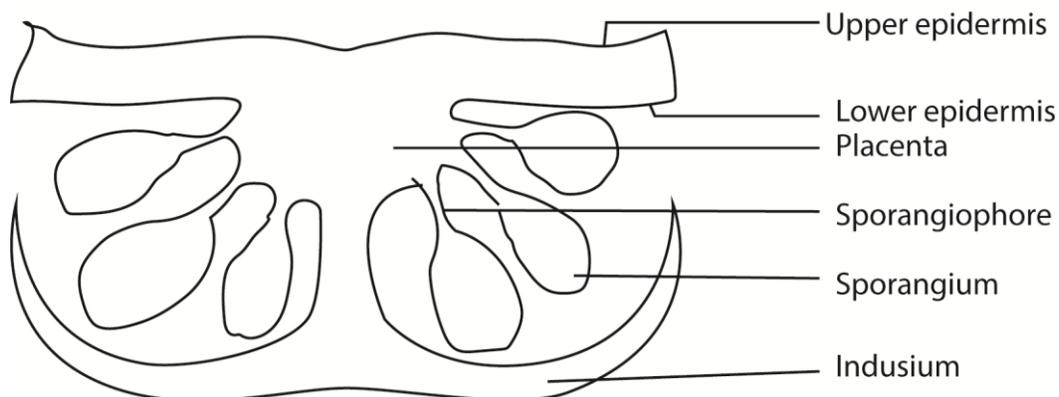
Transverse section of fern stipe



Activity 10

What evidence from the cross-section of the stipe of the fern above shows that a fern is more advanced than moss.

Structure of sorus



Adaptations of the Sorus in Ferns

- (i) **Indusium** covers and protects the delicate sporangia from drying out, physical damage, and being eaten by herbivores. When the spores are mature, the indusium often shrivels or flips back to allow for their release.
- (ii) **Sori** are groups of sporangia to increase spore output and ensure synchronized development
- (iii) **Sori** is **located** on the lower surface of fronds to reduce exposure to direct sunlight and physical damage
- (iv) **Sporangia** within a sorus mature at different times which extends the spore release period, improving chances of dispersal

- (v) **Specialized fertile fronds:** In some ferns, such as *Osmunda*, there are separate, non-photosynthetic fronds that are dedicated entirely to spore production. This specialization maximizes spore output without compromising the photosynthetic capacity of the vegetative fronds.

Animal tissues that may be investigated to master skills microscopic analysis

- (a) Cockroach antenna

Cockroach antenna



Hairs increase sensitivity

- (b) Cockroach tarsus

Cockroach tarsus



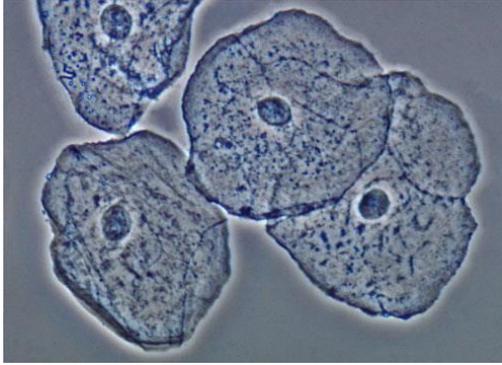
Claw for grip in cracked surface

Arolium for grip on smooth surface

Tarsomere

- (c) Epithelial tissue

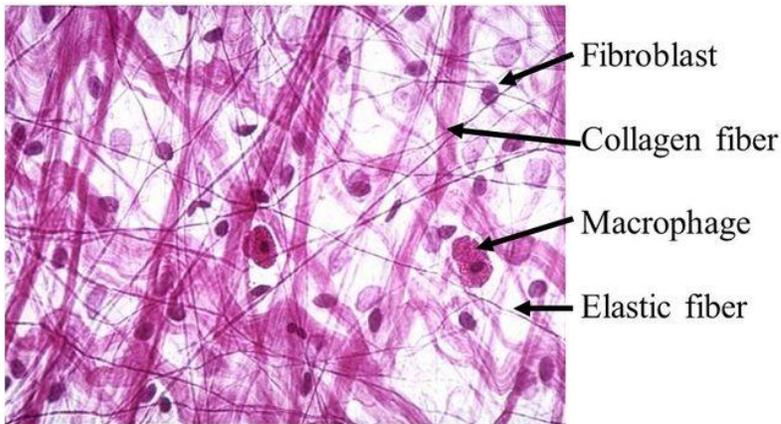
- **Cheek cell smear (simple squamous) investigate simple squamous epithelial tissue :** This is a simple, direct student-prepared slide. A swab of the inside of the cheek can be stained with a dye like methylene blue to reveal the individual, flattened cells and their nuclei.



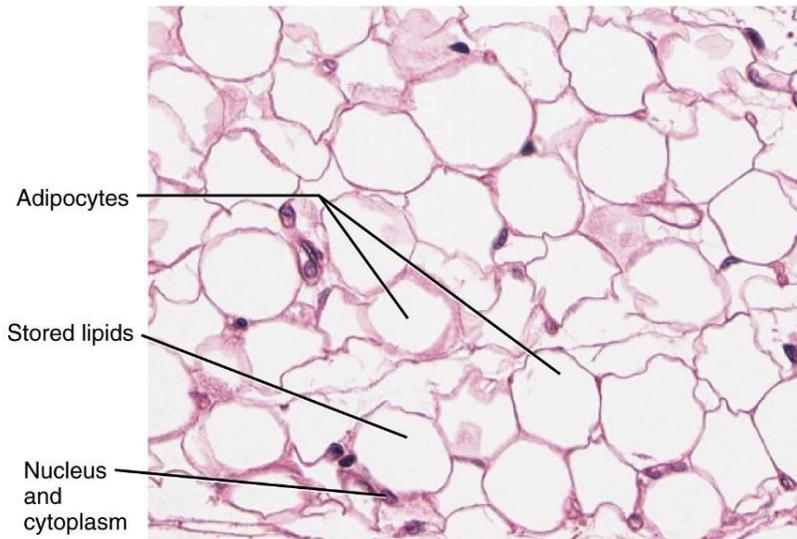
(d) Connective tissue

Connective tissue supports, connects, and separates different types of tissue and organs. Examples include:

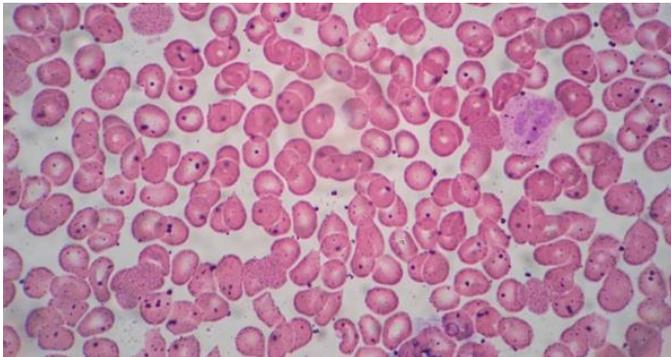
- **Loose (areolar) connective tissue:** These slides show a loose arrangement of fibers (collagen and elastic) and various cell types, serving as a packing material around organs.



- **Adipose tissue (fat):** Appearing as large, transparent, and spherical cells with the nucleus pushed to the periphery, this tissue functions in energy storage and insulation.



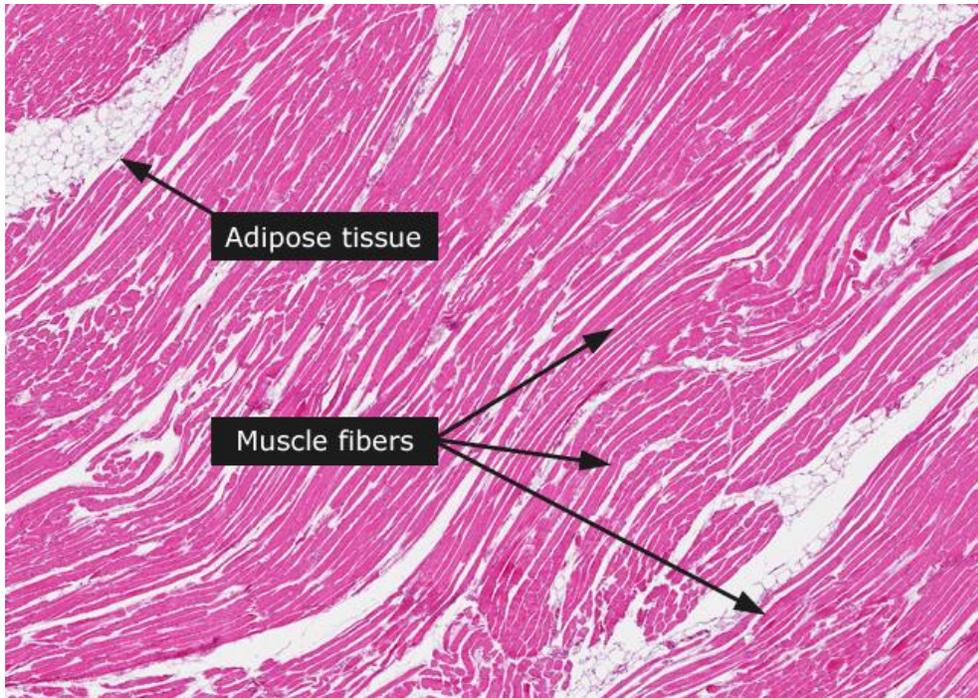
(e) **Blood smear:** A prepared slide of blood shows the different cellular components of this liquid tissue, including red blood cells (erythrocytes) and various white blood cells (leukocytes).



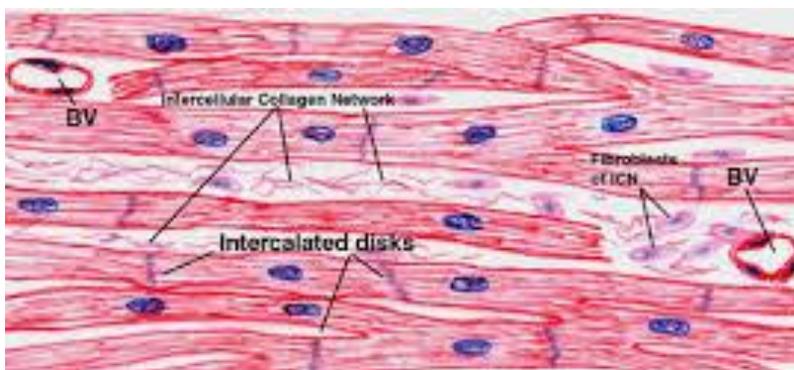
(f) Muscle tissue

This tissue is responsible for movement and is comprised of contractile cells called muscle fibers. The three types of muscle tissue are:

- **Skeletal muscle:** These cells are long, cylindrical, and multinucleated, with obvious dark and light bands called striations. They are responsible for voluntary body movements.



- **Smooth muscle:** Found in the walls of internal organs like the stomach and intestines, these cells are spindle-shaped, have a single nucleus, and lack striations. They are responsible for involuntary movements.
- **Cardiac muscle:** Exclusively found in the heart, these cells are branched, striated, and have a single nucleus. They also feature intercalated discs that facilitate coordinated contractions.



The cell

There are two types of cells:

- (i) A **prokaryotic cell** is a simple, single-celled organism that lacks a nucleus and other membrane-bound organelles. They are microscopic and include all bacteria and archaea, which are two of the three major domains of life.

Characteristics of a cell

- **No true nucleus:** The genetic material (DNA) is not contained within a membrane-bound nucleus. Instead, it is located in a region of the cytoplasm called the nucleoid.
- **Simple internal structure:** Prokaryotic cells lack complex, membrane-bound organelles such as mitochondria, chloroplasts, and the endoplasmic reticulum. Biochemical processes, like photosynthesis or respiration, occur on the cell membrane or in the cytoplasm.
- **DNA:** The genetic material usually consists of a single, circular chromosome. Many prokaryotes also have smaller, circular pieces of DNA called plasmids, which can carry genes for traits like antibiotic resistance.
- **Ribosomes:** They have ribosomes for protein synthesis, but these are smaller (70S) and structurally simpler than those found in eukaryotic cells.
- **Small size:** Prokaryotic cells are typically much smaller than eukaryotic cells, ranging from 0.1 to 5.0 micrometers in diameter. This large surface area-to-volume ratio allows for a high metabolic rate.
- **Cell envelope:** Most prokaryotes have a protective cell envelope that surrounds the cytoplasm. This may include a cell membrane, a cell wall, and sometimes an outer capsule.

Cellular structures

- **Capsule:** An outermost protective covering of some bacteria, made of polysaccharides. It helps with moisture retention and allows the cell to attach to surfaces.
- **Cell wall:** Located outside the cell membrane, the cell wall provides structural support and protects the cell from changes in osmotic pressure. In bacteria, it contains peptidoglycan, while archaeal cell walls do not.
- **Cell membrane:** This selectively permeable lipid bilayer encloses the cytoplasm and regulates the movement of substances into and out of the cell.

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- **Pili and fimbriae:** Hair-like appendages that help the prokaryote attach to surfaces or other cells and can be used for DNA transfer during conjugation.
- **Flagella:** Long, whip-like structures that help propel the cell through its environment.

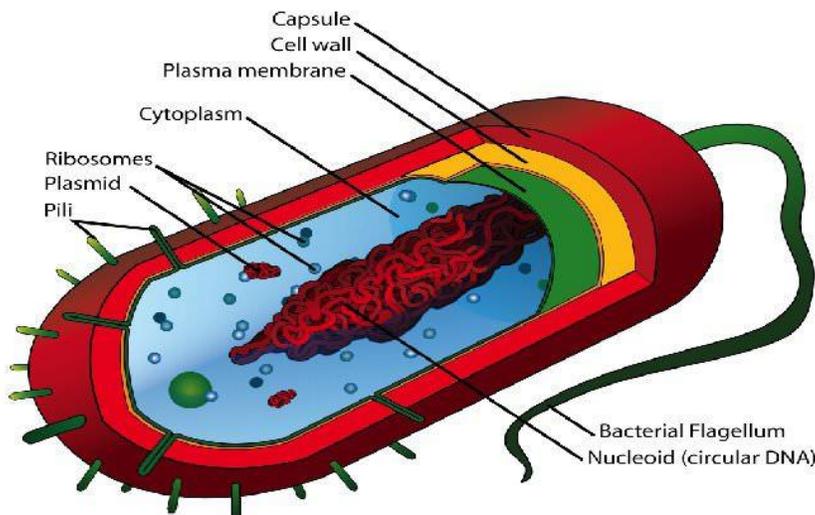
Reproduction

Prokaryotes primarily reproduce asexually through a process called binary fission, where a single cell divides into two identical daughter cells. They can also exchange genetic material through processes like conjugation, transduction, and transformation.

Examples

- **Bacteria:** A vast domain of prokaryotic organisms found nearly everywhere on Earth. Examples include *Escherichia coli* (*E. coli*), *Staphylococcus aureus*, and cyanobacteria.
- **Archaea:** Another domain of prokaryotes known for living in extreme environments, such as hot springs and saline water. Examples include halophiles and methanogens.

A diagram of a bacterial cell



Kingdom Monera

It was a kingdom that included all single-celled organisms with a prokaryotic cell structure. This kingdom encompassed all bacteria and archaea, which lack a true nucleus and other membrane-bound organelles.

Structural differences between eubacteria and archaeobacteria

Key structural differences between archaeobacteria (Archaea) and eubacteria (Bacteria) are found in their cell wall, cell membrane, and flagella

Both are prokaryotes, but distinct evolutionary paths have given them fundamental molecular differences.

Structural comparisons

Feature	Archaeobacteria (Archaea)	Eubacteria (Bacteria)
Cell wall	Lacks peptidoglycan , the polymer of amino acids and sugars that forms a rigid bacterial cell wall. Instead, archaea may have cell walls made of pseudopeptidoglycan, glycoproteins, polysaccharides, or a surface-layer (S-layer) of protein.	Contains peptidoglycan as a core component, which is used to classify them as either Gram-positive (thick wall) or Gram-negative (thin wall).
Cell membrane	Composed of glycerol-ether lipids with branched hydrocarbon chains. Some species have a lipid monolayer, which is more resistant to heat and harsh conditions.	Composed of glycerol-ester lipids with straight-chain fatty acids. The membrane is always a lipid bilayer.
Flagella	Different in structure and mechanism of action. They are anchored in the cytoplasm and are driven by the hydrolysis of ATP for a whip-like motion.	Possesses a more complex basal body anchored in the cell membrane and is driven by a proton motive force. They rotate in a corkscrew-like motion.
Ribosomes	The 70S ribosomes are structurally different from bacterial ribosomes, with distinct ribosomal RNA (rRNA) and unique proteins. They are not affected by many antibiotics that target bacterial ribosomes.	Has 70S ribosomes, which are the target of many common antibiotics. Distinct rRNA and proteins allow for this specificity.
Genetic organization	DNA replication, transcription, and translation more closely resemble those of eukaryotes. Their DNA may contain introns.	DNA processes are simpler and distinct from both archaea and eukaryotes. Introns are typically absent.

- (ii) A eukaryotic cell is the basic unit of a larger, more complex organism. Unlike prokaryotic cells (bacteria and archaea), eukaryotic cells have a true nucleus and other membrane-bound organelles that perform specialized functions. Organisms composed of these cells include animals, plants, fungi, and protists.

Characteristics of Eukaryotic cell

- **True nucleus:** The most significant difference from prokaryotic cells is that a eukaryotic cell's DNA is housed within a membrane-bound nucleus. The nucleus is essentially the control center of the cell.
- **Membrane-bound organelles:** The cytoplasm of a eukaryotic cell contains various specialized compartments, such as mitochondria, endoplasmic reticulum, Golgi apparatus, and lysosomes. This compartmentalization allows different chemical reactions to occur in separate, controlled environments.
- **Linear DNA:** The genetic material is organized into multiple linear chromosomes, which are tightly coiled around proteins called histones. In contrast, prokaryotes have a single, circular chromosome.
- **Large size:** Eukaryotic cells are typically much larger and more complex than prokaryotic cells.
- **Cytoskeleton:** A network of protein filaments provides structural support, helps maintain cell shape, and assists in the movement of organelles.
- **Reproduction:** Eukaryotic cells can reproduce through mitosis (asexual reproduction for growth and repair) and meiosis (sexual reproduction for creating gametes).

Cellular structures

- **Nucleus:** Contains the cell's genetic material (DNA) and controls all cellular activity.
- **Mitochondria:** Often called the "powerhouse of the cell," this organelle generates energy in the form of ATP through cellular respiration.
- **Endomembrane system:** This complex network of organelles includes the endoplasmic reticulum (involved in protein and lipid synthesis) and the Golgi apparatus (which modifies, sorts, and packages proteins).
- **Ribosomes:** Found both free in the cytoplasm and attached to the rough endoplasmic reticulum, ribosomes are responsible for protein synthesis.
- **Lysosomes:** These organelles contain digestive enzymes that break down waste materials, cellular debris, and foreign substances.

- **Cytoskeleton:** Composed of microfilaments, intermediate filaments, and microtubules, this internal scaffolding system provides shape and enables movement.

Examples of eukaryotic cells

Eukaryotic cells are found in the four major kingdoms of Eukarya:

- **Animals:** Including all cells found in mammals, birds, reptiles, and insects.
- **Plants:** Including all plant cells, which contain a rigid cell wall made of cellulose and chloroplasts for photosynthesis.
- **Fungi:** Such as yeasts and mushrooms, whose cells have cell walls made of chitin.
- **Protists:** A diverse group of mostly single-celled organisms, including algae and amoebas.

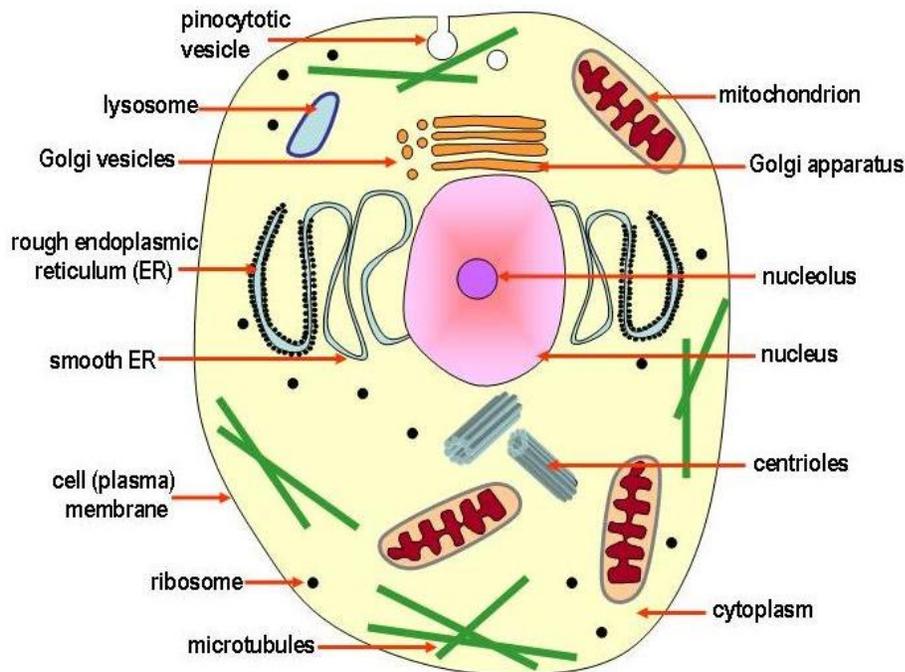
Advantages of membrane bound organelles

- Many metabolic processes involve enzymes embedded in membranes, so the membrane bound organelles increase the surface area for activities like respiration and photosynthesis.
- Maintain enzymes of a particular path way in one area for easy accessibility.
- The metabolic pathway inside an organelle can be controlled by controlling substances that enter and leave the organelle.
- Harmful reactants can be isolated

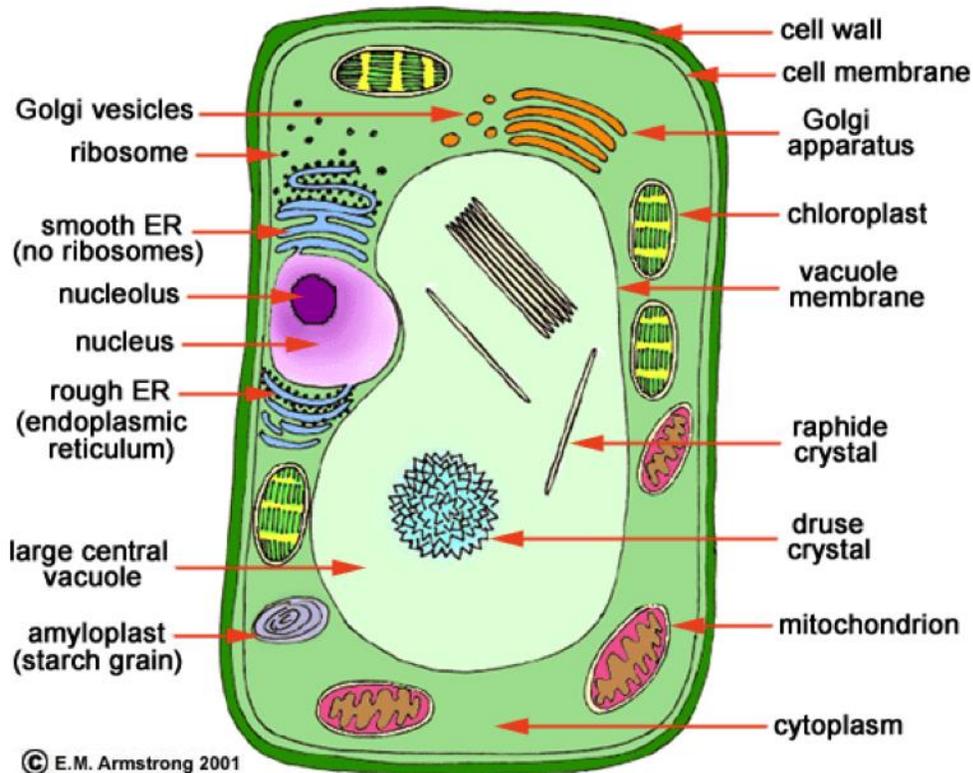
Differences between eukaryotic and prokaryotic cells

	Prokaryotic cell	Eukaryotic cell
1.	DNA not enclosed in membrane	DNA enclosed in a double membrane nucleus
2.	Has small ribosome (70s)	Has big ribosome (80s)
3	Lack mitochondria	Has mitochondria
4	Has no endoplasmic reticulum	Has endoplasmic reticulum
5	Small size	1000-1000 times the size of prokaryotes
6	Lack lysosomes and peroxisomes	contain lysosomes and peroxisomes
7	Lack Golgi apparatus	Has Golgi apparatus
8	Simple flagella	Complex flagella
9	Respiration occur in mesosome	Respiration occur in mitochondria
10	Lack chloroplasts	Plant cells have chloroplasts
11	Have ability to fix nitrogen	Lack ability to fix nitrogen

Fine structure of animal cell



Fine structure of plant cell



Differences between plant cell and animal cell

	Plant Cell	Animal cells
1	Has chloroplast	Lack chloroplast
2	Has cell wall	Lack cell walls
3	Has large central vacuole	Lack a vacuole or has small vacuoles
4	Has starch granule	Lack starch granule
5	Nucleus at the side	Nucleus centrally placed
6	Tonoplast present around vacuole	Tonoplast absent
7	Centrioles absent	Centrioles present
8	Cilia and flagella absent in higher plants	Cilia and flagella present
9	Few cells are capable of division	Almost all cells are capable of division

Functions of parts of a cell

1. Cytoplasm

All cells have a cytoplasmic matrix. It is an aqueous solution or colloidal suspension of mainly vital cellular materials. It is the site for protein synthesis and metabolic activities

Functions of the cytoplasm

- (i) Contain or keep organelles
- (ii) Contains nutrients for organelles
- (iii) Stores materials
- (iv) Maintain conductive atmosphere for cellular reaction

2. Cell membrane

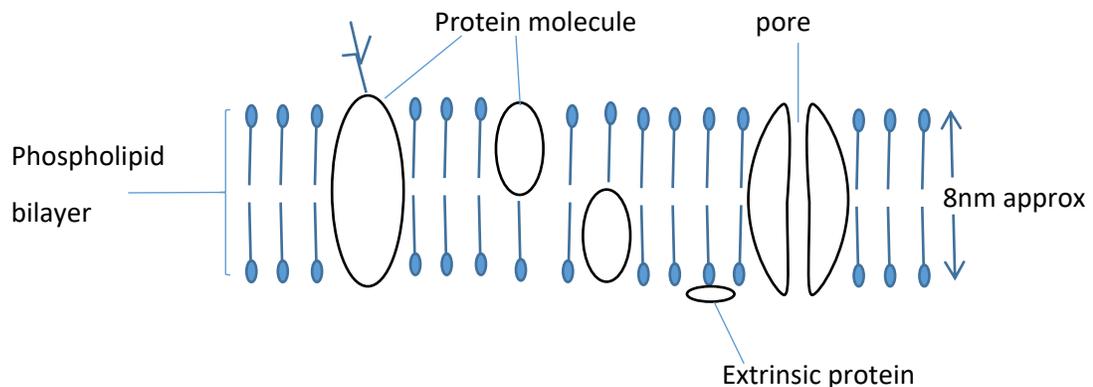
It serves as a boundary between the cell and its environment. It may permanently exclude some items from the cell while permanently retaining others.

Functions of the cell membranes

- (i) It separates the contents of the cell from the external environment.
- (ii) Controls exchange of materials between the cells and external environment
- (iii) It separates compartment with specialized functions inside the cell
- (iv) Acts as receptor site for recognizing external stimulus such as hormones.
- (v) Allows uptake of materials by phagocytosis and pinocytosis.
- (vi) Support enzymes of complex metabolic pathways in place for close proximity.

The fluid mosaic model of the cell

- The cell membrane is about 7nm thick
- It consists of a continuous phospholipid bilayer in which proteins are scattered in a mosaic manner.
- Proteins penetrate through the bilayer at a varying degree to form intrinsic and extrinsic proteins that can move laterally, **much like "icebergs in a sea of lipids."**
- Intrinsic proteins are those that penetrate through the bilayer while extrinsic proteins are those that float on top as islands in a sea.
- The mosaic of components also include **cholesterol** for fluidity and **carbohydrates** (glycoproteins and glycolipids) on the outer surface, gives the membrane its flexible and selective barrier function.



Components of cell membrane and their function

- Phospholipids: affect the fluidity and permeability of the membrane
- Cholesterol: make the membrane less fluid at higher temperature.
- Glucolipids: act as recognition sites e.g. human blood group system is as result of different glycolipids on the cell membrane of red blood cell.
- Proteins:
 - provide structural support for the membrane,
 - assist in active transport across the membrane
 - act as recognition sites
 - act as enzyme, energy transducers and electron carriers
- Glycoproteins are recognition sites, e.g., for neurotransmitters and hormones.

The nucleus

This is the largest cell organelle enclosed by a double membrane perforated by nuclear pores. It contains chromatin which is the form of chromosomes during interphase. The nucleus also contains nucleolus that produces ribosomes

Functions of nucleus

- Contains DNA for inheritance controlling cell division and protein synthesis.

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- (ii) The nucleolus manufactures ribosome
- (iii) Controls all activities of the cell

Trial 1

Growth in size of a single cell is limited by the

- A. cytoplasm.
- B. nucleus.
- C. cell vacuole.
- D. cell membrane.

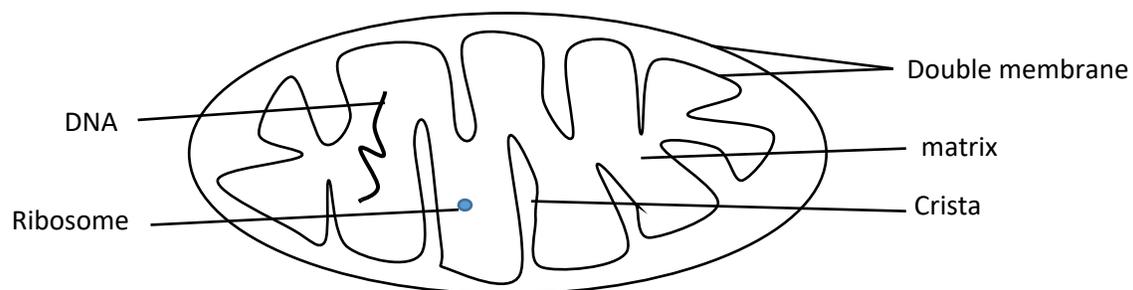
Nucleoli

Functions of nucleoli

The nucleolus is the site of synthesis of ribosomal RNA which is combined with proteins in the cytoplasm to make ribosomes.

Mitochondria

It a cell organelle surrounded by two membranes, the inner being folded to form **cristae**. The mitochondrion contains a matrix with a few ribosomes a circular DNA molecule and phosphate granules. Its main function is producing energy by aerobic respiration.



Adaptations of mitochondria to its function

1. The inner membrane is folded to form cristae that increase surface area for enzymatic activities.
2. Contains circular DNA to produce the necessary enzymes.
3. Has a large surface area for diffusion of gases.
4. Matrix contain necessary enzymes for Krebs cycle

Endoplasmic reticulum

This is a system of flattened membranes bound sacs called cisternae, forming tubes and sheet. Is continuous with the outer membrane of the nuclear envelope. Some of its parts is covered by ribosome and this is called **rough endoplasmic reticulum**. The part without ribosomes is called **smooth endoplasmic reticulum**.

Functions of endoplasmic reticulum

1. Ribosomes are site of protein synthesis
2. Smooth endoplasmic reticulum is a site of lipids and steroid synthesis.
3. The tubes are for intracellular transport

Golgi apparatus

Consists of stack flattened membrane-bound sacs, called cisternae, continuously being formed at one end of the stack and budded off as vesicles at the other.

Functions of Golgi apparatus

1. Producing glycoproteins by adding carbohydrates to proteins
2. Producing secretory enzymes, e.g. digestive enzymes
3. Replenishing the cell wall
4. Produces materials for synthesis of plant cell wall.
5. Produces lysosomes concerned with breakdown of worn out structures in the cell.

Lysosome

Single small organelle that contain enzymes to destroy worn out parts of the cell and autolysis (digestion of the cell)

Cell wall

The plant cell wall is a rigid, multi-layered structure composed primarily of cellulose, hemicellulose, and pectin, with some cells also containing lignin. It is made of three main layers:

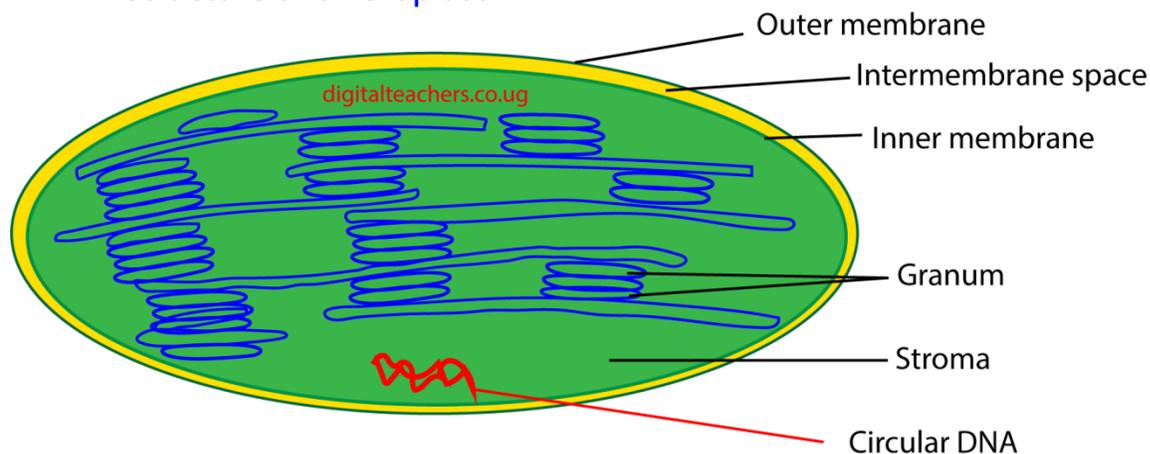
- (i) **Middle lamella is the** outermost layer; it's rich in pectin and connects adjacent plant cells, acting as a "glue" between them.
- (ii) **Primary cell wall is** found inside the middle lamella, it is a thin, flexible layer formed during cell growth. It is composed of cellulose microfibrils arranged in a network that provides tensile strength, with hemicellulose cross-linking the microfibrils and pectin embedded within the matrix.
- (iii) **Secondary cell wall** is a thick, rigid layer that forms inside the primary wall after the cell has stopped growing. It is not present in all plant cells but is common in those needing extra support. It can be several layers thick and is often reinforced with lignin, which adds strength and waterproofing.

Functions of cell wall

- (i) **Provides shape and rigidity:** The cell wall gives cells a definite, stable shape, which is crucial for the structure of plants and other organisms.
- (ii) **Offers mechanical protection:** It acts as a rigid outer layer that protects the cell from physical damage and environmental stress.
- (iii) **Prevents osmotic lysis:** It prevents the cell from bursting when it absorbs too much water by withstanding the internal pressure.
- (iv) **Limits the entry of large molecules:** The cell wall acts as a barrier, preventing potentially toxic large molecules from entering the cell.
- (v) **Regulates intercellular transport:** It helps control the passage of substances between neighboring cells.
- (vi) **Supports plant growth:** In plants, the cell wall's properties are linked to cell growth, allowing them to grow tall and maintain their structure without a skeleton.

Chloroplasts

Structure of chloroplast



It is restricted to plant cell and used for photosynthesis. It is surrounded by an envelope of two membranes and contains a gel-like stroma through which runs a system of membranes that are stacked in places to form grana. The stroma contains ribosomes, circular DNS and lipid droplets.

Similarities between mitochondria and chloroplasts

1. Both have double membrane, circular DNA
2. Inner membrane is folded to increase the surface area
3. Contain ATPase enzyme for ATP synthesis
4. Both occur in plant

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5. Both contain carrier proteins
6. Both contain circular DNA
7. Both contain ribosome,

Differences between mitochondria and chloroplasts

Chloroplast	Mitochondria
Structural difference	
1. Contain chlorophyll	Does not contain chlorophyll
2. Inner membrane form grana	Inner membrane folded to form cristae
3. May contain starch granules	Does not contain starch granules
Functional difference	
4. Use water	Produce water
5. Produce O ₂	Produce CO ₂
6. Use sunlight and store its energy in food made	Set energy free from food for work
7. Occur only in green plants	Occur in both plants and animals

Histology

Definition

A tissue is a group of similar cells linked with associated intercellular substances to perform a particular function(s). In complex organism, different tissues combine to form organs and organs combine to form organ system. Organ system combine to form organism

Advantages of unicellular state

Advantages multicellular state

Can exist on its own

There is specialization

Do not need gaseous exchange surface

Indefinite growth

Types of animal tissues

Classification of tissues depending on their function lead to the following:

Animal tissues

- a. Epithelial tissues
- b. Connective tissue
- c. Skeletal tissue
- d. Nerve tissue
- e. Reproductive tissue

Types of plant tissue

- a. Meristematic tissue
- b. Epidermal tissue
- c. Parenchyma
- d. Collenchyma
- e. Sclerenchyma
- f. Vascular
- g. Cork

Animal tissues

1. Epithelium

These are tissues that cover the external and internal surfaces of animal body. They may be made up of one or more layers of cells resting on a basement membrane. The cells are connected together by substance called hyaluronic acid.

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The epithelial tissues function to protect underlying structures from injury through abrasion or pressure and from infection. Stress is combated by the tissues becoming thickened and keratinized, and where cells are sloughed off due to contact friction the epithelium shows a very rapid rate of cell division so that lost cells are speedily replaced. The free surface of the epithelium often is highly differentiated and may be absorptive or secretory in function

Epithelial tissues are subdivided into two major categories

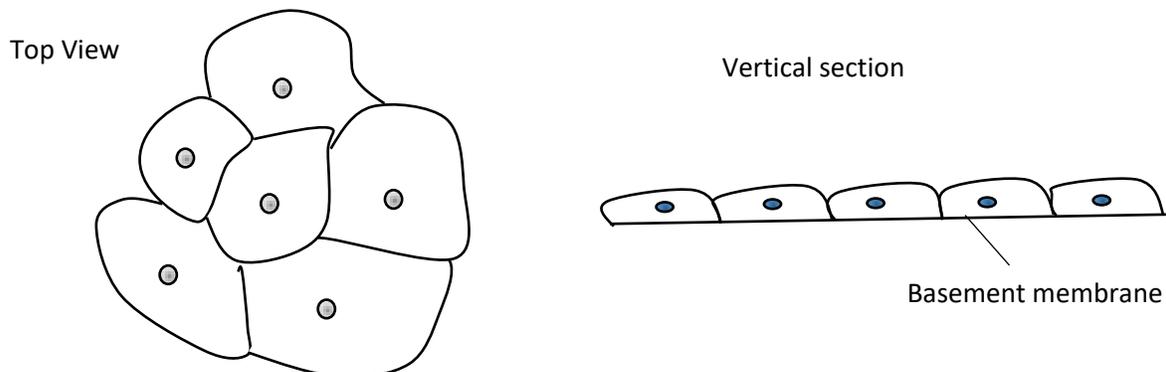
- a. Simple epithelium
- b. Compound epithelium

Simple epithelium

This type of epithelium is made up of only one layer of cells. Simple epithelium is divided into 5 types

- (i) Squamous
- (ii) Cuboidal
- (iii) Columnar
- (iv) Ciliated
- (v) Pseudostratified

(a) Squamous epithelium consists of a sheet of flattened cells which fit closely together rather like crazy paving



Location of squamous epithelial tissue

- Skin outer layer
- Bowman's capsule in the kidney
- Alveoli of lungs
- Capillary walls

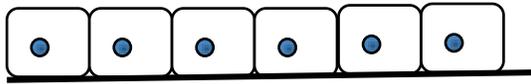
Squamous epithelium is thin and therefore allows easy diffusion of materials across it.

Functions

- Protective
- Allow easy diffusion

(b) Cuboidal

Height of the cell is approximately equal to its width, when viewed in vertical section the cells appear square.



Location

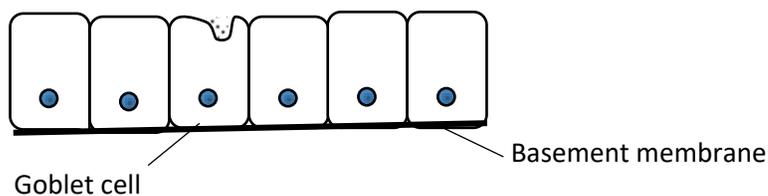
- Salivary duct
- Collecting duct of the kidney
- Thyroid gland

Functions

- Secretory
- Absorptive and its surface may be increased by microvilli to increase surface area.

(c) Columnar epithelium

It is made of elongated cells at right angles to the basement membrane.



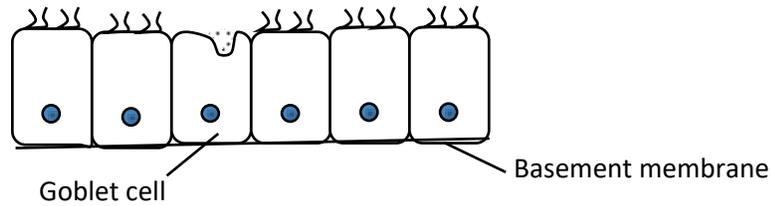
Location

Lining of the stomach and small intestines

Functions

- Secretory e.g. secretion of mucus in the stomach
- Absorptive e.g. absorption of digested food in the intestines.

(d) Ciliated epithelium



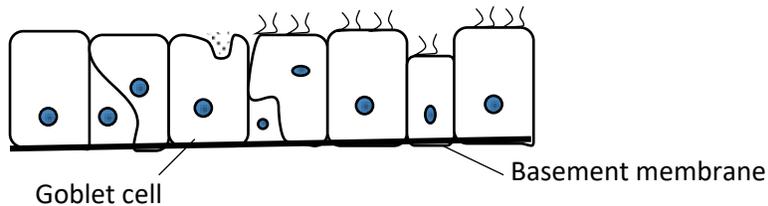
This is made of columnar shaped cells but having numerous cilia at their end. The cells are associated with mucus secreting goblet cells producing fluids in which cilia set up current.

Location

- Oviduct
- Trachea
- Bronchi

(e) Pseudo-stratified epithelium

This is made up of one layer of cells but some cells do not reach the free surface. It appears as if it is stratified.



Location

- Urinary tract
- Trachea
- Olfactory mucosa

Function

Secretory

Compound epithelium

They are made up of more than one layer of cells. There are two types of compound epithelium

a. Stratified epithelium

Made up of a number of layers of cells. The cells are made by mitotic division of the germinal layer which rests on the basement membrane

Occurrence: vagina, esophagus and skin

Function: protects the body against friction.

b. Transitional epithelium

This is made of 3-4 layers of cell. The cells are able to modify their shape when placed under different conditions.

Location: urinary bladder, ureter and pelvis

Glandular epithelium

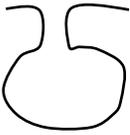
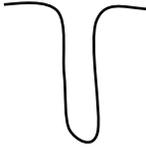
These are epithelium cells that are folded inwards forming invagination where cells lining the bottom of the invagination are secretory.

There are two types

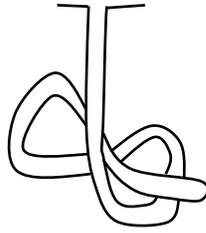
- (i) Exocrine glands: these are glands whose secretion are released through ducts
- (ii) Endocrine glands: are glands without ducts and pass their secretion into blood streams.

Types of exocrine glands

There are different types of glands depending on the epithelial folding.

Types of gland	Structure	Examples
1. Simple saccular		Mucus glands in the skin of amphibian
2. Simple tubular		Crypts of Lieberkühn of the walls of mammalian small intestines Fundic region of the stomach

3. Coiled tubular



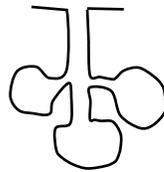
Sweat gland

4. Simple branched tubular



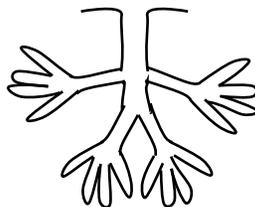
Brunner's gland in walls of mammalian small intestines

5. Simple branched saccular



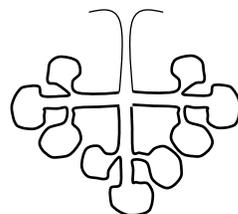
Secretory sebaceous glands in mammalian skin

6. Compound tubular gland



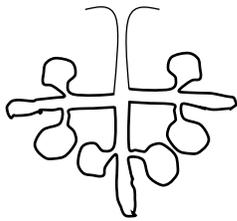
Parts of the pancreas which secretes digestive enzyme and mammary glands

7. Compound saccular



Mammary gland

8. Compound tubular-saccular



Connective tissues

These are the tissues that hold specialized tissues and organs in the right position and fill the spaces between them. They consist of jelly-like ground substances or matrix in which several types of cells are embedded.

Classification of connective tissues

- (i) Loose connective tissue
- (ii) Fibrous tissue (white and yellow)
- (iii) Adipose tissue
- (iv) Dentine tissue
- (v) Skeletal tissue
- (vi) Blood cell making tissue

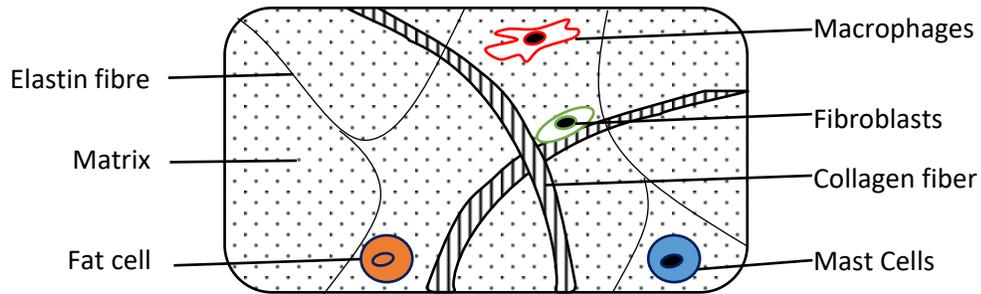
(i) Areolar

This is the fundamental type of connective tissue found all over the body beneath the skin and therefore connecting the skin and therefore connecting the skin to structures below it. It binds sheets of epithelium to mesenteric (capillary network around alimentary canal). It joins blood vessel and nerves whereby they enter or leave body organs. It also fills up space between adjacent tissue and therefore acts like packing tissue.

Functions of areolar tissue

- packing tissue
- insulator due to accumulation of fat cells
- support other organs

Structure

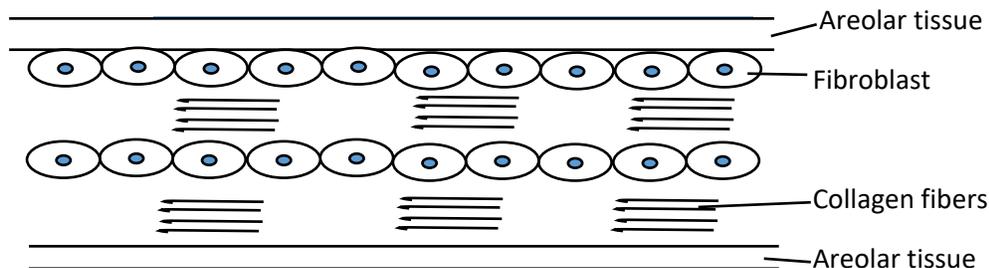


Functions of parts of connective tissue

- **Fat cells** store fats
- **Collagen and elastic fibers** provide mechanical support and flexibility.
- **Matrix** provide nutrients to the cell
- **Fibroblast** produce ground substance
- **Neutrophil, macrophages, mast cells** for defense

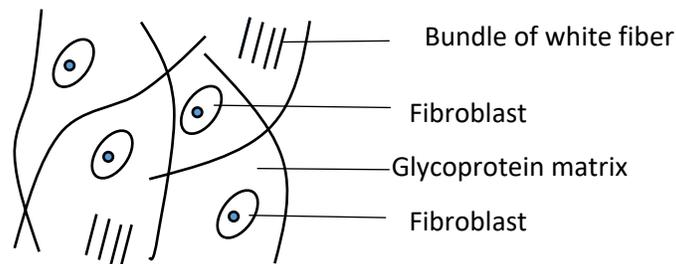
2. White fibrous tissue

This is a tough tissue composed of organized bundles of collagen fibers closely packed together and running parallel to each other. Rows of fibroblasts are scattered among the collagen and run alongside the bundles. Each bundle is bound to a neighboring tissue by areolar tissue. Fibrous tissue is abundant in tendons, ligaments, sclera, and cornea of the eye. These are areas where great strength and limited flexibility are required.



3. Yellow fibrous tissue

This contains a glycoprotein matrix containing only elastic fibers. The fibers are irregularly arranged and are branched. Fibroblasts are randomly distributed throughout the matrix. The elastic fiber provides the tissue with elasticity and flexibility. It also contains some few bundles of collagen which give it strength. It is found in ligaments, walls of arteries as components of lung and associated passages.



4. Adipose tissue

This tissue has no specific matrix but closely packed fat filled cells arrange in two lobules

The bone

Is a tissue that provided skeletal network in the body

Functions of bones

1. Provided shape that allow easy movement and recognition.
2. Protect delicate parts of the body; for, example rib cage protects the hear and the lung
3. Provide support
4. Provide a means of attachment of the muscle to allow movement
5. Store minerals like calcium and phosphorus
6. Produce blood cells like red blood cell

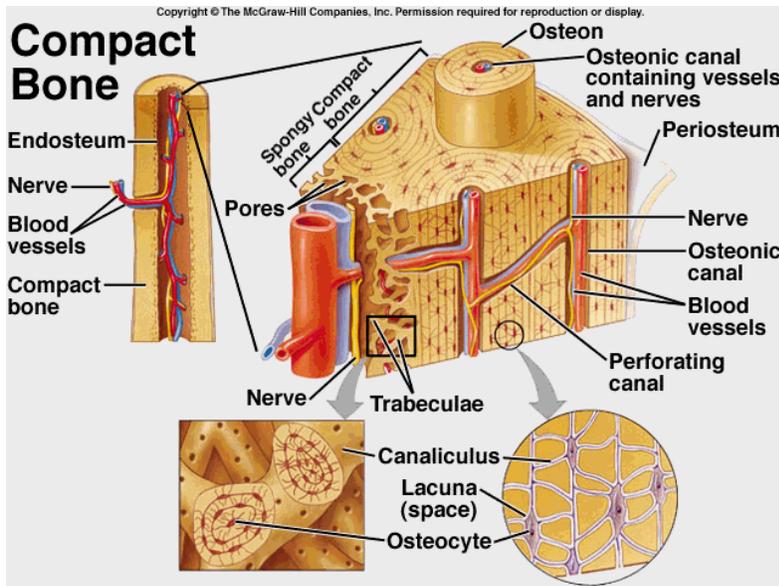
Structure of a bone

The bone is made of a matrix and cells.

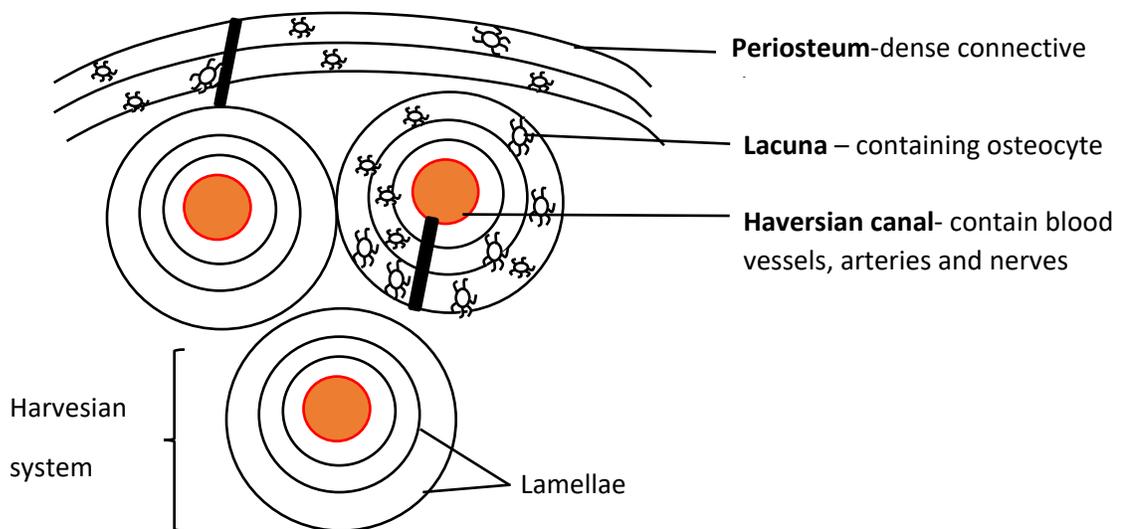
The matrix of compact bone is made of collagen fibers together with inorganic substances such as calcium, magnesium and phosphorous. These components are arranged in concentric circles called **lamellae**, around an **Haversian canal** containing an artery, a vein, lymph vessel and nerve fibers.

Bone cells are found in spaces in the lamellae known as **lacunae** and fine channels called **canaliculi** link lacunae.

The system of lamellae around one Haversian canal is called an **Haversian system**.



Drawing of cross section of a bone



Process of bone formation

Bone formation, or ossification, occurs through two main processes: **intramembranous ossification**, which forms flat bones directly from mesenchymal tissue, and **endochondral ossification**, where bone replaces a cartilage model, forming most other bones. Both processes involve mesenchymal cells differentiating into osteoblasts, which then secrete an organic matrix that hardens through calcification to form bone tissue.

1. Intramembranous ossification

This process is responsible for the formation of flat bones like the skull, clavicle, and some cranial bones:

- (i) Mesenchymal cells cluster together, forming an ossification center.
- (ii) These cells differentiate into osteoblasts, which secrete an unmineralized matrix called osteoid.
- (iii) Calcium and other minerals bind to the osteoid, hardening it.
- (iv) Some osteoblasts become trapped within the matrix and mature into osteocytes.
- (v) The bone is then remodeled into mature bone tissue.

2. Endochondral ossification

This process is responsible for the formation of most other bones, particularly the long bones:

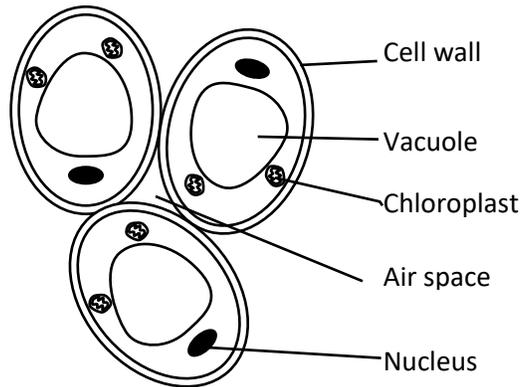
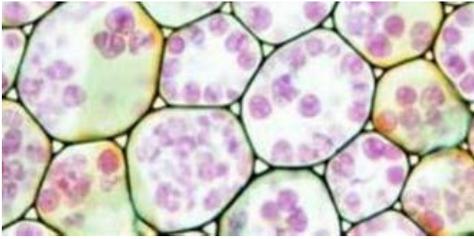
- (i) Mesenchymal cells first differentiate into chondrocytes, forming a hyaline cartilage model.
- (ii) Blood vessels invade the cartilage model.
- (iii) Osteoblasts form around the model and begin to deposit bone tissue, replacing the cartilage.
- (iv) Primary and secondary ossification centers appear, and the bone continues to lengthen and grow until adulthood.
- (v) The remaining cartilage in the epiphyseal plates allows for further lengthening after birth.

Plant tissues

Simple plant tissues consist of only one type of cells. They are grouped according to the degree of thickening present in the cell wall

1. Parenchyma

It is a simple permanent tissue of unspecialized usually spherical cells with thin cell walls. Parenchyma form the bulky of packing tissue within the plant.



Functions of parenchyma tissue

- (i) Store water and food reserve
- (ii) When tightly packed and turgid provide support for herbaceous plants
- (iii) It is a ground tissue
- (iv) Air spaces allow buoyancy in floating plants
- (v) Air spaces allow gaseous exchange

Trial 2

Which one of the following plant tissues performs both storage and supportive functions?

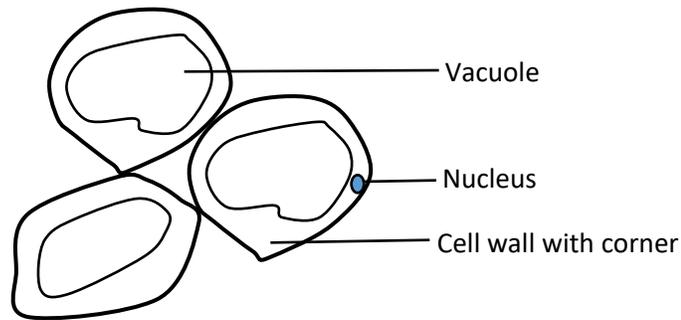
- A. Parenchyma.
- B. Sclerenchyma.
- C. Collenchyma.
- D. Phloem.

The answer is A

Parenchyma is the plant tissue that has both storage and supportive function. It store water and starch in most plants and also serves as the main supporting tissue in non-woody plants.

2. Collenchyma

Contains cells with additional cellulose deposited in the corners.

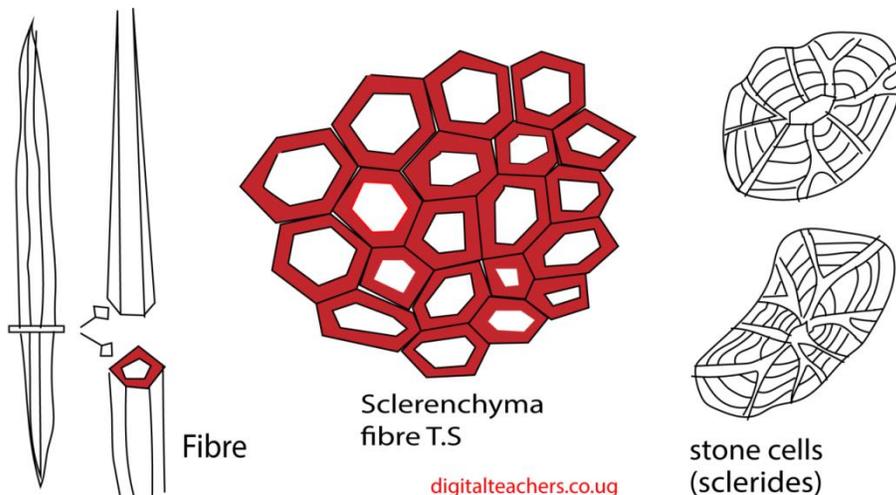


Function collenchyma tissue

- (i) It provides mechanical strength to the petiole, leaves and stem of young dicot plants.
- (ii) Collenchyma confers flexibility to various parts of the plant like petiole and stem, allowing for easy bending without breakage.
- (iii) It allows for growth and elongation of plant organs.
- (iv) Collenchyma present in leaves also prevents them from tearing.
- (v) The living cells of collenchyma store food.
- (vi) Collenchyma when containing chlorophyll performs the function of photosynthesis.

3. Sclerenchyma

Mature sclerenchyma cells are dead and cannot grow. They develop fully when the growth of surrounding tissue is complete. Sclerenchyma cells have large deposits of lignin in the cell wall and the cell content is lost in places, lignin is not deposited due to presence of plasmodesmata in primary cell wall, such regions are called pits. Some sclerenchyma cells are roughly spherical and are known as **sclereids**. These are usually found in small group in fruits and seeds, cortex, pith and phloem.



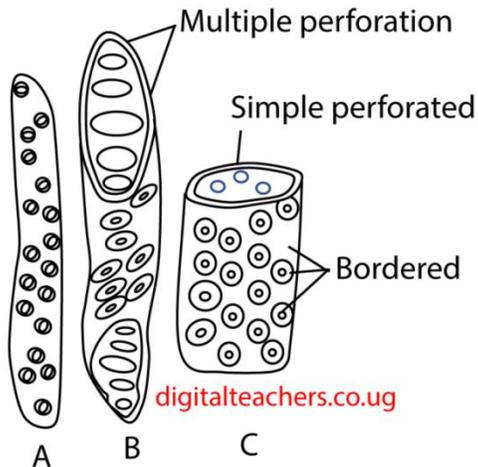
Sclerenchymatous fibre and stone cells

Functions of sclerenchyma

- (i) They provide mechanical support
- (ii) They make up xylem and tracheid for water transport
- (iii) In hypodermis of xerophytic plant, they prevent water lost
- (iv) Sclerenchyma cells in the fruit walls help in its dehiscence and seed dispersal
- (v) Sclerenchyma of seed coat protect the seed from desiccation

Xylem

Consist of parenchyma cells and fibers together with vessels and tracheid.

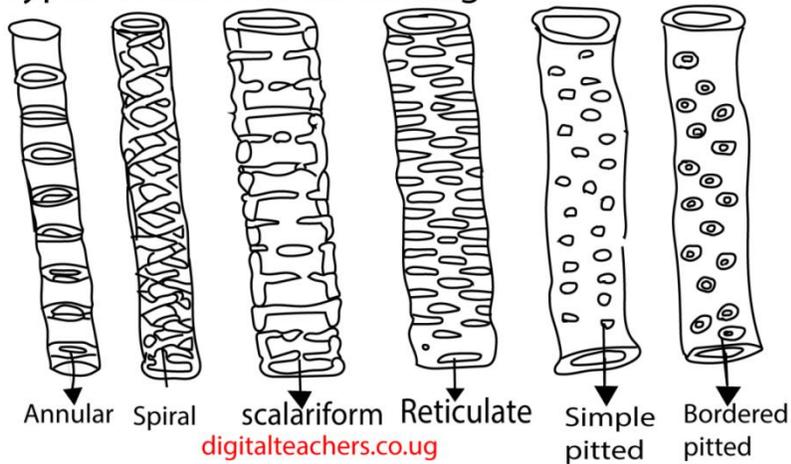


Xylem (A- tracheid, B and C vessels)

Vessels are made of cylindrical dead cells, one on top of another with the cross wall broken down to form a long continuous tube from the roots to the leaves.

The type of vessel found depend on the degree and nature of cell thickening. In the **protoxylem** the lignin is deposited in rings or spirals to the cells is still capable of expansion. In metaxylem there is more extensive lignification arranged in patterns known as reticulate, scalariform or pitted.

Types of cell wall thickening



Tracheid are spindle-shaped cell arranged in rows with ends of the cells overlapping. The cells have heavily lignified cell wall with no cell contents.

Functions of xylem

Transport water and mineral salts

They provide mechanical support.

Adaptations of the xylem

1. Cross walls are perforated or completely removed to form continuous tubes from roots to stems and leaves
2. Xylem vessels have no living contents to allow water to flow freely
3. Contain bordered pits to allow water cross to living cells
4. Lignified to prevent water loss
5. Lignified to prevent them from collapsing under negative pressure of transpiration pull.
6. Small tube to enable high capillarity
7. Xylem walls have high adhesive forces.

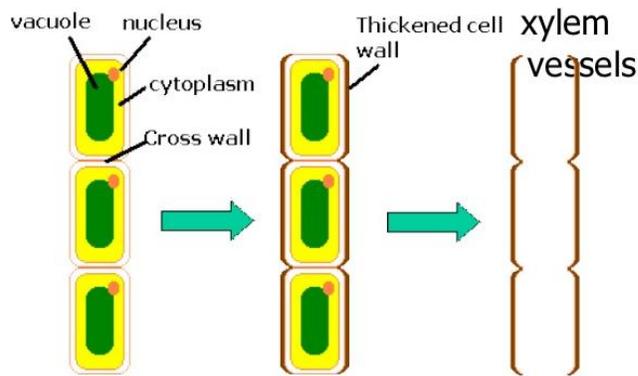
Adaptation to provide support

1. Walls are lignified
2. Vessels are circular for additional support.

Development of xylem

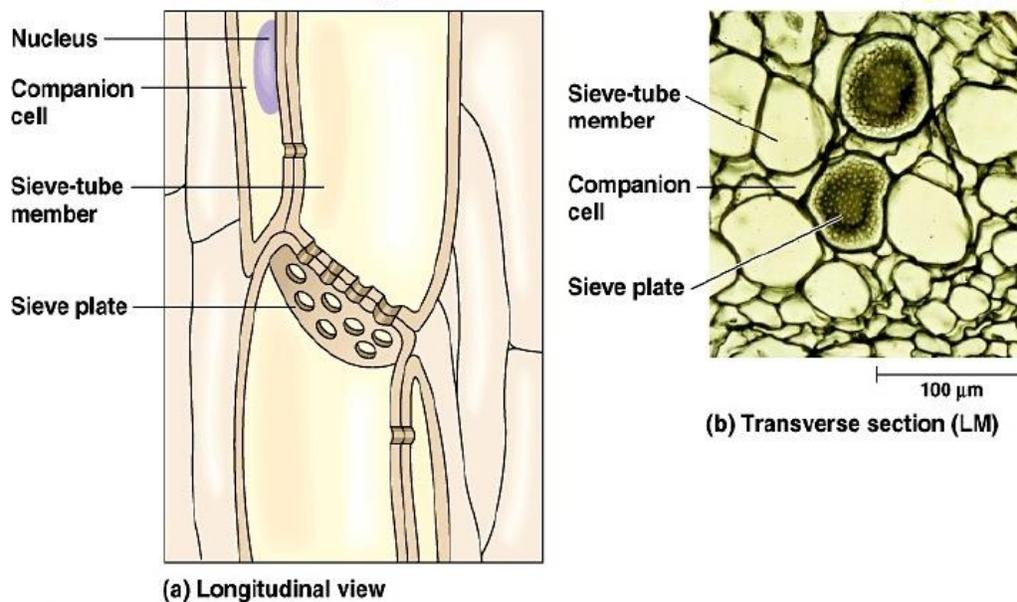
Cells destined to form xylem vessel elongate and develop thickened secondary wall. The walls are later lignified. The cell content die and cross section walls degenerate to form continuous open tube.

Development of xylem vessels



Phloem

Structure of phloem vessel



The phloem consists of sieve tubes and companion cells.

Sieve tubes consist of columns of elongated, thin walled living cells called sieve tubes/elements. They have cross walls with many holes or pores called sieve plates. Each sieve tube has a companion cell.

Functions of phloem

Transport of manufactured food (sucrose and amino acid) from leaves to other parts of the plant.

Adaptations of phloem

- Lack a nucleus and most cell organelles to leave room for transportation of food
- The sieve plates are perforated to allow rapid flow through

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- Has filament for quick transport by streaming
- Intimate association with companion cells to obtain energy and materials

Differences between xylem and phloem

	Xylem	Phloem
1	Vessels are made of dead cells	Elements are made from living cells
2	Vessels have lignified cell walls	Phloem do not have lignified cell walls
3.	The end wall disappears completely	The end wall form sieve plates. They do not disappear completely
4.	Have pits	Have plasmodesmata
5.	Thick walls	Thin walls
6	Transport water and mineral salts	Transport food (sucrose and amino acids)

Development of phloem

Cells destined to become sieve elements elongate, most cell organelles degenerate leaving cytoplasmic filament. The plasmodesmata of the end wall widen forming sieve pores.

Hold a debate titled "Organisms at the organ level are more efficient than those at the cellular and tissue level".

Debate: "Organisms at the organ level are more efficient than those at the cellular and tissue level"

The motion:

"Organisms at the organ level are more efficient than those at the cellular and tissue level."

For the motion: Organ-level organisms are more efficient

1. **Specialization and division of labor:** The development of specialized organs allows for a highly efficient division of labor. Different organs can evolve to perform specific tasks with extreme precision and effectiveness, far surpassing the capabilities of a single cell or a homogeneous group of cells.

Example: The human digestive system, composed of organs like the stomach, small intestine, and liver, is vastly more efficient at breaking down food and absorbing nutrients than the simple diffusion and intracellular digestion of a single-celled amoeba.

2. **Increased complexity and adaptability:** The integration of multiple tissues into a single organ, and multiple organs into a system, allows for complex, coordinated functions that enable an organism to adapt to a wider range of environments and challenges. This complexity provides a level of control and regulation that is impossible at a simpler level.

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Example: A complex circulatory system with a heart (an organ) allows for the rapid and efficient transport of oxygen and nutrients to distant tissues. This enables a large, active mammal to sustain high metabolic rates, a feat unachievable by an organism that relies on simple diffusion.

3. **Homeostasis and stability:** Organ-level organisms have evolved dedicated organs to maintain a stable internal environment (homeostasis), making them more robust and resilient to external changes. This frees up individual cells and tissues from having to constantly manage their own conditions, allowing them to focus on their specialized tasks.

Example: The kidneys (an organ) regulate the body's water balance and filter waste, ensuring that all cells are bathed in a stable, toxin-free fluid. A single-celled organism must perform all these regulatory functions itself, making it more vulnerable to changes in its external environment.

4. **Large size and high energy demands:** For large, multicellular organisms, organ-level organization is not just an advantage but a necessity. The limitations of diffusion mean that single cells or simple tissue layers cannot meet the high energy demands or transport needs of a large body.

Example: A large predator requires organs like a heart and lungs to rapidly deliver oxygen and nutrients to all its cells for the burst of energy needed to chase prey. A sponge, with a tissue-level organization, is limited to a sessile, low-energy existence.

5. **Complex Behaviors and Intelligence:** Organ-level organisms often have brains or neural networks enabling learning, memory, and decision-making. This leads to better resource acquisition, predator avoidance, and social cooperation.

Against the motion: Organ-level organisms are *not* more efficient

1. **The definition of "efficiency" is key:** Efficiency is context-dependent. While an organ-level organism may be more "powerful," a simpler organism can be more efficient in terms of a low energy-to-output ratio. Single-celled and tissue-level organisms have evolved elegant solutions for their specific needs that avoid the metabolic costs associated with maintaining complex organs.

Example: A bacterium is incredibly efficient at reproducing and utilizing resources. It does not waste energy on developing and maintaining complex structures, making it highly efficient from a purely energetic and reproductive standpoint.

2. **The burden of complexity:** The very complexity that defines an organ-level organism is also its greatest vulnerability. The high metabolic cost of maintaining organs, combined with the risk of catastrophic failure in a single organ system, makes it less resilient in some respects.

Example: The failure of a single vital organ, such as the heart or liver, can be fatal for a mammal. In contrast, if a group of cells is damaged in a tissue-level organism like a sea anemone, other cells can often take over the function, or the organism can simply regenerate the lost tissue.

3. **The simplicity of direct interaction:** Organisms without organs can achieve their life functions through direct, simple **interactions** with their environment, avoiding the need for complex, energy-intensive transport systems.

Example: A sponge, a tissue-level organism, has cells that can directly absorb nutrients from the water that passes through it. It has no need for a complex and energy-demanding digestive system, making its nutrient acquisition highly efficient for its lifestyle.

4. **Evolutionary success of simpler forms**

Argument: The sheer number and diversity of single-celled organisms demonstrate their **incredible** evolutionary success and efficiency. The fact that they have persisted for billions of years, adapting to every conceivable niche, is a testament to their efficient life strategy.

Example: The domain Bacteria, consisting of prokaryotic single-celled organisms, represents a vast and successful lineage of life. Their simple structure is a highly efficient design for their size and environment.

Debate conclusion

The debate highlights that "efficiency" is not a universal metric. For large, complex life forms, the division of labor and specialization afforded by organs provides a type of efficiency related to power and adaptability. However, for smaller, simpler organisms, a cellular or tissue-level organization is a highly efficient strategy, allowing them to minimize energy expenditure and reproduce rapidly. The most "efficient" level of organization depends entirely on the organism's size, environment, and evolutionary niche.

Revision questions for chemicals of life:

Even when the structure of exams may have changed, going through these questions may enhance understanding

- Lack of iodine in the diet causes cretinism because iodine
 - Controls metabolism
 - Is essential in the formation of metabolic enzymes
 - Influence growth of bones
 - Is required for synthesis of thyroxineD
- In the body, proteins combine with acids or bases depending on the
 - Temperature of the medium
 - Hydrogen ion concentration in the medium
 - Number of solvent molecules present in the medium
 - Number of amino acid molecules in the proteinB
- Starch, glycogen and cellulose are all composed of
 - α -glucose
 - β -glucose
 - monosaccharides
 - polysaccharidesC
 - Starch is composed of α -glucose while cellulose is composed of β -glucose both of which are monosaccharides
- Some amino acids are known as essential because they are
 - more important in the body metabolism than other
 - not made by the animal body
 - contained in first class proteins
 - required in larger amounts than others.B
- Which of the following sugars is not reducing?
 - Maltose
 - Fructose
 - Galactose
 - SucroseD
- Among the following compounds, one cannot be hydrolyzed is
 - Glycogen
 - Galactose
 - Lactose
 - MaltoseB

➤ Galactose is a simple sugar

7. Which one of the following is the correct formula of a polysaccharide?

- A. $(C_6H_{10}O_5)_n$
- B. $(CH_2O)_n$
- C. $(C_6H_{12}O_6)_n$
- D. $C_{12}H_{22}O_{11})_n$

A

8. Which one of the following statements is true of essential fatty acids? They

- A. They are the most required lipids in the body
- B. Are required in the body in large quantities
- C. Cannot be synthesized in the body
- D. Are most abundant in animal tissues

C

9. Which one of the following properties of water facilitates its efficient transportation of glucose?

- A. Forms hydrogen bonds with other molecules
- B. Has high surface tension
- C. Has low freezing points
- D. Has high boiling point

A

10. Which of the following vitamins is water soluble?

- A. A
- B. E
- C. D
- D. C

D

11. Lack of iodine in diet causes cretinism because iodine

- A. Controls metabolism
- B. Is essential for formation of metabolic enzymes
- C. Influence growth of bones
- D. Is required for synthesis of thyroxine

D

12. A property of water that makes it suitable component of a hydrostatic skeleton is it

- A. High density
- B. High surface tension
- C. Low viscosity
- D. Incompressibility

D

13. Aquatic organism survives under solidified water body because
- A. Water solidifies from bottom to top of lakes
 - B. Ice is less dense than water at 4⁰C
 - C. Cold water is more dense than hot water and falls to the bottom
 - D. Warm water floats on top of cold water
- B
14. In the body, proteins combine with acids or bases depending on the
- A. Temperature of the medium
 - B. Hydrogen ion concentration in the medium
 - C. Number of solvent molecules present in the medium
 - D. Number of amino acid molecules in the protein
- B
15. Which one of the following is not a fibrous protein?
- A. Keratin
 - B. Globulin
 - C. Elastin
 - D. Collagen
- B
16. Sucrose is a non-reducing sugar because it
- A. It is not fully digested
 - B. It lacks reducing groups
 - C. Is a disaccharide molecule
 - D. Is a ketose sugar
- D
17. Which one of the following is a fibrous soluble protein?
- A. Myosin
 - B. Collagen
 - C. Myoglobin
 - D. Fibrinogen
- D
18. A green plant develops yellow leaves as a result of being deficient in
- A. Magnesium
 - B. Manganese
 - C. Nitrogen
 - D. Calcium
- C
20. In the blood plasma, proteins can act as bases or acids depending on the
- A. Temperature of the medium
 - B. Hydrogen ion concentration of the medium
 - C. Nature of the protein

D. Concentration of the solute in the plasma B

21. Which of the following is the function of manganese in the human body?

- A. Essential for formation of erythrocytes
- B. Activate enzymes
- C. Acts as growth factor in bone development
- D. Utilized as a component of bone and teeth B and C

22. Which of the following substances consists of globular proteins?

- A. Enzymes
- B. Keratin
- C. Elastin
- D. Collagen A

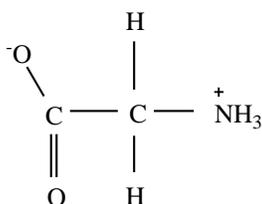
23. Which one of the following symptoms is likely to be caused by magnesium deficiency in plants?

- A. Yellow leaves and stunted growth
- B. Poor root growth
- C. Weak stems
- D. Yell spotted leaves D

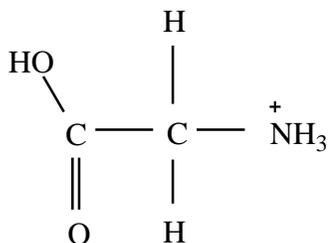
24. Which one of the following is not a function of globular proteins in the body?

- A. Acts as buffers in blood plasma
- B. Form structural proteins
- C. Are vital constituents of plasma membrane
- D. Form enzymes B

25. The following structural formula is for an amino acid in solution



A substance was added to this solution and the structure of the amino acid molecule changed to



What substance was added and what effect would this have had on the final pH of the solution?

- A. Salt added, pH unchanged
 - B. Acid added, pH lowered
 - C. Acid added, pH unchanged
 - D. Base added, pH higher B
26. We need to eat iodized salt in order to
- A. Prevent obesity
 - B. Get a balanced diet
 - C. Improve vision
 - D. Avoid goiter D
27. Water has comparatively high surface tension and boiling point in relation to other substances of similar sized molecules because its molecules are
- A. doubly bonded
 - B. polar
 - C. ionic
 - D. covalent B
28. Evaporation of water from the body surface causes cooling because water has a high
- A. Latent heat of vaporization
 - B. Latent heat of fusion
 - C. Boiling point
 - D. Specific heat capacity A
29. The complexity and variety of organic molecules is due to the ability of the carbon atom to
- A. form covalent and ionic bond
 - B. form covalent bonds in three dimensions
 - C. form strong chemical bonds
 - D. bonds with very many other elements D

30. When a lipid is combined with a phosphate group, it becomes
- A. saturated
 - B. a complex molecule
 - C. water soluble
 - D. amphoteric
- C
31. A property of water which facilitates its efficient transportation of glucose
- A. ability to form hydrogen bonds with other molecules
 - B. high surface tension
 - C. low freezing point
 - D. high boiling point
- A
32. When a lipid is combined with a phosphate group, it becomes
- A. saturated.
 - B. a complex molecule.
 - C. water soluble.
 - D. amphoteric.
- C
33. Water has a comparatively high surface tension and boiling point in relation to other substances of similar sized molecules because its molecules are
- A. doubly bonded.
 - B. polar.
 - C. ionic.
 - D. covalent.
- B
34. Starch and glycogen are suitable storage molecules because they
- A. are large in size which makes them less soluble in water
 - B. are chemistry reactive in the cell
 - C. can easily be hydrolyzed
 - D. exert an osmotic pressure in the cell
- A
35. The high heat capacity of water has biological importance of
- A. minimizing temperature changes in animal fluids
 - B. cooling animals
 - C. Preventing freezing of cell contents
 - D. controlling heat loss in animals
- A

Paper 1 section B

1. Fat and glycogen are energy storage compounds in animals

(a) Compare the suitability of the two substances as storage compounds (4marks)

- They are both compactly arranged to take up little space.
- they are both less soluble in water and little or none can be lost in solution

Differences

Fat	Glycogen
-Has a high calorific value.	-Has a lower calorific value.
-Has higher hydrogen- oxygen content and can yield more metabolic water.	-Has a lower hydrogen- oxygen content and yield less metabolic water
Others	
- Has less weight and keeps body weight to a minimum which allows buoyancy	-Is heavier and can lead to overweight.

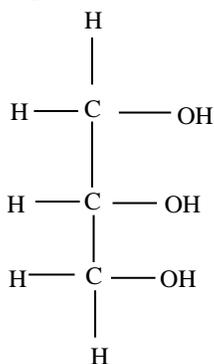
(b) State advantage of storing fat over glycogen (3marks)

- (i) Fat stores more energy per unit mass compared to glycogen
- (ii) Fat is more compact and light compared to glycogen
- (iii) Fat deposits are infinite

(c) Why is glycogen more suitable energy compound in muscle than fat? (3marks)

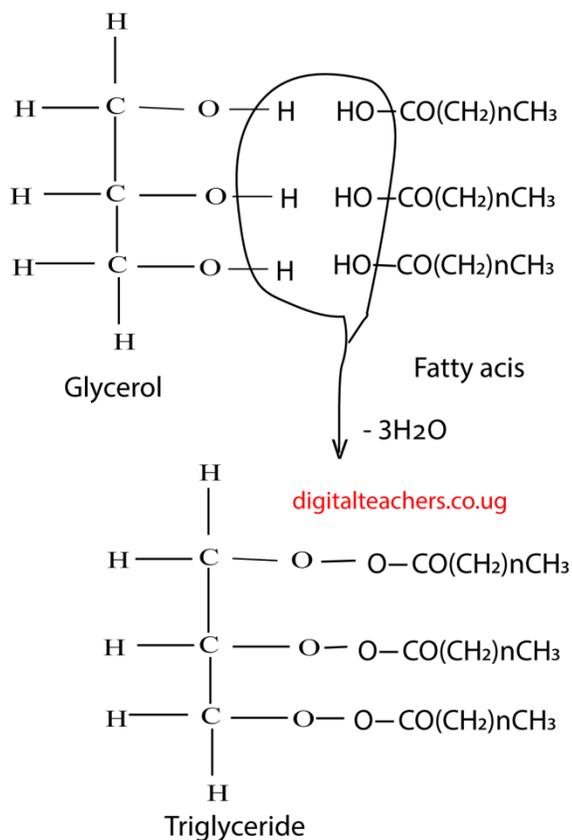
- It is easily broken down to glucose
- Can be used anaerobically
- It is easily transported because it is water soluble
- It can be locally stored in muscles.

2. Using the structural formula



(a) For glycerol, and molecular formula $\text{CH}_3(\text{CH}_2)_n\text{COOH}$ for a fatty acid show the formation of triglyceride from fatty acids and glycerol. (2marks)

Formation of triglyceride from glycerol and fatty acids



(b) What properties do lipids possess as storage food substances? (2marks)

- i. Has high energy content than carbohydrates
- ii. It is lighter
- iii. It is compact and requires less space
- iv. It is a raw material for hormones
- v. Insoluble in water that they have low osmotic value

(c) Outline the structural and physiological functions of lipids in living organisms.

(i) Structural (3marks)

- Make up cell membrane
- Protection: lipids are constituents of the waxy cuticle of plants and insects
- Lipids are water repellent thus prevent water loss from or entry into an animal skin
- Their spongy nature protects delicate organs as shock absorbers.
- Being bad conductors, they reduce water loss from the body when deposited beneath the skin for insulation
- Storage ; they are better storage compounds than carbohydrates due high calories value, due to high hydrogen content, they are light, insoluble in water, compact to fit in a small volume and are easily used when required.

(ii) Physiological (2marks)

- Source of metabolic water
- Store fat soluble vitamins (ADEK)
- Source of metabolic water
- Raw materials for hormones

3. (a) State three ways in which water has similar functions in both plants and animals.

(3marks)

- It is a solvent and medium for transport
- It is a medium of fertilization
- Evaporation cools the body
- Provides support to aquatic organism
- Component of the cell
- A reagent in hydrolytic reaction
- A medium in which biological reaction occur

(b) Give two ways, in each case, in which flowering plants minimize water loss through

(i) behavioral means (4marks)

- Folding or rolling of leaves on a hot day
- Reduction of number of stomata
- Storage of water in leaves
- Sunken stomata

(ii) physiological means (4marks)

- Shedding leaves in hot season
- Reversal of normal stomata rhythm
- Thickening of waxy cuticle

4. Explain how the structure of proteins enable them to form body tissues and structures (4marks)

- Fibrous proteins are used to form body tissue and structures such as muscles because they are insoluble and have high tensile strength due to coiled and cross linked polypeptide chains.
- Structural proteins such as keratin have a secondary structure in form of an extended spiral helices with cross linking disulphide bridges between neighboring chains, this provide hardness allowing keratin to be found in wool, hair and nails.
- **Globular Proteins such as Actin and tubulin form dynamic structures:** They polymerize to form long, stiff fibers that make up the **cytoskeleton**. The cytoskeleton is a dynamic network that gives cells their shape, provides internal support, and allows for cell movement.

5. (a) Describe the significance of physical properties of water to organism. (12marks)

- (i) **High specific heat capacity:** Water absorbs or releases large amounts of heat with little temperature change, buffering aquatic environments and helping organisms maintain stable internal body temperatures.
- (ii) **High latent heat of vaporization:** Its high heat of vaporization allows organisms to cool down as water evaporates from their surfaces, like sweating in mammals.
- (iii) **High latent heat of fusion** minimizes solidification of water in winter protecting aquatic organisms.
- (iv) Transparency enables aquatic organisms to see food, look for mates and run away from predators.
- (v) **Universal Solvent:** water dissolves many substance which enables to transport nutrients to the body and waste products from the body
- (vi) **Lower Density as Ice:** ice floats on water insulating bottom water and allowing aquatic organisms to survive in winter
- (vii) **Water Movement:** Cohesion (water sticking to itself) and adhesion (water sticking to other surfaces) create surface tension and help water move up through plants in their vascular systems.
- (viii) **Neutral pH:** enables countless biochemical reactions necessary for life
- (ix) **Liquid State:** Water's ability to remain liquid over a wide temperature range provides a stable, mobile medium where essential life processes, such as metabolic reactions, can occur.

(b) Explain why lipids are better storage material in animals than carbohydrates (8marks)

- Fat stores more energy per unit mass compared to glycogen
- Fat is more compact and light compared to carbohydrates
- Fat deposits are infinite while carbohydrate deposits are limited
- They are insoluble making their storage secure

6. (a) Giving examples, describe the use of nitrogen to plant and animal bodies

- (i) protein synthesis
- (ii) production of enzymes
- (iii) production of muscles and tissues
- (iv) production of nucleic acid

(b) how is the concentration of nitrogen maintained at constant level in nature?

Describe the nitrogen cycle

7. Distinguish between the following

(a) Monosaccharide and polysaccharide (05marks)

Monosaccharide	Polysaccharide
Made of 3 to 6 carbon atoms	Many carbon atoms
Composed of one sugar unit	Composed of many sugar units
Low molecular mass	High molecular mass
Soluble	Insoluble
Used for respiration	Used for storage
Low energy content	High energy content

(b) Starch and cellulose (04marks)

Starch	cellulose
Polymer of alpha glucose	Polymer of beta glucose

(c) Saturated and unsaturated fats (05marks)

- **Saturated fatty acids** lack double bonds **between** the individual carbon atoms, while in **unsaturated fatty acids** there is at least one double bond **in the** fatty acid chain.

- **Saturated fats** tend to be solid at room temperature and from animal sources, while **unsaturated fats** are usually liquid and from plant sources.

(d) Globular and fibrous proteins

(06marks)

Fibrous proteins are insoluble in water, weak acids and weak bases but soluble in strong acids and alkalis whereas **globular proteins** are soluble in water, acids and bases.

Fibrous proteins are highly resistant to digestion by enzymes and are extremely tensile

8. Relate the properties of water to its biological importance. (20 marks)

Answer 1(a)

Revision questions for Enzymes:

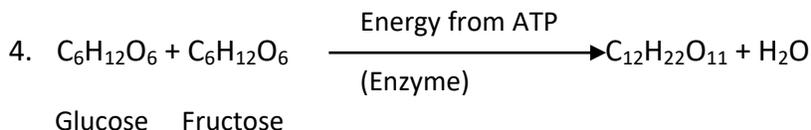
Objective questions

- Chloride ions are vital for efficient functioning of salivary amylase because ion
 - Activator
 - Are coenzyme
 - Are co factor
 - For alkaline medium

C
- Enzyme that catalyze the removal of water molecules from a substrate are known as
 - Reductase
 - Dehydratase
 - Hydrolase
 - Hydrase

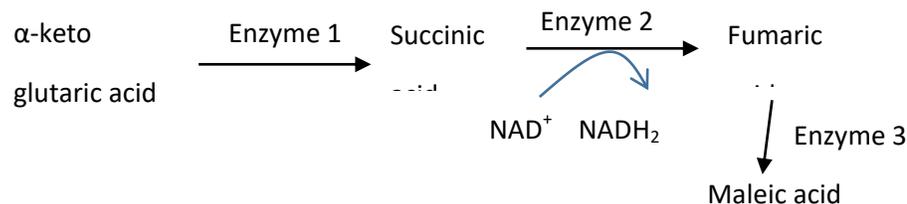
B
- What name is given to a chemical reaction in which two or more hexose sugars combine to form larger units
 - condensation
 - hydrolysis
 - dehydrogenation
 - isomerization

A



What is the above called?

- A. Dehydration synthesis
 - B. Hydrolysis
 - C. Dehydration process
 - D. Condensation reaction D
5. The activity of an enzyme in a
- A. Molecular weight of the enzyme
 - B. Protein nature of the enzyme
 - C. Activation energy of the enzyme
 - D. Surface configuration of the enzyme D
6. The reaction rate of salivary amylase with starch decrease as the concentration of chloride ions.
- A. Co enzymes
 - B. Competitive inhibitor
 - C. Co factor
 - D. Allosteric inhibitor C
7. Which one of the following characteristic of enzyme distinguishes than from inorganic catalyst
- A. Initiation and speed up the rate of reaction
 - B. Remain the same at the end of the reaction
 - C. May promote reversible reaction
 - D. Exert their effect when present even in small quantities A
8. Use the figure below, the part of reaction of the Krebs cycle to answer 8 and 9



Succinic acid accumulates when malonic acid is added to the reaction medium. Which one of the following statements best describes the role of malonic acid?

- A. Malonic acid is an inhibitor of enzyme 1
 - B. Malonic acid reacts with α -keto glutaric acid to form succinic acid
 - C. Malonic acid is an inhibitor of enzyme 2
 - D. Malonic acid acts as coenzyme of enzyme 1 C
9. Enzyme 2 is a
- A. Dehydrogenase
 - B. Decarboxylase
 - C. Dehydrase
 - D. Reductase D

10. An enzyme which catalyze the conversion of dipeptide into separate amino acid is example of

- A. Dehydrogenase
- B. Hydrolase
- C. Transferase
- D. Oxidase

B

➤ **Hydrolase:** This is the general classification for enzymes that break down molecules by adding water to cleave chemical bonds. In this case, the peptide bond in the dipeptide is broken.

11. An enzymatic reaction of the type

ATP + hexose \longrightarrow ADP+ hexose-6-phosphate is an example of

- A. A hydrolysis
- B. An isomerase
- C. Transfer
- D. A synthesis

C

12. When a piece of liver is dropped into containing H₂O₂, there is vigorous reaction. this is due to enzyme

- A. Catalyze
- B. Amylase
- C. Trypsin
- D. Carbonic anhydrase

A

13. In the lock and key hypothesis for the mechanism of enzyme the mechanism of enzyme action, how does inhibitor substance stop enzyme action? By

- A. Raising activation energy
- B. Distorting substrate molecule
- C. Destroying coenzyme
- D. Occupying active sites on enzyme

D

14. When the extent of inhibition in an enzyme controlled reaction depends entirely on the concentration of the inhibitor, it indicates that the inhibition is

- A. Competitive
- B. Reversible
- C. Non-competitive
- D. Irreversible.

B

15. Which **one** of the following is not true about the lock and key theory in enzyme-catalyzed reaction?

- A. A small change in the active site alter the enzyme
- B. The substrate and active site are complementary
- C. Enzyme catalyzed action go through the enzyme-substrate complex stage
- D. A molecule which fits in the active site is a substrate

D

➤ Sometimes an inhibitor can fit into active site

16. Which one of the following does not have an effect on a non-competitive inhibition?
 A. Temperature change
 B. pH change
 C. enzyme concentration
 D. substrate concentration D
17. Which one of the following describes the turnover number of an enzyme?
 A. Number of molecules affected by the enzyme
 B. Number of substrate molecules turned into its product per minute
 C. Number of product molecules formed
 D. Number of substrate molecules catalyzed per minute B
18. Which of the following is true about non-competitive inhibition of enzyme catalyzed reaction?
 A. The degree of inhibition decreases with increase in substrate concentration
 B. The inhibitor has a similar structure and chemical composition with the substrate
 C. The degree of inhibition is independent of the substrate concentration
 D. The shape of the enzyme is not affected by the inhibitor C
19. When the extent of inhibition of an enzyme-controlled reaction depends entirely on the concentration of the inhibitor, it indicates that the inhibition is
 A. Competitive
 B. Reversible
 C. Non-competitive
 D. Irreversible B
20. Chloride ion are vital for efficient functioning of salivary amylase because the ions
 A. are activator
 B. are co-enzyme
 C. are co-factors
 D. form alkaline medium C
21. The activity of an enzyme in a chemical reaction depends on the
 A. Molecular weight of the enzyme
 B. Protein nature of the enzyme
 C. Activation energy of the enzyme
 D. Surface configuration of the enzyme D
22. Which one of the following correctly represents the effect of increasing substrate concentration on the degree of inhibition in a competitive and noncompetitive inhibition reaction?
- | | competitive | noncompetitive | |
|---|-------------|----------------|---|
| A | Decrease | increased | |
| B | Decrease | No change | |
| C | increased | Decrease | |
| D | No change | No change | B |



If an excess X controls the metabolic pathway of the reaction, the control mechanism is known as,

- A. Multi-enzyme control
- B. Excess inhibition
- C. End product inhibition
- D. Negative feedback D

23. An adaptation by plant to obtain nitrogen include all the following except.

- A. Mycorrhiza on plant roots
- B. Bacteria in root nodules
- C. Possession of aerial roots
- D. Being insectivorous C

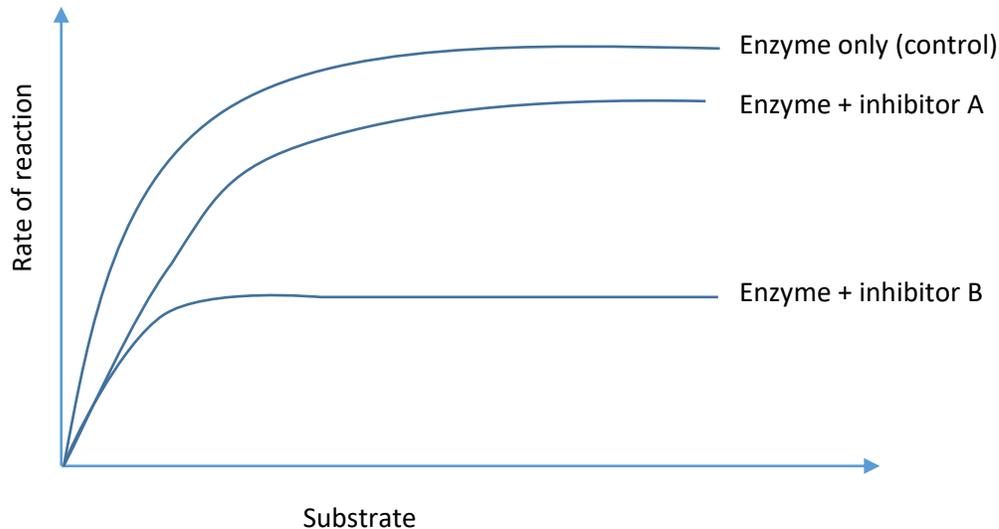
➤ Aerial roots are meant for gaseous exchange

24. Which one of the following environmental factors has a direct effect on all organisms?

- A. Light.
- B. Humidity.
- C. Temperature.
- D. Rainfall. C

➤ Temperatures affects enzyme controlled reactions in all organisms.

25. Figure 4 show the effect of increasing the concentration of a substrate on the rate of an enzyme controlled reaction in presence of inhibitors A and B, in relation to the control experiment without an inhibitor.



(a) Describe the effect of each inhibitor on the rate of reaction.

(i) Inhibitor A

Inhibitors A reduced of reaction initially but as substrate concentration increase the rate of reaction also increase at a lower rate than the control. It attains a lower maximum but at a higher substrate concentration than the control.

(ii) Inhibitor B

Inhibitors B greatly reduces rate of reaction, however, rate increase gradually with substrate concentration to a very low maximum at a lowest substrate concentration than all.

(b) Explain the difference in the effect of inhibitors A and B on the rate of reaction

Inhibitor A is reversible competitive inhibitors of the enzyme. It competes with the substrate to bind to the active site of the enzyme, being structurally similar to the substrate. At low substrate concentration, the inhibitors out compete the substrate for the active site. Fewer than normal substrate molecules combine with the enzyme and the reaction is slower than the control.

As substrate concentration increase, the substrate competes more favorable for the active site and the reaction increase with the substrate concentration up to saturation.

Saturation is slightly lower than control since some enzyme active sites still occupied by inhibitors A molecules.

Inhibitor B is a non-competitive inhibitor. It binds with the enzyme permanently and prevents the substrate from binding to the enzyme. This reduces effective enzyme molecules and the reaction proceeds as it would occur if the enzyme concentration was lower than the control.

26. (a) Explain the following

(i) Competitive inhibition

- Substances structurally similar to enzyme substrate compete with enzyme substrate for active site on the enzyme molecule where both reversibly bind.
- fewer true substrate bind to the enzyme and so the rate is reduced or inhibited.
- this is a competitive inhibition whose degree depends on the relative amount of the substrate and inhibitor.

(ii) Noncompetitive inhibitor

- A substance with the structure different from that of the substrate irreversibly binds on the enzyme at a point different from the active site stops or reduces the action of the enzyme. The degree of inhibition depends on the concentration of inhibitor and not the substrate.

(b) In what way do enzymes differ from catalyst?

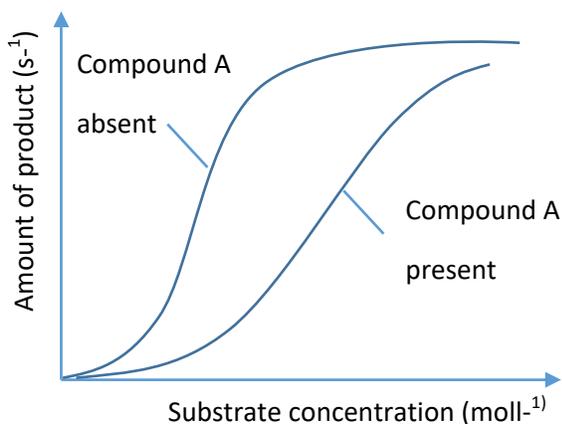
Differences between enzyme and catalysts

	Enzymes	Catalysts
1.	proteins in nature	inorganic chemicals e.g. Pt
2.	catalyze specific reactions Such as hydrolysis of starch	may catalyze more than one reaction e.g. platinum catalyze decomposition of H ₂ O ₂ and reduction of benzene
3.	Denatured by heat above 45 ⁰ C	Usually are not affected by heat
4.	Very sensitive to pH	Not sensitive to pH
5.	Initiate reaction	Do not initiate reaction

(c) Briefly describe the lock and key hypothesis of enzyme action

- The enzyme's active site and its substrate have complementary structure.
- The enzyme randomly binds with the substrate to form enzyme-substrate complex like a key fits in the lock.
- The enzyme acts on the substrate to form products.
- The products do not fit in the active site, leave the active site for another substrate.

27. The figure below shows the effect of varying substrate concentration on an enzyme catalyzed reaction, in absence and presence of compound A



(a) Explain the relationship between the reaction rate and substrate concentration

(i) In absence of compound A (3marks)

Reaction rate increase rapidly with substance concentration. Rate then increase gradually before it becomes constant at higher substrate concentration

Explanation

Initially, the number of enzymes molecules available for reaction is higher than the number of substrate molecules; any available substance will react to form a product.

As the substrate concentration increase, the number of enzymes molecules occupied by substrate at a given time increase, hence more amount of product is formed per unit time. This continues until all the enzymes molecules are occupied so that a substrate has to wait for the active site of the enzymes to be freed before it can bind the enzymes, in order to react. the rate of formation of products therefore becomes constant.

(ii) In presence of compound A(4marks)

Rate of reaction increase slowly with substrate concentration and reaches a lower maximum at a higher substrate concentration.

Explanation:

Compound A competes with the substrate for the active sites of the enzyme molecules.

As a result, the number of enzymes molecules available for binding the substrate at a given time is lower.

As the substrate concentration increase, the substrate (out-competes compound A and the reaction rate increase, through at a lower rate. The enzyme molecules become saturated at a higher substrate concentration. However, at this point, the output is lower because some enzyme molecules are occupied by compound A and cannot react with substrate.

(b) State two factors which would have kept constant in this experiment (1mark)

Temperature of the reaction medium

PH of the reaction medium

The amount of the enzyme.

(c) What would be the effect of increasing the concentration of compound A in this experiment? (2marks)

The rate of reaction would decrease with increase in amount of compound A added until the reaction stops altogether at higher concentrations of compound A.

28. (a) Explain the difference between coenzyme and activators

Cofactors/activators serve the same purpose as **coenzymes**, as they regulate, control, and adjust how fast these chemical reactions would respond and take effect **in** our body. The big **difference** is that **coenzymes** are organic substances, while **cofactors/activators** are inorganic.

(b) Giving example explain what is meant by enzyme inhibitors

Enzyme inhibitors are molecules that interact in **some** way with the **enzyme** to prevent it from working in the normal manner. There are a variety of types of **inhibitors** including: nonspecific, irreversible, reversible - competitive and noncompetitive. Poisons and drugs are **examples of enzyme inhibitors**.

(i) Competitive reversible inhibitor;

Here a compound is structurally similar to that of the usual substrate associates with the enzymes active site but it's unable to react with it. While it remains there, it prevents access of any molecules of the substrate. This type of inhibition depends on the concentration of the substrate and that of an inhibitor. At high concentration of the substrate, inhibition is overcome.

(ii) Noncompetitive reversible inhibitors.

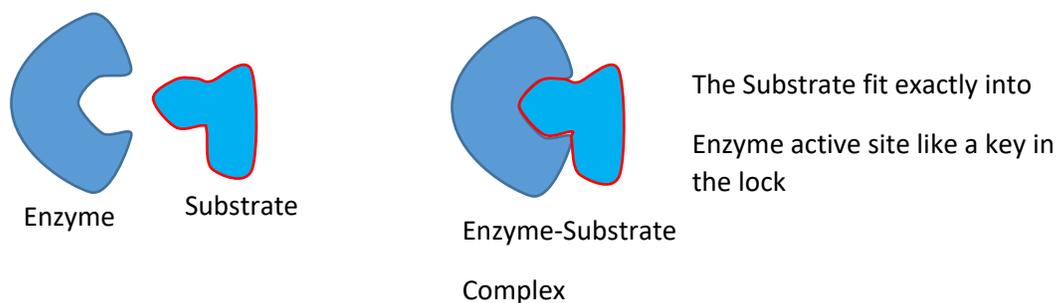
This is a type of inhibition in which the inhibitors attach themselves outside the active site thereby preventing the enzyme normal catalytic reaction by changing the shape of the enzyme or allosteric effect. It may be reversible when the inhibitor forms loose attachment to the enzyme that may be detached when circumstances permit e.g. cyanide or irreversible noncompetitive inhibition when the inhibitor permanently disorganizes the structure of the enzyme that it may no longer react with the substrate, e.g., mercury.

(c) How do enzymes bring about their effects.

Enzymes catalyse their reactions by lowering activation energy by a lock and key hypothesis.

Enzymes are very specific to the substrates they act on because they have particular shape / configuration into which substrate with complementary shape fit in exactly as the key fits into the lock, thus the lock (enzyme) and key (substrate) hypothesis.

When an enzyme - substrate complex is formed; the substrate is activated into forming the product of the reaction. Once formed, the product no longer fits into the active site and hence escapes into the surrounding medium leaving the active site free to receive other substrate molecules.



29. (a) Describe the working of an enzyme using the Lock and Key hypothesis (11mark)

Refer to Qn 28 ©

(b) Explain the

- (i) Effect of excessive heat on the enzyme action (3marks)
Denatures the enzyme
- (ii) Non-competitive inhibition in an enzyme controlled reaction (6mark)
Qn 28 (b)(ii)

31. (a) Classify enzymes basing on the type of reaction they catalyze. (06marks)

Here's a breakdown of each class:

1. **Oxidoreductases:** Catalyze oxidation-reduction (redox) reactions, involving the transfer of electrons. E.g. Dehydrogenases.
2. **Transferases :** Transfer a functional group (like a methyl or phosphate group) from one molecule (the donor) to another (the acceptor). E.g. Kinases (which transfer phosphate groups).
3. **Hydrolases:** Catalyze hydrolysis, the breaking of a chemical bond by adding a molecule of water. E.g. Lipases, which break down fats.
4. **Lyases:** Cleave chemical bonds (other than by hydrolysis or oxidation) and typically form new double bonds or rings. They can also add groups to double bonds. E.g. Decarboxylases, which remove carbon dioxide.
5. **Isomerases:** Catalyze the rearrangement of atoms within a single molecule, converting it into an isomer. E.g. Racemases, which interconvert stereoisomers.
6. **Ligases:** Join two molecules together by forming a new chemical bond, a process often coupled with the breakage of a high-energy pyrophosphate bond. E.g. DNA ligase, which joins DNA strands.

7. **Translocases:** Move ions or molecules across cell membranes or facilitate their separation within membranes. E.g. ATP synthase.

(b) Explain how competitive and noncompetitive inhibitions of enzymes occur. (10marks)

Qn 28 (b)

(c) What is the importance of enzyme in enzyme catalyzed reaction?

It lowers the activation energy for the reaction

Exercise on cells and tissues

Objective questions

1. Which of the following epithelium tissues line blood capillaries?

- A. Cuboidal tissue
- B. Squamous tissue
- C. Columnar tissue
- D. Glandular tissue

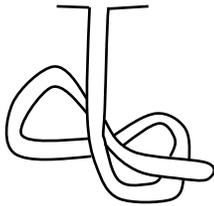
B

2. The function of the nucleoli in a cell is to form

- A. The nuclear membrane
- B. Ribose
- C. The spindle during nuclear division
- D. Centrioles

B

3. The figure below shows a glandular tissue



In which part of the mammalian body is the tissue likely to be?

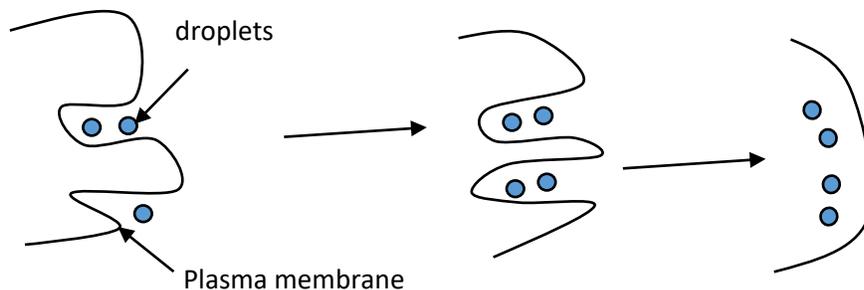
- A. Ileum
- B. Lungs
- C. Stomach
- D. Skin

D

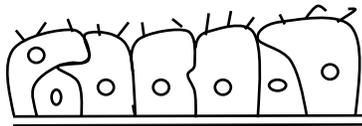
4. Which one of the following consists of a pair of tissues specialized for support?

- A. Parenchyma and collenchyma
- B. Collenchyma and sclerenchyma
- C. Parenchyma and sieve tubes
- D. Xylem and phloem

5. The type of feeding mechanism shown in figure below is



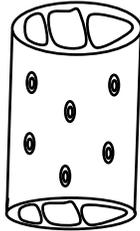
- A. Pinocytosis
 - B. Phagocytosis
 - C. Filter feeding
 - D. Predation A
 - Pinocytosis take in liquid substance while phagocytosis take in solid substance
6. One disadvantage of multicellular state is the individual cells
- A. Are always small in size
 - B. Lose independence
 - C. Becomes less functional
 - D. Become less specialized B
7. The walls of collenchyma cells stained deep blue by methylene blue but not aniline hydrochloride. This shows that the wall
- A. Are not thickened
 - B. Are thickened by lignin
 - C. Contains living protoplasm
 - D. Are thickened by material other than lignin D
8. Squamous epithelium is made up of thin and delicate sheets of cell as an adaptation to
- A. Rapid cell division
 - B. Facilitation of liquid movement
 - C. Shortening diffusion distance
 - D. Protecting the body from abrasion C
9. The figure below represents a human tissue



The tissue would most likely be lining the

- A. Salivary gland
- B. Stomach
- C. Ileum
- D. Oviduct

10. The figure below represents a



- A. Tracheid
- B. Xylem vessel element
- C. Sieve tube
- D. Phloem parenchyma cell

B

11. Which of the following is not correct about cells of a tissue?

- A. Are of one type
- B. Have the same origin
- C. Have same particular function
- D. Are physically linked

C

e.g. (i) Most epithelium is derived from the ectoderm and endoderm, but the endothelium (lining of blood vessels) and mesothelium (lining of body cavities) are derived from the mesoderm.

(ii) Tissues often contain multiple types of cells (e.g., in nervous tissue, you have neurons and various glial cells like microglia and oligodendrocytes) that are highly dissimilar in structure and function, but they work together for a common purpose and are still considered part of the same tissue type.

12. The epithelial type lining the mammalian alveoli is

- A. Columnar
- B. Cuboid
- C. Stratified
- D. Squamous

D

13. A probable function of cell membrane is to

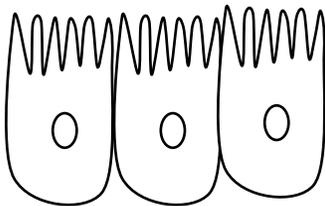
- A. Control entry and exist of materials form the cells
- B. Rapid conversion of sugar to starch
- C. Act as a template for in protein synthesis
- D. Enable substances diffuse against concentration gradient

A

14. Which of the following is a simple branched tubular gland?

- A. Brunner's gland
- B. Salivary gland
- C. Sweat gland

- D. Mammary gland A
15. Which of the following is not correct about cells of a tissue? A
- A. Have similar function
 - B. Are of the same origin
 - C. Are of one type
 - D. Have physical linkage B
16. A property of cells in a multicellular organism is that they B
- A. Small
 - B. Less functional
 - C. Less specialized
 - D. Dependent D
17. Which one of the following tissues has the least power of regeneration? D
- A. Blood tissue
 - B. Epithelial tissue
 - C. Bone tissue
 - D. Nerve tissue D
18. Which one of the following structures is found in both xylem and phloem in higher plants B
- A. Sieve tracheid
 - B. Parenchyma cells
 - C. Companion cells
 - D. Hollow vessels B
19. Which of the following have a sole function of offering support to the plants? C
- A. Sclerenchyma and vessel elements
 - B. Vessel elements and tracheid
 - C. Sclerenchyma and collenchyma
 - D. Parenchyma and collenchyma C
20. Which one of the parts of a mammal possesses an epithelial tissue as shown in the figure below?



- A. Oviduct
- B. Ileum
- C. Respiratory tract
- D. Loop of Henle A

21. The main distinguishing character of a eukaryotic cell is
- A. Membrane organelles
 - B. Lack of a nucleus
 - C. Presence of a nucleus
 - D. Presence of DNA double strand
- A
22. Which of the following organelle would most likely be abundant in the tail of a tadpole at a time of its reabsorption during metamorphosis?
- A. Centrioles
 - B. Lysosomes
 - C. Golgi apparatus
 - D. Endoplasmic reticulum
- B
- Lysosome removes unwanted bodies from the cells/tissue
23. In higher plants, the lateral roots originate from the
- A. Endodermis
 - B. Epidermis
 - C. Pericycle
 - D. Cambium
- C
24. A plant tissue which is tubular, open ended, with lignified and thickened walls is
- A. Tracheid
 - B. Xylem vessel
 - C. Parenchyma
 - D. Sieve tube
- B
25. Viruses cannot reproduce outside the body because
- A. Not all of them contain DNA
 - B. They are too small to reproduce
 - C. They are unable to synthesize their own DNA
 - D. They are unable to absorb raw materials from the surroundings.
- C
26. Rapid transport of materials within the cytoplasm of a cell is associated with the presence of
- A. Spindle fibers in the dividing cell
 - B. An extensive endoplasmic reticulum
 - C. Many plasma membrane pores
 - D. Extensive Golgi apparatus
- B
27. Which of the following types of epithelia lines the walls of the mammalian alveoli?
- A. Columnar epithelium
 - B. Cuboidal epithelium
 - C. Stratified epithelium
 - D. Squamous epithelium
- D

28. Which of the following does **not always** form part of a bacterium cell?
- A. Cell wall
 - B. Flagellum
 - C. Cytoplasm
 - D. Ribosome
- B
29. Which one of the following cell organelles would be most active at sites where substances move against diffusion gradient?
- A. Ribosome
 - B. Lysosome
 - C. Mitochondria
 - D. Golgi bodies
- C
- Mitochondria provides energy for active transport
30. Which one of the following is not correct about viruses? They
- A. can only reproduce in living cells
 - B. Are the smallest living organisms
 - C. Are facultative parasites
 - D. Do not have cellular structures
- D
31. Which one of the following structures operates independently of nervous control?
- A. cilia of paramecium
 - B. flagella of euglena
 - C. stinging cells of coelenterates
 - D. pigment cells of fishes
- C

Explanation

The stinging cells, or cnidocytes, of coelenterates (also known as Cnidarians, such as jellyfish and sea anemones) are considered independent effectors. The firing of a stinging cell is a direct, local response to a specific mechanical or chemical stimulus on the cell itself, rather than being triggered by a signal from the organism's simple nerve net.

Why other options are incorrect

- **A. cilia of paramecium** and **B. flagella of euglena**: Both Paramecium and Euglena are unicellular organisms that lack a nervous system entirely. Their movement is controlled by internal cellular mechanisms, not a nervous system.

- **D. pigment cells of fishes:** The color changes in the pigment cells (chromatophores) of fishes are explicitly controlled by their nervous system, hormonal system, or both.

32. Which one of the following features would be prominent in mucus secreting cells?

- A. Large nucleus and dense matrix
- B. Numerous rough endoplasmic reticulum and Golgi body
- C. Numerous mitochondria and lysosome
- D. Dense matrix and smooth endoplasmic reticulum

B

Explanation

Mucus-secreting cells, such as goblet cells, produce and secrete mucin, a large glycoprotein that is the main component of mucus. The synthesis, modification, and packaging of this protein require a significant amount of cellular machinery.

- **Rough endoplasmic reticulum (RER):** The RER is where proteins, including mucin, are synthesized and undergo initial folding. Cells that produce a large amount of secretory proteins, like mucus-secreting cells, have extensive RER.
- **Golgi body:** After synthesis in the RER, the proteins are transported to the Golgi body, where they are further modified, sorted, and packaged into vesicles for secretion. This process, especially the addition of sugar chains (glycosylation), is crucial for creating the mucin's final structure.

33. Which one of the following types of epithelia experiences the highest wearing?

- A. Stratified
- B. Columnar
- C. Glandular
- D. Ciliated

A

34. In which one of the following is ciliated epithelium found?

- A. Kidney tubules
- B. Small intestines
- C. Respiratory tract
- D. Lining of alveoli

C

- In the **respiratory tract**, ciliated epithelium moves a layer of mucus, which traps dust and pathogens, up towards the pharynx to be coughed up or swallowed.

35. Which of the following gland is compound saccular?
 A. mammary gland
 B. sebaceous gland
 C. sweat gland
 D. gastric gland A
36. Which one of the following cell organelle is associated with the final stage of most cell secretion?
 A. Smooth endoplasmic reticulum
 B. Rough endoplasmic reticulum
 C. Ribosome
 D. Golgi Apparatus D
37. Which of the following is a function of the Golgi body in the cell?
 A. Secreting substances out of the cells
 B. Synthesis of proteins
 C. Assembling of raw materials for secretion
 D. Synthesis of carbohydrates C
38. Which of the following cell types are unlikely to be found in the mammalian intestines?
 A. Columnar
 B. Ciliated
 C. Stratified
 D. Squamous D
39. Which one of the following glands has a compound tubular structure?
 A. Mucus gland in the skin of frog and other amphibians
 B. Salivary gland in the mouth of a mammal
 C. Brunner's gland in the walls of a mammalian small intestine
 D. Pancreas C
40. What role is associated with the endoplasmic reticulum?
 A. Site for protein synthesis
 B. Isolation and transport of the proteins synthesized
 C. Synthesis and transport of lipids and steroids
 D. Production of amino acids B
41. Which of the following is the main function of the Golgi apparatus in a living cell?
 A. Destruction of worn out cell organelles
 B. Synthesis of cell wall components
 C. Synthesis of proteins
 D. Intracellular transport B
42. Which one of the following epithelial tissue is illustrated in figure below?



- A. Columnar
- B. Squamous
- C. Cuboidal
- D. Stratified

B

43. Cells with uniformly thickened and lignified walls are likely to be

- A. Phloem
- B. Parenchyma
- C. Collenchyma
- D. Sclerenchyma

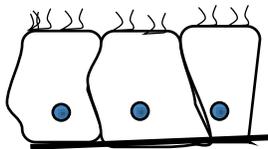
D

44. Which one of the following plant tissues perform both storage and support functions?

- A. parenchyma
- B. sclerenchyma
- C. collenchyma
- D. phloem

A

45. The figure below shows an epithelial tissue

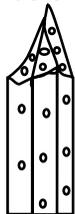


The function of the tissue is to

- A. Increase surface area for absorption of material
- B. Provide smooth lining for movement of materials
- C. Act as a junction between different tissues
- D. Move materials along the surface

A

46. The figure below is a section of a structure from a plant tissue.



The tissue with such a structure is the

- A. Collenchyma
- B. Parenchyma
- C. Phloem
- D. Xylem

D

47. Viruses resemble living organism because they possess
- A. A nucleus
 - B. Genetic material
 - C. A cell membrane
 - D. Oxidative enzymes
- B
48. A companion cell has a large nucleus because
- A. It supports the sieve tube element which has no nucleus
 - B. It controls a large volume of cytoplasm
 - C. Movement of material in the sieve tube is active process
 - D. of its high metabolic rate
- A
49. Which one of the following tissues would be stained deepest red by a dye that stains nucleic acid?
- A. Sieve tube
 - B. Tracheid
 - C. Collenchyma
 - D. Cambium
- D
50. Which one of the following plant tissues, have cell with walls least adapted to support?
- A. Sclerenchyma
 - B. Collenchyma
 - C. Tracheid
 - D. Xylem vessels
- B
- Collenchyma lacks lignin
51. Growth in size of a single cell is limited by the
- A. Cytoplasm
 - B. Nucleus
 - C. Cell wall
 - D. Cell membrane
- D

Explanation

The growth in size of a single cell is primarily limited by the **surface area-to-volume ratio**. As a cell grows, its volume increases much faster than its surface area. The cell membrane, which represents the surface area, is responsible for transporting nutrients into the cell and waste products out of it. A larger cell volume requires a greater rate of exchange, but the proportionally smaller surface area of the membrane cannot keep up, which limits the cell's maximum size.

The nucleus's ability to control a large volume of cytoplasm is a secondary limiting factor. However, the more fundamental limitation is the surface area-to-volume ratio, which is directly related to the cell membrane.

52. The tails of the phospholipids lie in the center of the cell membrane due to their being
- A. Light
 - B. Hydrophilic
 - C. Polar
 - D. Hydrophobic D
53. A young herbaceous stem maintains an erect position mainly due to
- A. Lignified tissue in the stem
 - B. Water pressure in xylem tissue
 - C. High turgor pressure in the parenchyma cells
 - D. Low osmotic pressure in the parenchyma cells C
54. In sponges, the different types of cells are independent of each other in function because
- A. The different cell show division of labor
 - B. Collar cells maintain the flow of water
 - C. Sponges are made of collar flagellates
 - D. The cell are not coordinated D
55. Which one of the following parts would show a distinct blue color if a cross section of a dicotyledonous plant was stained with iodine solution?
- A. Pericycle
 - B. Poriferous layer
 - C. Endodermis
 - D. Pith C
- In a dicotyledonous plant, endodermis cells have a high content of starch grains. As such, they show a distinct blue colour in a cross-section of root stained with iodine. It is for this reason that the endodermis is also sometime called the starch sheath.
56. Chromophores are
- A. reproductive cells
 - B. fat-containing cells
 - C. carotenoid containing cells
 - D. pigment-containing cells in certain vertebrates D

Paper 1 Section B

57. (2013/1/44) (a) Name two areas in plants where each of the following tissue is found?

(i) Sclerenchyma (1mark)

Please find free notes, tests and marking guides of physics, chemistry, biology and mathematics from:

- Vascular bundles.
 - Hypodermis of monocotyledonous stems.
- Others
- Pericycle of dicotyledonous stems, in form of strands of secondary xylem and secondary phloem.
 - Sclerenchymatous fibres on the surface of seeds, e.g. cotton
 - Endocarp of nut.
 - Gritty mass in the pulp skin of pears and guava fruits

(ii) Collenchyma (1marks)

- In petiole and leaf lamina.
- Stems of herbaceous plants.

(b) Give three structural adaptation of the sclerenchyma tissue for its function (3marks)

- Cells have highly lignified thick walls provide enough resistance to forces of the environment.
- Cells are dead and therefore place no extra metabolic demand on the plant.
- Sclerenchyma fibre are elongated and arranged in sheets or strands to increase their strength

Others:

- Sclerenchyma fibre are interlocked to enhance their combined strength

(c) Explain the importance of collenchyma tissue in leaves and young stems (02marks)

- Collenchyma is the strengthening mechanical tissue of leave and young stems. It supplements the effects of turgid parenchyma in maintaining shape and form of leave and young stems.

(d) Outline three structural differences between the collenchyma and sclerenchyma tissue. (03marks)

Collenchyma	sclerenchyma
Consists of living cells	Consists of dead cells
Cell wall is thickened with cellulose	Cell wall is thickened with mainly lignin
Cell wall thickening is non -uniform	Cell wall thickening is uniform

others

Collenchyma	sclerenchyma
May contain chloroplasts	Does not contain chloroplasts
Cell cavity is wide	Cell cavity is very narrow or even closed
Has no pores	May be perforated with pore in the walls

58. (a) Describe the adaptations of each of the following tissues for their functions, giving one example of the site where each of them is found.

(i) Stratified tissue

(3marks)

Function: protection

Adaptations

- **Multiple Layers** to protect underlying tissue; surface cells continuously replaced as they are sloughed off by abrasion or wear and tear.
- **Keratinization (in some forms)** to reduce water loss and to form a protective barrier against water loss, chemicals, and microbes.
- **Non-Keratinization (in other forms):** Non-keratinized forms (e.g., esophagus) remain moist and are well-suited for lining wet surfaces subject to friction.

Example Site:

- **Keratinized:** Epidermis of the skin.
- **Non-Keratinized:** Lining of the esophagus, mouth, and vagina.

(ii) Collagen tissue

(3marks)

Function: support

Adaptation: fibres with high tensile strength for support

Location: connective tissues, tendons

(b) Explain how the structure of proteins enable them to form body tissues and structures

(4marks)

- Fibrous proteins are used to form body tissue and structures such as muscles because they are insoluble and have high tensile strength due to coiled and cross linked polypeptide chains.
- Structural proteins such as keratin have a secondary structure in form of an extended spiral helices with cross linking disulphide bridges between neighboring chains, this provide hardness allowing keratin to be found in wool, hair and nails.
- **Globular Proteins such as Actin and tubulin form dynamic structures:** They polymerize to form long, stiff fibers that make up the **cytoskeleton**. The cytoskeleton is a dynamic network that gives cells their shape, provides internal support, and allows for cell movement.

59. (a) State **two** important difference which can be recognized under the light microscope between plant and animal cells

Feature	Plant Cell	Animal Cell
Cell Wall	Present (rigid, outermost layer)	Absent (cell membrane is the outermost layer)
Chloroplasts	Present (contain green pigment, visible as green oval structures)	Absent
Shape	Usually fixed and rectangular/square	Usually irregular or round
Vacuole	Typically one large central vacuole	Several small, temporary vacuoles, or none

(b) (i) Name the membrane-bounded channels which form a network and almost fill the cytoplasm of most cells and are only recognizable under the electron microscope

Endoplasmic reticulum

(ii) What are the 'small granules' associated with the channels mentioned in (i) and what is their function?

Ribosome for protein synthesis

C (i) Give one way by which you would recognize the "colloidal state" of protoplasm

You can recognize the "colloidal state" of protoplasm in one of two main ways through microscopic observation:

1. **Observe the Tyndall Effect:** When a strong beam of light is passed through the protoplasm at right angles in a dark field, the light path becomes visible as a cone (the Tyndall cone). This light scattering is a characteristic property of colloids because their particles (ranging from 1 nm to 1000 nm) are large enough to scatter light.
2. **Observe Brownian Motion:** Under a powerful microscope, the suspended colloidal particles within the protoplasm can be seen moving in a continuous, rapid, zig-zag, or erratic fashion. This motion is caused by the unbalanced bombardment of these particles by the molecules of the surrounding dispersion medium (water).

(ii) Which constituent of the protoplasm are responsible for its colloidal state?

Proteins, lipids, and polysaccharides (macromolecules)

(d) Viewed under the electron microscope, the cell membrane has a three-layered structure. What is the chemical nature of each of these layers?

The two outer layers are composed primarily of the **protein** components of the membrane and the **polar (hydrophilic) heads** of the lipid molecules.

Central layer is composed of the **nonpolar (hydrophobic) tails** of the lipid molecules

Assay questions

60. Describe how each of the following tissues are related to their functions

(i) Parenchyma

(03marks)

- They possess relatively thin and flexible primary cell walls, allowing for expansion and growth, and facilitating the rapid diffusion of materials in and out of the cell.

- For storage have large central vacuole and abundant cytoplasm
 - For regeneration and repair have ability to divide
 - For gaseous exchange (aerenchyma) have large intracellular space
 - For support have strong cell walls that resist osmotic pressure leading to close packing that provides hydrostatic support when turgid.
- (ii) Collenchyma (03marks)
- For photosynthesis they contain chloroplasts that trap light
 - Unevenly thickened cell walls provides both strength and crucial flexibility, allowing stems and petioles to bend without breaking
 - Living cells enable them to stretch and grow with the young plant organs they support with ability to recover from stress.
 - Strategic placement: Collenchyma is found in growing regions like young stems, petioles, and expanded leaves, where flexible support is most needed.
 - Elongated or cylindrical shape: The cell shape maximizes the surface area for support and stress distribution.
- (iii) Sclerenchyma (06marks)
- Have thick, lignified Secondary Walls to provide tensile strength
 - Dead cells to support heavy loads
 - Fibers have long, slender cells with tapered ends that interlock, providing strong, fibrous support, as seen in stems and vascular bundles.
 - Sclereids have shorter cells with variable shapes (spherical, oval, cylindrical) that interlock to form hard coatings, like in seed coats, nutshells, and the gritty texture of pears.
 - They have small openings (pits) in the thick walls that allow limited water movement between cells while maintaining structural integrity.

(b) Explain the distribution pattern of mechanical tissue in a stem and root of a dicotyledonous plant. (08marks)

Dicot Stem

- Mechanical strength is concentrated in vascular bundles, which are arranged in a distinct ring within the cortex.
- Collenchymas are often found just beneath the epidermis in patches or strands, providing primary support to young, growing stems and flexibility. While Sclerenchyma fibers and the lignified xylem within the vascular bundles create a strong, yet flexible, outer cylinder.

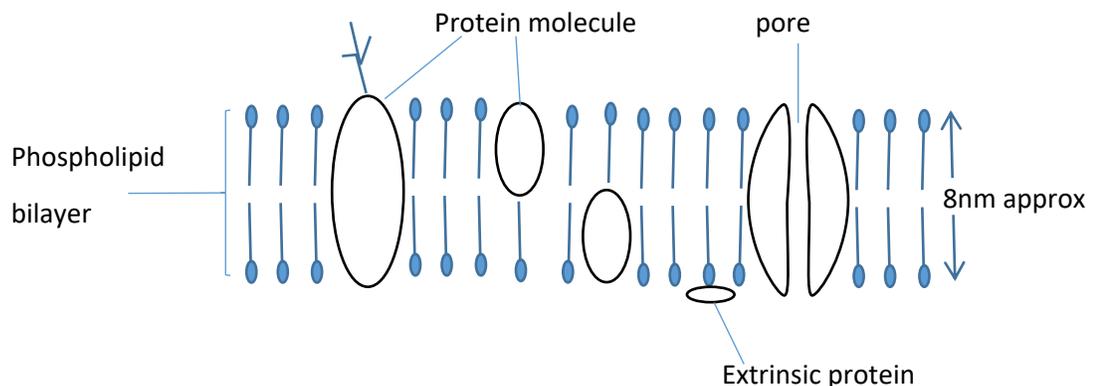
- This arrangement mimics an I-girder, where the strong flanges (vascular bundles) are at the top and bottom (outer and inner parts of the ring) to resist compression and tension from forces like wind.

Dicot Root

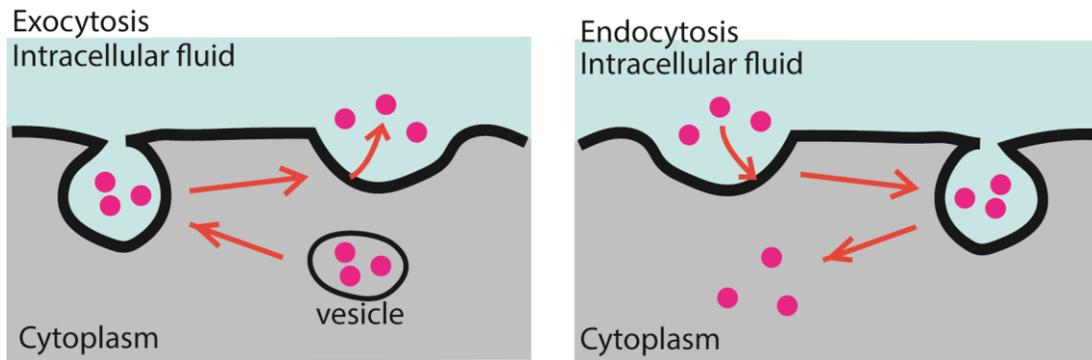
- Mechanical tissues are aggregated in a central core called the stele, with the robust xylem forming a star-shaped structure in the center.
- The lignified xylem in the center provides the main rigid support for anchoring the root in the soil. While Pericycle located just outside the xylem is meristematic layer that contributes to secondary growth and overall root support.
- The central placement of dense, lignified tissue provides maximum stability against the pulling forces encountered in the soil, contrasting with the stem's need to resist bending.

61. (a) Describe the structure of the plasma membrane according to fluid mosaic model (10marks)

- The cell membrane is about 7nm thick
- It consists of a continuous phospholipid bilayer in which proteins are scattered in a mosaic manner.
- Proteins penetrate through the bilayer at a varying degree to form intrinsic and extrinsic proteins that can move laterally, **much like "icebergs in a sea of lipids"**
- Intrinsic protein are those that penetrate through the bilayer while extrinsic proteins are those that float on top as islands in a sea.
- The mosaic of components, include **cholesterol** for fluidity and **carbohydrates** (glycoproteins and glycolipids) on the outer surface, gives the membrane its flexible and selective barrier function.



(b) Explain how exocytosis and endocytosis occur across the plasma membrane. (05marks)



Exocytosis releases substances from the cell; a vesicle, containing molecules destined for export, forms inside the cell and travels to the plasma membrane, where it fuses with the plasma membrane, opening up and releasing its contents (like enzymes or hormones) into the extracellular space. Finally, the vesicle's membrane components become part of the plasma membrane, which can be recycled or used to add new components to the cell surface.

Endocytosis take in substances into a cell from surrounding. External substances or particles bind to the plasma membrane, or are simply close to it, causing the membrane to bend inwards and folds to engulf the material and released inside the cell. When solid particle is taken in the process is phagocytosis (cell eating) while for liquids it is pinocytosis (cell drinking).

(c) Explain the role of proteins within plasma membranes. (05marks)

- (i) provide structural support for the membrane,
- (ii) assist in active transport across the membrane
- (iii) act as recognition sites/receptors
- (iv) act as enzyme, energy transducers and electron carriers
- (v) for communication
- (vi)

62. (a) Describe the structure of the vascular system in higher plants (7marks)

The vascular system in higher plants consists of interconnected networks of **xylem** and **phloem**, organized into **vascular bundles** for transport and structural support. In dicot stems the bundles are in a circular ring in the cortex, in the dicot stem the bundles are located in the center, in the monocot stems the bundles are scattered while in the monocot root, the bundles are located in a circular ring in the cortex.

Xylem is composed of specialized cells like tracheids and vessel elements, which are dead at maturity and form continuous tubes for transport of water and mineral salts and providing mechanical support. While phloem consists of sieve elements (sieve cells or sieve-tube elements) and companion cells for transport of sugars

(b) How are the vascular bundles adapted? (13marks)

Vascular bundles contain specialized tissues; xylem for support and transport of water and phloem for transport of organic substances.

Adaptations of the xylem for transport of water

- (i) Cross walls are perforated or completely removed to form continuous tubes from roots to stems and leaves
- (ii) Xylem vessels have no living contents to allow water to flow freely
- (iii) Contain bordered pits to allow water cross to living cells
- (iv) Lignified to prevent water loss
- (v) Lignified to strengthen xylem tubes and prevent them from collapsing under negative pressure of transpiration pull.
- (vi) Small tube to enable high capillarity
- (vii) Xylem walls have high adhesive forces.

Adaptation xylem for support

- (i) Walls are lignified
- (ii) Vessels are circular for additional support.

Adaptations of phloem

- (i) Lack a nucleus and most cell organelles to leave room for transportation of food
- (ii) The sieve plates are perforated to allow rapid flow through
- (iii) Has filament for quick transport by streaming
- (iv) Intimate association with companion cells to obtain energy and materials

63. Explain how organisms have overcome the challenges of being multicellular.

- (i) To be able to perform complex functions efficiently different cells have specialized to perform specific tasks, such as nerve cells for communication, muscle cells for movement, and skin cells for protection.
- (ii) **Coordinating** many individual cells is done by grouping cells into organs and systems to perform specialized functions and development of specialized coordination systems.
- (iii) To keep cells connected, cells use proteins (like cadherin) to stick to each.

- (iv) **Cells** communicate by sending chemical signals to each other and maintain stability. Gap junctions in animals allow direct transport of substances between cells.
- (v) **Multicellular** organisms have developed transport systems that deliver necessities to individual cells while removing metabolic wastes.
- (vi) Some multicellular organisms have developed extensive specialized surfaces such as alveolar and tracheal systems for gaseous exchange and/or flattened bodies to increase the rate of diffusion while obtaining necessities from the environment.
- (vii) Homeostatic mechanisms have been developed to provide each cell with desirable internal conditions
- (viii) Ability to replace dead cells to lengthen the lifespan of whole organism
- (ix) For **transport**, complex organisms rely on *circulatory systems* (like blood vessels in animals or xylem/phloem in plants) to transport nutrients, gases, and waste efficiently across large distances.
- (x) **Support and Protection:** Multicellular organisms have evolved *skeletal systems, exoskeletons, or cell walls* to provide structural integrity and protect internal organs.
- (xi) **Reproductive Efficiency:** Only specific cells (e.g., gametes) are responsible for reproduction, while others support the organism's survival. This division ensures energy is focused where needed most.

64. Describe the structure of cartilages and bones

Structure of cartilages

Cartilage is a flexible, semi-rigid connective tissue composed of chondroblasts, chondrocytes and extracellular matrix. Chondroblasts produce cartilage matrix while Chondrocytes are mature cells that maintain the matrix, residing in spaces called lacunae. The matrix contains *Water (about 75%)* for resilience and *collagen fibers* for strength and flexibility.

Functions of cartilages are cushion joints and reduce friction; support soft tissues and serve as a template for bone development in embryos

Structure of bones

A bone is a rigid connective tissue made of Osteoblasts and osteocytes embedded in a mineralized matrix of collagen and calcium phosphate. Osteoblasts build new bone tissue and also break down old bone tissue while Osteocytes, the mature bone cells maintain bone structure. The matrix of a bone is made of collagen fibers that provide flexibility and calcium phosphate crystals that give it hardness and strength.

Functions of bones:

- Support and protect organs.
- Facilitate movement.
- Maintain body shape
- Store minerals (especially calcium and phosphorus).
- Produce blood cells in the marrow.

(c) How is cartilage replaced by bone?

Cartilage is replaced by bone through a process called *endochondral ossification*, where a cartilage model is gradually transformed into bone tissue during growth and development.

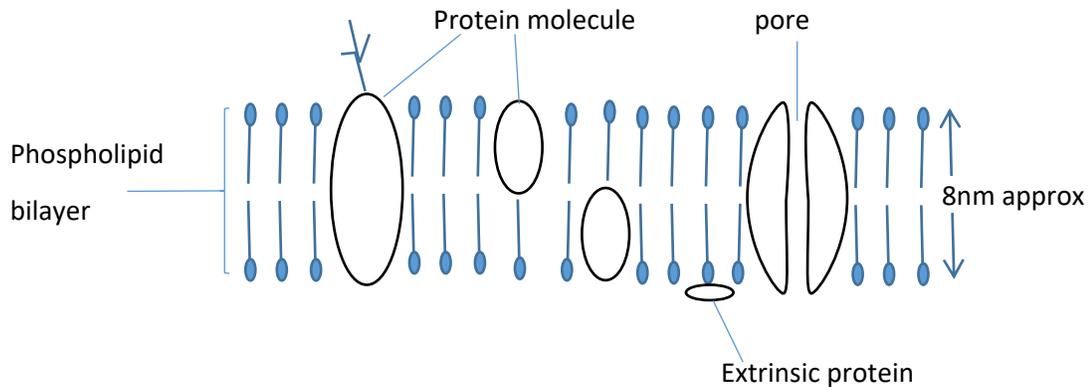
Steps of Endochondral Ossification

- Cartilage Model Formation:** In the embryo, bones begin as *hyaline cartilage templates*. These models resemble the shape of future bones.
- Growth and Calcification of Cartilage:** The cartilage enlarges and chondrocytes (cartilage cells) begin to die as the matrix calcifies, making it less flexible and more rigid.
- Development of the Primary Ossification Center:** Blood vessels invade the center of the cartilage. Osteoblasts (bone-forming cells) arrive and start replacing the calcified cartilage with bone tissue.
- Formation of the Medullary Cavity:** Osteoclasts (bone-resorbing cells) break down newly formed bone in the center, creating the marrow cavity.
- Development of Secondary Ossification Centers:** These form in the ends of the bone (epiphyses) after birth, continuing the replacement of cartilage with bone.
- Formation of Articular Cartilage and Epiphyseal Plate** Not all cartilage is replaced. *Articular cartilage* remains at joint surfaces, and the *epiphyseal plate* (growth plate) allows bones to lengthen during childhood and adolescence.
- Closure of the Epiphyseal Plate** Eventually, the growth plate ossifies, and bone growth in length stops, typically after puberty.

65. (a) Describe the fluid mosaic structure of the plasma membrane. (10marks)

- The cell membrane is about 7nm thick
- It consists of a continuous phospholipid bilayer in which proteins are scattered in a mosaic manner.
- Proteins penetrate through the bilayer at a varying degree to form intrinsic and extrinsic proteins that can move laterally, **much like "icebergs in a sea of lipids"**
- Intrinsic proteins are those that penetrate through the bilayer while extrinsic proteins are those that float on top as islands in a sea.

- The mosaic of components, include **cholesterol** for fluidity and **carbohydrates** (glycoproteins and glycolipids) on the outer surface, gives the membrane its flexible and selective barrier function.



- (b) How does the structure account for the movement of materials in and out of the cells.
- Simple Diffusion:** Small, nonpolar molecules pass directly through the fluid phospholipid bilayer.
 - Facilitated Diffusion & Active Transport:** Larger or polar molecules (e.g., glucose, ions) move via *channel or carrier proteins* embedded in the membrane.
 - Osmosis:** Water moves across the membrane through *aquaporins* (specialized channels) from areas of low solute concentration to high solute concentration.
 - Bulk Transport:** The membrane's fluidity allows for bulk movement through endocytosis and exocytosis, where parts of the membrane can engulf or expel substances in vesicle

66. Explain how the epithelial tissue is adapted for its function. (20marks)

- Tightly Packed Cells with Minimal Intercellular Space** Epithelial cells are closely joined by *tight junctions and desmosomes*, forming a continuous sheet that acts as a protective barrier against mechanical injury, pathogens, and fluid loss.
- Polarity** Epithelial cells exhibit *apical-basal polarity*, meaning they have distinct top (apical) and bottom (basal) surfaces. This allows directional transport of substances—important in absorption and secretion.
- Surface Specializations**
 - *Microvilli* on intestinal epithelial cells increase surface area for absorption.
 - *Cilia* on respiratory epithelium help move mucus and trapped particles out of airways.
 - *Keratinization* in skin epithelium provides waterproofing and extra protection.

- (iv) **Basement Membrane Support** A thin, fibrous *basement membrane* anchors epithelial cells to underlying connective tissue, offering structural support and regulating exchange of materials.
- (v) **Regenerative Capacity** Epithelial tissues have a *high mitotic rate*, allowing rapid repair and replacement of damaged or lost cells—essential for tissues exposed to friction or environmental stress.
- (vi) **Variety of Cell Shapes and Layers**
 - *Simple epithelium* (single layer) is ideal for absorption and filtration (e.g., alveoli, capillaries).
 - *Stratified epithelium* (multiple layers) provides protection in high-friction areas (e.g., skin, esophagus).
 - *Transitional epithelium* in the bladder stretches to accommodate volume changes.
- (vii) **Secretory Adaptations** *Glandular epithelium* contains cells specialized to produce and release substances like mucus, enzymes, and hormones. These cells often have abundant rough ER and Golgi apparatus for protein synthesis and packaging.

67. (a) Describe the structure of plant cell wall

The plant cell wall is a rigid, multi-layered structure composed primarily of cellulose, hemicellulose, and pectin, with some cells also containing lignin. It is made of three main layers:

- (i) **Middle lamella is the** outermost layer; it's rich in pectin and connects adjacent plant cells, acting as a "glue" between them.
- (ii) **Primary cell wall is** found inside the middle lamella, it is a thin, flexible layer formed during cell growth. It is composed of cellulose microfibrils arranged in a network that provides tensile strength, with hemicellulose cross-linking the microfibrils and pectin embedded within the matrix.
- (iii) **Secondary cell wall** is a thick, rigid layer that forms inside the primary wall after the cell has stopped growing. It is not present in all plant cells but is common in those needing extra support. It can be several layers thick and is often reinforced with lignin, which adds strength and waterproofing.

(b) Compare the structures of plant cell wall and plasma membrane

Similarities of cell wall and cell membrane

- Both form protective barrier to internal contents of a cell
- Both regulate entry and exit from a cell
- Both enclose and contribute to the shape of the cell

Differences between cell wall and cell membrane

Cell wall	Cell membrane
Thick, rigid, and strong.	Thin, flexible, and dynamic (fluid mosaic model).
Made of Primarily cellulose (plants), chitin (fungi), peptidoglycan (bacteria).	Made of phospholipid bilayer with embedded proteins, carbohydrates, and cholesterol.
Found plants, fungi, bacteria, algae; absent in animal cells.	Found in all living cells
Fully permeable to small molecules	Selectively (or semi-) permeable, controlling passage of substances.
Generally metabolically inactive (though alive in some forms).	Metabolically active and alive; continuously synthesized.
Increases in thickness over the cell's life by depositing new material.	Maintains a relatively constant thickness throughout its lifespan.

(c) How is plant cell wall suited for functions

- Rigid to maintain shape
- Contain cellulose microfibril embedded in a matrix of other polysaccharides, forming a network that provides significant mechanical strength and prevents the cell from bursting under high internal pressure.
- It many contain lignin to provide exceptional rigidity, strength, and waterproofing, particularly in vascular tissues like xylem for water transport.
- Cutin and suberin form waxy, water-repellent layers (cuticle and cork) that reduce water loss and protect against environmental damage.
- The cell wall can be rapidly remodeled and reinforced at the site of infection by depositing additional materials (like callose or lignin) to halt pathogen penetration. Fragments of the cell wall itself (oligosaccharins) can also act as signaling molecules to trigger active plant defense responses.
- **Middle lamella** is pectin-rich layer effectively "cements" adjacent cells together, ensuring tissue integrity and cohesion in multicellular structures.
- The presence of small channels called plasmodesmata allows for direct, efficient communication and transport of water, nutrients, and signaling molecules between the cytoplasm of adjacent cells. The cell wall's structure accommodates these essential connections.
- The cell wall is porous allowing the free movement of water, minerals, and small nutrient molecules, while limiting the passage of larger, potentially harmful molecules.

68. (a) What is meant by the term cell organelle?

A **cell organelle** (or simply **organelle**) is a specialized, membrane-bound subunit or structure within a living cell that has one or more specific jobs to perform, much like the organs of a body

(b) Describe the fine structures of the following

(i) Golgi complex

It is composed of stacks of flattened structures that contain numerous vesicles, interconnecting tubules, and cisternae containing secretory granules,

(ii) Nucleus

A porous nuclear membrane encloses a nucleoplasm (gel-like substance) containing chromosomes and nucleolus, a dense, prominent, non-membrane-bound structure.

(iii) Mitochondrion

It is enclosed by a double membrane, the inner membrane is highly folded into numerous inward projections called **cristae**. It is filled with a matrix.

(c) How is the structure related to functioning in each of structures in (b) above.

Relationship of the structure of Golgi apparatus to its functions

- Has stacked Cisternae that hold processing enzymes
- The distinct polarity of the Golgi apparatus ensures an organized workflow and precise sorting
- The membrane-bound nature of the cisternae creates distinct environments within the Golgi for specialized activities
- Contain enzymes in its matrix for metabolic processes

Relationship of the structure of nucleus to its functions

- Nuclear membrane is a selective barrier for movement in and out of the cells
- Chromosomes store DNA/genetic material
- Nucleolus produce ribosome
- Matrix contain metabolic enzymes for replication and transcription

Relationship of the structure of mitochondrion to its functions

- Membrane is a selective barrier for movement in and out of the cells
- Membrane protects the inner content of the cell
- Inner membrane has stacked Cisternae that hold respiratory enzymes
- Matrix contain metabolic enzymes for replication and transcription

69. (a) Describe the functions of Golgi apparatus in animal cells

- **Modification of Proteins and Lipids:** The Golgi receives proteins and lipids from the endoplasmic reticulum (ER) and chemically modifies them. Common modifications include the addition or trimming of carbohydrate chains (glycosylation), and the addition of phosphate or sulfate groups.
- **Sorting and Packaging:** It acts as a sorting station, organizing modified molecules into specific transport vesicles. These vesicles are targeted to their correct final destinations within or outside the cell.
- **Secretion:** It packages materials destined for secretion outside the cell (such as hormones, enzymes, and antibodies) into secretory vesicles, which then release their contents via exocytosis.
- **Lysosome Formation:** In animal cells, the Golgi processes and packages digestive enzymes into vesicles that become functional **lysosomes**, the cell's waste disposal system.
- **Cell Wall Synthesis (in Plants):** In plant cells, the Golgi apparatus plays a critical role in synthesizing and transporting the complex polysaccharides (like pectin and hemicellulose) needed to build and maintain the plant's cell wall.
- **Acrosome Formation (in Animals):** It helps form the **acrosome**, the enzyme-filled cap on the head of sperm cells necessary for fertilization.

(b) Explain the role of lysosomes in animal cells

The main roles of lysosomes include:

- (i) **Intracellular Digestion:** Breaking down large biological molecules (proteins, lipids, carbohydrates, nucleic acids) into simpler components (amino acids, simple sugars, fatty acids, nucleotides) for the cell to reuse.
- (ii) **Phagocytosis (Defense):** Digesting foreign particles, such as bacteria, viruses, and cellular debris, that have been engulfed by immune cells like macrophages.
- (iii) **Autophagy (Recycling):** Breaking down and recycling the cell's own old, damaged, or non-functional organelles (like mitochondria or parts of the ER) and protein aggregates.
- (iv) **Waste Management:** Processing and eliminating indigestible waste materials from the cell via exocytosis.
- (v) **Immune Response:** Processing and presenting parts of foreign invaders (antigens) to other immune cells to trigger an immune response.
- (vi) **Programmed Cell Death (Apoptosis):** In specific regulated instances, the release of lysosomal enzymes into the cytoplasm can trigger the controlled self-destruction of the cell.

- (vii) **Nutrient Sensing:** Acting as signaling hubs that monitor the cell's nutrient and energy levels, coordinating metabolic responses.
- (viii) **Bone Remodeling:** In bone tissue, lysosomes help in the breakdown of bone matrix, a process essential for bone growth and repair.
- (ix) **Plasma Membrane Repair:** Assisting in the repair of damaged areas of the cell membrane by fusing with the membrane and releasing specific components.