1 Cell structure (12)

1.1 The microscope in cell studies

1. make temporary preparations of cellular material suitable for viewing with a light microscope

   - Place a drop of water or mounting medium on a slide.
   - Collect a small sample of the material to be viewed.
   - Transfer the sample to the drop on the slide.
   - Gently lower a coverslip onto the sample.
   - Place the slide on the microscope stage.
   - Start with low magnification, then increase to observe cells.
   - Record your observations.
   - Clean the slide and coverslip after use.

2. draw cells from microscope slides and photomicrographs
   - Observe cells, noting shapes and structures.
   - Lightly sketch cell outlines with a pencil.
   - Add details like organelles, using shading for contrast.
   - Label structures if identifiable.
   - Review and refine the drawing for accuracy.
   - Finalize by darkening lines and erasing guidelines.
   - Add annotations if necessary.
   - Repeat for other cells or structures.

3. calculate magnifications of images and actual sizes of specimens from drawings, photomicrographs and electron micrographs (scanning and transmission)

- Find the scale or magnification provided.
- Use the formula: Magnification = Image Size / Actual Size.
- If magnification is given, use Actual Size = Image Size / Magnification.
- Ensure units are consistent (e.g., micrometers).
- For electron micrographs, apply additional corrections if needed.
- Verify your calculations.
- Record and report your results.

4. use an eyepiece graticule and stage micrometer scale to make measurements anduse the appropriate units, millimetre (mm), micrometre (μm) and nanometre (nm)

- Calibrate the Microscope: Place the stage micrometer on the stage and focus on the scale using the lowest magnification. Note the number of eyepiece graticule units that correspond to a known distance on the stage micrometer (e.g., 1 mm = 100 eyepiece units).
- Measure the Object: Place the object on the stage and focus on it. Use the eyepiece graticule to measure the size of the object in eyepiece units.
- Calculate the Size: Use the calibration factor to convert the eyepiece units to the appropriate units (mm, μm, or nm). For example, if 1 mm on the stage micrometer corresponds to 100 eyepiece units, and you measure 20 eyepiece units, the size of the object would be 0.2 mm.
- Use Correct Units: Use the appropriate units based on the size of the object. For larger objects, use millimeters (mm); for smaller objects, use micrometers (μm); for very small objects, use nanometers (nm).
- Record and Report: Record your measurements and units accurately, andreport

them in your findings or reports.

5. define resolution and magnification and explain the differences between these terms, with reference to light microscopy and electron microscopy

    - Resolution: Ability to distinguish two points as separate. Limited by wavelength.
    - Magnification: Enlargement ratio of image to actual size. Achieved with lenses.
    - Light Microscopy: Resolution limited by visible light wavelength (400-700 nm).
    - Electron Microscopy: Higher resolution due to shorter electron wavelength (0.005 nm).

1.2 Cells as the basic units of living organisms

1. recognise organelles and other cell structures found in eukaryotic cells and outline their structures and functions, limited to:

·cell surface membrane

·Structure: Phospholipid bilayer with embedded proteins and cholesterol molecules.
·Function: Regulates the movement of substances in and out of the cell; provides cell-cell recognition and communication; maintains cell integrity and shape.

·nucleus, nuclear envelope and nucleolus

Nucleus:
·Structure: Surrounded by a double membrane called the nuclear envelope, which has nuclear pores for transport.
·Function: Contains genetic material (DNA) and controls cell activities such as growth, metabolism, and reproduction.

Nuclear Envelope:
·Structure: Double membrane with nuclear pores.
·Function: Regulates the movement of materials between the nucleus and cytoplasm.

Nucleolus:
·Structure: Dense region within the nucleus.
·Function: Site of ribosome assembly.

·rough endoplasmic reticulum

·Structure: Network of membrane-bound sacs and tubules with ribosomes attached to its surface.
·Function: Involved in protein synthesis, folding, and transport; plays a role in the synthesis of membrane proteins and proteins destined for secretion.

·smooth endoplasmic reticulum

·Structure: Network of membrane-bound tubules and vesicles lacking ribosomes on its surface.
·Function: Synthesizes lipids, including steroids

・Golgi body (Golgi apparatus or Golgi complex)

・Structure: Stack of flattened membrane-bound sacs (cisternae).

・Function: Modifies, sorts, and packages proteins and lipids from the endoplasmic reticulum for transport to other parts of the cell or for secretion outside the cell.

・mitochondria (including the presence of small circular DNA)

・Structure: Double membrane structure with inner folds called cristae; contains small circular DNA molecules.
・Function: Site of cellular respiration, where ATP (energy) is produced through aerobic metabolism.

・ribosomes (80S in the cytoplasm and 70S in chloroplasts and mitochondria)

・Structure: Made of ribosomal RNA (rRNA) and protein; two subunits: large (50S in prokaryotes, 60S in eukaryotes) and small (30S in prokaryotes, 40S in eukaryotes).
・Function: Protein synthesis; 80S in the cytoplasm (composed of 60S and 40S subunits in eukaryotes), 70S in chloroplasts and mitochondria (composed of 50S and 30S subunits).

・lysosomes

・Structure: Membrane-bound vesicles containing digestive enzymes.
・Function: Breaks down and recycles cellular waste, foreign substances, and damaged organelles.

・centrioles and microtubules

Centrioles

・Structure: Pair of cylindrical structures composed of microtubules

・Function: Organize the microtubules of the cytoskeleton during cell division and form the bases of cilia and flagella.

Microtubules

・Structure: Hollow tubes made of tubulin protein subunits arranged in a cylindrical shape.

・Function: Provide structural support for the cell, serve as tracks for intracellular transport, and are involved in cell division (forming the mitotic spindle) and cellular movement (cilia and flagella).

・Cilia

・Structure: Hair-like structures protruding from the cell surface, composed of microtubule bundles.
・Function: Beat in a coordinated fashion to move fluid, mucus, or other substances across the cell surface; also used for sensory functions in some cells.

・Microvilli

・Structure: Small, finger-like projections of the cell membrane containing actin filaments.
・Function: Increase the surface area of the cell membrane to aid in absorption and secretion; commonly found in cells involved in absorption, such as intestinal and kidney tubule cells.

・chloroplasts (including the presence of small circular DNA)

・Structure: Double membrane organelles containing chlorophyll; internal membranes called thylakoids are stacked into grana.
・Function: Site of photosynthesis, where light energy is converted into chemical energy (glucose); contains small circular DNA molecules.

・cell wall
・Structure: Rigid, outer layer made of cellulose (plants), chitin (fungi), or peptidoglycan (bacteria).
・Function: Provides structural support and protection; helps maintain cell shape; prevents excess water uptake.

·plasmodesmata

·Structure: Channels that traverse the cell walls of plant cells, connecting the cytoplasm of adjacent cells.

·Function: Facilitate communication and transport of molecules between plant cells, allowing for the exchange of nutrients, signaling molecules, and other substances.

·large permanent vacuole and tonoplast of plant cells

·**Vacuole**: Membrane-bound organelle containing cell sap (mostly water, enzymes, and ions).
·**Tonoplast**: Membrane surrounding the vacuole, separating its contents from the cytoplasm.
·Function: Stores water, sugars, ions, pigments, and waste products; maintains turgor pressure; facilitates plant growth and development.

2. describe and interpret photomicrographs, electron micrographs and drawings of typical plant and animal cells

·Cell Shape and Size: Note the overall shape and size of the cells. Plant cells are generally rectangular with a rigid cell wall, while animal cells are more rounded without a cell wall.

·Cellular Structures: Identify key organelles such as the nucleus, mitochondria, endoplasmic reticulum (ER), Golgi apparatus, and lysosomes (in animal cells), as well as chloroplasts and a large central vacuole (in plant cells).

·Nucleus: Look for a prominent nucleus in the center of the cell, surrounded by a nuclear envelope. The nucleus contains genetic material (chromatin) and a nucleolus.

·Cytoplasm: Observe the cytoplasm, which appears granular and contains various organelles.

·Endoplasmic Reticulum: Identify the rough endoplasmic reticulum (RER) by the presence of ribosomes on its surface. The smooth endoplasmic reticulum (SER) lacks ribosomes and appears smoother.

- Golgi Apparatus: Look for a stack of flattened membrane-bound sacs (cisternae) near the nucleus, involved in processing and packaging proteins and lipids.
- Mitochondria: Identify elongated structures with inner folded membranes (cristae) responsible for energy production (ATP synthesis).
- Lysosomes (in animal cells): Look for membrane-bound vesicles containing digestive enzymes, involved in breaking down waste materials.
- Chloroplasts and Large Vacuole (in plant cells): Identify chloroplasts containing chlorophyll for photosynthesis, and a large central vacuole for storage and turgor pressure maintenance.
- Cell Membrane: Observe the outer boundary of the cell, known as the cell membrane or plasma membrane, which regulates the movement of substances in and out of the cell.

3. compare the structure of typical plant and animal cells

Same Aspects:

- Both have a cell membrane, nucleus, mitochondria, endoplasmic reticulum, Golgi apparatus, and cytoplasm.
- Both use ribosomes for protein synthesis.
- Both store genetic material in the nucleus.

Different Aspects:

- Plant cells have a cell wall made of cellulose, while animal cells do not.
- Plant cells have chloroplasts for photosynthesis, which are absent in animal cells.
- Plant cells have a large central vacuole for storage and support, while animal cells have smaller vacuoles or none.
- Plant cells have plasmodesmata for cell-cell communication, which are absent in animal cells.
- Animal cells have lysosomes for intracellular digestion, while plant cells have fewer lysosomes or none

4. state that cells use ATP from respiration for energy-requiring processes

- Cells use ATP (adenosine triphosphate) from respiration for energy-requiring processes.

5. outline key structural features of a prokaryotic cell as found in a typical bacterium, including:

- Unicellular
- Prokaryotic cells, such as those found in bacteria, are single-celled organisms.

- generally 1–5 μm diameter

- Size: Prokaryotic cells typically range from 1 to 5 μm in diameter.

·peptidoglycan cell walls

Peptidoglycan Cell Wall: A structural feature of bacterial cells, peptidoglycan is a polymer consisting of sugars and amino acids that forms a mesh-like layer outside the cell membrane, providing structural support and protection.

·circular DNA

·Prokaryotic cells, including bacteria, have a single, circular DNA molecule located in the nucleoid region, which contains the genetic information essential for the cell's function and reproduction.

·70S ribosomes

Prokaryotic cells contain ribosomes that are smaller (70S) compared to eukaryotic cells (80S). Ribosomes are the cellular machinery responsible for protein synthesis.

·absence of organelles surrounded by double membranes

·Unlike eukaryotic cells, prokaryotic cells lack membrane-bound organelles such as mitochondria, chloroplasts, and nuclei.

5. compare the structure of a prokaryotic cell as found in a typical bacterium with the structures of typical eukaryotic cells in plants and animals

·Same Aspects:

·Both have a plasma membrane that regulates the passage of substances in and out of the cell.

·Both contain ribosomes for protein synthesis.

·Both have genetic material (DNA) that carries the instructions for cellular functions.

·Different Aspects:

·Eukaryotic cells have a nucleus, while prokaryotic cells have a nucleoid region.

- Eukaryotic cells have membrane-bound organelles, such as mitochondria and endoplasmic reticulum, while prokaryotic cells do not.
- Eukaryotic cells (in plants) have a cell wall made of cellulose, while prokaryotic cells have a cell wall made of peptidoglycan.
- Eukaryotic cells undergo mitosis or meiosis for cell division, while prokaryotic cells undergo binary fission.
- Eukaryotic cells are generally larger and more complex than prokaryotic cells.

6. state that all viruses are non-cellular structures with a nucleic acid core (either DNA or RNA) and a capsid made of protein, and that some viruses have an outer envelope made of phospholipids

·All viruses consist of genetic material, either DNA or RNA, which contains the instructions for making new virus particles. This genetic material is surrounded by a protein coat called a capsid, which protects the genetic material and helps the virus infect host cells.

·Some viruses have an additional outer envelope, which is a lipid membrane derived from the host cell membrane. This envelope contains viral proteins that help the virus attach to and enter host cells.

2 Biological molecules (23)

2.1 Testing for biological molecules

1. describe and carry out the Benedict' s test for reducing sugars, the iodine test for starch, the emulsion test for lipids and the biuret test for proteins

Benedict' s Test for Reducing Sugars:

- Principle: Detects the presence of reducing sugars (e.g., glucose) that can reduce Cu^2+ ions to Cu^+ ions, forming a brick-red precipitate.
- Procedure:
- Prepare a sample solution (e.g., glucose solution).
- Add an equal volume of Benedict's reagent (copper(II) sulfate solution with sodium citrate) to the sample.
- Heat the mixture in a boiling water bath for a few minutes.
- Observe the color change. A green, yellow, orange, or red precipitate indicates the presence of reducing sugars.

Iodine Test for Starch:

- Principle: Starch forms a blue-black complex with iodine.
- Procedure:
- Prepare a sample solution (e.g., starch solution).
- Add a few drops of iodine solution (iodine dissolved in potassium iodide) to the sample.
- Observe the color change. A blue-black color indicates the presence of starch.

Emulsion Test for Lipids:

- Principle: Lipids are hydrophobic and form an emulsion when shaken with water.

- Procedure:
- Prepare a sample solution (e.g., lipid solution in ethanol).
- Add the sample to water in a test tube and shake vigorously.
- Observe the formation of a milky emulsion. More milky appearance indicates a higher lipid content.

Biuret Test for Proteins:

- Principle: Proteins react with copper(II) ions in an alkaline solution to form a violet-colored complex.
- Procedure:
- Prepare a sample solution (e.g., protein solution).
- Add an equal volume of Biuret reagent (sodium hydroxide and copper(II) sulfate solution) to the sample.
- Mix gently and observe the color change. A violet color indicates the presence of proteins.

2. describe and carry out a test to identify the presence of non-reducing sugars, using acid hydrolysis and Benedict' s solution

Prepare Test Sample:

Prepare a test solution containing the non-reducing sugar (e.g., sucrose).

Perform Acid Hydrolysis:

In a test tube, add 2 mL of the test solution.

Add a few drops of dilute hydrochloric acid (HCl) to the test tube.

Place the test tube in a boiling water bath for a few minutes to hydrolyze the non-reducing sugar into reducing sugars (glucose and fructose).

Neutralize the Solution:

Add a few drops of sodium hydroxide (NaOH) solution to neutralize the acid.

Check the pH using pH paper to ensure the solution is neutral (pH 7).

Perform Benedict's Test:

Add 2 mL of Benedict's reagent to the test tube.

Heat the mixture in a boiling water bath for a few minutes.

Observe Color Change:

After heating, observe the color change in the test tube.

A color change from blue (no reducing sugar) to green, yellow, orange, or red indicates the presence of reducing sugars produced from the hydrolysis of the non-reducing sugar.

2.2 Carbohydrates and lipids

1. describe and draw the ring forms of α-glucose and β-glucose

- In their ring forms, α-glucose and β-glucose both form a six-membered ring structure. The ring is created when a hydroxyl group on one carbon atom reacts with the carbonyl carbon atom, forming a closed ring structure.

- The distinguishing feature between α-glucose and β-glucose lies in the position of the hydroxyl group on the first carbon atom (C1) relative to the ring structure:

- In α-glucose, the hydroxyl group on C1 is positioned in a way that points above the plane of the ring.
- In β-glucose, the hydroxyl group on C1 is oriented to project outside the plane of the ring.

2. define the terms

- Monomer: A small molecule that can join together with other monomers to form a larger polymer molecule. Monomers are the building blocks of polymers.

- Polymer: A large molecule composed of many repeated subunits (monomers) bonded together. Polymers can be natural or synthetic and have a wide range of properties and uses.

- Macromolecule: A large molecule, such as a polymer or complex protein, typically composed of thousands of atoms. Macromolecules are essential for the structure and function of living organisms.

- Monosaccharide: The simplest form of carbohydrate, consisting of a single sugar molecule. Examples include glucose, fructose, and galactose. Monosaccharides are the building blocks of more complex carbohydrates.

- Disaccharide: A carbohydrate molecule composed of two monosaccharide units joined together by a glycosidic bond. Common examples include sucrose (glucose + fructose), lactose (glucose + galactose), and maltose (glucose + glucose).

- Polysaccharide: A complex carbohydrate molecule composed of multiple monosaccharide units joined together in long chains. Polysaccharides serve as energy storage molecules (e.g., starch and glycogen) and structural components (e.g., cellulose) in living organisms.

3. state the role of covalent bonds in joining smaller molecules together to form polymers.

   Covalent bonds play a crucial role in joining smaller molecules together to form polymers. These bonds involve the sharing of electrons between atoms, creating strong and stable connections between the monomer units.

   In the process of polymerization, monomers undergo a chemical reaction that forms covalent bonds between their individual units. This reaction typically involves the loss of a small molecule, such as water (dehydration synthesis) or another functional group, to form the new bond.

   The resulting polymer chain is held together by a series of covalent bonds, which provide structural integrity and stability to the molecule. This allows polymers to have distinct properties and functions that are different from those of their individual monomer units.

4. state that glucose, fructose and maltose are reducing sugars and that sucrose is a non-reducing sugar

5. describe the formation of a glycosidic bond by condensation, with reference to disaccharides, including sucrose, and polysaccharides

Glycosidic bonds are formed through a condensation reaction, where two hydroxyl groups (-OH) on different monosaccharides combine, releasing a water molecule. This reaction forms an oxygen bridge (-O-) between the two carbon atoms, creating the glycosidic bond.

In sucrose, a disaccharide composed of glucose and fructose, the glycosidic bond forms between the anomeric carbon (C1) of glucose and the hydroxyl group on carbon 2 (C2) of fructose. This linkage is called an α,β-1,2-glycosidic bond.

In polysaccharides like starch and glycogen, multiple glucose molecules are linked by glycosidic bonds. The specific type of glycosidic bond and arrangement of glucose units determine the structure and properties of the polysaccharide.

6. describe the breakage of a glycosidic bond in polysaccharides and disaccharides by hydrolysis, with reference to the non-reducing sugar test

Hydrolysis is the process of breaking a glycosidic bond in polysaccharides and disaccharides by the addition of water. This process involves the following steps:

Addition of Water: Water is added to the glycosidic bond, causing it to break. The oxygen atom in the glycosidic bond gains a hydrogen ion (H+) from water, while the other part of the broken bond gains a hydroxyl group (-OH).

Formation of Monosaccharides: The glycosidic bond is cleaved, resulting in the formation of two monosaccharide units. In the case of disaccharides, such as sucrose, glucose, and fructose are produced.

Non-Reducing Sugar Test:

- In the non-reducing sugar test, a small amount of the sugar (e.g., sucrose) is heated with dilute hydrochloric acid (HCl) to hydrolyze it into its monosaccharide components (glucose and fructose).
- After hydrolysis, the solution is neutralized with sodium hydroxide (NaOH) to make it slightly alkaline.
- The resulting solution is then tested with Benedict's reagent to detect the presence of reducing sugars (glucose and fructose), which can reduce the copper ions in the reagent, forming a colored precipitate.
- If the original sugar was a non-reducing sugar (e.g., sucrose), no color change will occur, indicating the absence of reducing sugars.

7. describe the molecular structure of the polysaccharides starch (amylose and amylopectin) and glycogen and relate their structures to their functions in living organisms

Starch:

Amylose: Consists of unbranched chains of α-glucose units linked by α-1,4-glycosidic bonds. It has a helical structure.

Amylopectin: Contains α-1,4-glycosidic bonds like amylose but also has occasional α-1,6-glycosidic bonds, creating branch points. It is more branched and has a larger molecular weight than amylose.

Glycogen:

Similar to amylopectin but more highly branched, with frequent α-1,6-glycosidic bonds, creating a highly branched structure.

Glycogen is the main storage polysaccharide in animals, found in liver and muscle cells.

Starch (Amylose and Amylopectin):

Storage: Efficiently stores glucose in plants for energy.

Accessibility: Amylose is easily accessible for quick energy release.

Controlled Release: Amylopectin's branching allows for gradual energy release.

Glycogen:

Rapid Energy: Highly branched for quick glucose release.

Efficient Storage: Maximizes glucose storage in animals.

Regulation: Metabolism is tightly regulated for energy balance.

8. describe the molecular structure of the polysaccharide cellulose and outline how the arrangement of cellulose molecules contributes to the function of plant cell walls

Cellulose Structure:

·Consists of β-glucose monomers linked by β-1,4-glycosidic bonds.

·Forms long, straight chains with hydrogen bonds between adjacent chains.

·Chains are arranged in parallel and form microfibrils, which are bundled together to form cellulose fibers.

Function in Plant Cell Walls:

·Strength: Provides strength and rigidity.
·Permeability: Allows water and nutrient passage.
·Protection: Protects against pathogens and damage.
·Support: Maintains cell and tissue structure.

9. state that triglycerides are non-polar hydrophobic molecules and describe the molecular structure of triglycerides with reference to fatty acids (saturated and unsaturated), glycerol and the formation of ester bonds

Triglycerides are non-polar hydrophobic molecules consisting of three fatty acid chains esterified to a glycerol molecule.

Molecular Structure:

Fatty Acids: Long hydrocarbon chains with a carboxyl group (-COOH) at one end.

Saturated: Have no double bonds between carbon atoms, resulting in a straight chain.

Unsaturated: Contain one or more double bonds, causing kinks in the chain.

Glycerol: A three-carbon alcohol with a hydroxyl group (-OH) attached to each carbon.

Formation of Ester Bonds:

Each fatty acid chain undergoes esterification with a hydroxyl group of glycerol.

The reaction releases three water molecules, one for each ester bond formed.

This process results in the formation of a triglyceride molecule, with three fatty acid chains attached to the glycerol backbone through ester bonds.

10. relate the molecular structure of triglycerides to their functions in living organisms

- Energy Storage: Triglycerides serve as a highly efficient form of energy storage due to their high energy content per gram.
- Insulation: In animals, adipose tissue rich in triglycerides acts as an insulating layer, helping to maintain body temperature.
- Protection: Triglycerides cushion and protect vital organs from mechanical shock.
- Metabolic Water Reserve: During metabolism, triglycerides can be hydrolyzed to release water, which is important in water-stressed environments.
- Buoyancy: In marine animals, triglycerides stored in the liver or adipose tissue help provide buoyancy.

11. describe the molecular structure of phospholipids with reference to their hydrophilic (polar) phosphate heads and hydrophobic (non-polar) fatty acid tails

Molecular Structure:

Hydrophilic Head: Consists of a phosphate group ($-PO_4$) attached to a glycerol molecule. The phosphate group is polar and hydrophilic, meaning it interacts well with water.

Hydrophobic Tails: Two fatty acid chains attached to the glycerol backbone. These chains are non-polar and hydrophobic, meaning they do not interact well with water.

2.3 Proteins

1. describe and draw the general structure of an amino acid and the formation and breakage of a peptide bond

Amino acids are organic molecules composed of an amino group ($-NH_2$), a carboxyl group (-COOH), a hydrogen atom (H), and a variable side chain (R group) attached to a central carbon atom (alpha carbon, Cα).

Formation of Peptide Bond:

A peptide bond forms between the carboxyl group of one amino acid and the amino group of another amino acid.

During the formation of a peptide bond, a molecule of water is released in a condensation reaction.

The carbon atom from the carboxyl group of one amino acid and the nitrogen atom from the amino group of another amino acid bond together, forming a peptide bond.

Breakage of Peptide Bond:

Peptide bonds can be broken through hydrolysis, which involves the addition of a water molecule.

In hydrolysis, the water molecule is split into a hydrogen ion (H+) and a hydroxide ion (OH-).

The hydroxide ion (OH-) binds to the carbon atom, and the hydrogen ion (H+) binds to the nitrogen atom, breaking the peptide bond and separating the amino acids.

2. explain the meaning of the terms primary structure, secondary structure, tertiary structure and quaternary structure of proteins

Primary Structure:

The primary structure of a protein refers to the chain of amino acids connected by peptide bond.

Secondary Structure:

Secondary structure refers to the local folding patterns within a protein chain.

The two main types of secondary structure are alpha helices and beta sheets, which are stabilized by hydrogen bonds between the backbone atoms of amino acids.

These structures give the protein its overall shape and stability.

Tertiary Structure:

Tertiary structure refers to the three-dimensional arrangement of the entire polypeptide chain.

It is stabilized by a variety of interactions, including hydrogen bonds, disulfide bonds, hydrophobic interactions, and ionic bonds.

The tertiary structure determines the overall shape and function of the protein.

Quaternary Structure:

Quaternary structure refers to the arrangement of multiple polypeptide chains (subunits) in a multi-subunit protein.

Proteins with quaternary structure have more than one polypeptide chain, each with its own tertiary structure, that come together to form a functional protein complex.

The arrangement of these subunits is critical for the function of many proteins, such as enzymes and antibodies.

3. describe the types of interaction that hold protein molecules in shape:

Hydrophobic Interactions:

Occur between non-polar molecules or regions of molecules in an aqueous environment.

Non-polar amino acid side chains tend to cluster together away from water, stabilizing protein structures.

Hydrogen Bonding:

Formed between hydrogen atoms covalently bonded to electronegative atoms (e.g., oxygen or nitrogen) and other electronegative atoms.

Commonly occurs between backbone atoms in protein secondary structures (e.g., between amino and carbonyl groups in alpha helices and beta sheets).

Ionic Bonding:

Formed between charged groups on amino acid side chains (e.g., between positively charged amino groups and negatively charged carboxyl groups).

Helps stabilize protein structures, especially in environments with varying pH.

Covalent Bonding:

Includes disulfide bonds, which form between two cysteine residues when their sulfhydryl groups (-SH) oxidize to form a covalent S-S bond.

Disulfide bonds are important for stabilizing the tertiary and quaternary structures of proteins.

4. state that globular proteins are generally soluble and have physiological roles and fibrous proteins are generally insoluble and have structural roles

Globular proteins are generally soluble in water and have physiological roles. They are often enzymes, hormones, or antibodies, and they typically have compact, rounded shapes.

Fibrous proteins, on the other hand, are generally insoluble in water and have structural roles. Examples include collagen, which provides strength to connective tissues, and keratin, which forms hair, nails, and the outer layer of skin. Fibrous proteins are characterized by their long, elongated shapes.

5. describe the structure of a molecule of hemoglobin as an example of a globular protein, including the formation of its quaternary structure from two alpha (α) chains (α–globin), two beta (β) chains (β–globin) and a haem group

Structure of Hemoglobin:

- Alpha (α) Chains: Each alpha chain is composed of 141 amino acid residues.
- Beta (β) Chains: Each beta chain is composed of 146 amino acid residues.
- Heme Group: Each subunit of hemoglobin contains a heme group, which consists of an iron ion (Fe^{2+}) coordinated to a porphyrin ring.
- Quaternary Structure: The four subunits come together to form a quaternary structure through non-covalent interactions, including hydrogen bonds, hydrophobic interactions, and salt bridges.

Quaternary Structure Formation:

The quaternary structure of hemoglobin is stabilized by interactions between the alpha and beta chains, as well as interactions between the heme groups and the

protein chains.

The folding and assembly of the four subunits are critical for the proper functioning of hemoglobin as an oxygen carrier in the blood.

6. relate the structure of haemoglobin to its function, including the importance of iron in the haem group

Hemoglobin's structure is crucial for its function as an oxygen carrier. The heme group, which contains iron, binds oxygen in a reversible manner. Each hemoglobin molecule has four heme groups, allowing it to carry up to four oxygen molecules. The quaternary structure of hemoglobin, formed by two alpha and two beta subunits, creates a pocket where the heme groups are located. This structure allows hemoglobin to undergo conformational changes that enhance its ability to bind and release oxygen. Hemoglobin's cooperativity enables it to load and unload oxygen efficiently in different tissues. Additionally, hemoglobin acts as a buffer for hydrogen ions and carbon dioxide, helping to regulate the pH of the blood.

7. describe the structure of a molecule of collagen as an example of a fibrous protein, and the arrangement of collagen molecules to form collagen fibres

Structure of Collagen Molecule:

Collagen is a fibrous protein made up of three polypeptide chains, known as alpha chains, that are twisted together in a helical conformation to form a triple helix.

Each alpha chain is composed of a repeating amino acid sequence, with glycine occurring every third residue.

The triple helix structure of collagen is stabilized by hydrogen bonds between the amino acid residues in adjacent chains.

Arrangement of Collagen Molecules to Form Collagen Fibers:

Collagen molecules align themselves in a staggered array, with the ends of the molecules overlapping slightly.

These aligned collagen molecules then undergo cross-linking, which involves the formation of covalent bonds between certain amino acids (e.g., lysine and hydroxylysine residues) in adjacent collagen molecules.

The cross-linked collagen molecules aggregate to form collagen fibrils, which further aggregate to form collagen fibers.

Collagen fibers are strong, flexible, and resistant to stretching, making them ideal for providing structural support in tissues such as skin, tendons, and bones.

8. relate the structures of collagen molecules and collagen fibres to their function

- Structural Support: Collagen provides structural support to tissues such as skin, tendons, ligaments, and bones, helping them resist tensile forces.
- Flexibility: The staggered arrangement of collagen molecules and their cross-linking allow collagen fibers to be flexible and resistant to stretching.
- Wound Healing: Collagen plays a crucial role in wound healing, providing a scaffold for cell migration and tissue regeneration.
- Organ Function: Collagen is essential for the structure and function of organs such as the skin, blood vessels, and organs in the digestive system.

2.4 Water

1. explain how hydrogen bonding occurs between water molecules and relate the properties of water to its roles in living organisms, limited to solvent action, high specific heat capacity and latent heat of vaporization

Solvent Action:

Water is known as the universal solvent because of its ability to dissolve a wide range of substances due to its polar nature.

This property is essential for biological processes, such as the dissolution of nutrients and waste products in cells and the transport of substances in the bloodstream.

High Specific Heat Capacity:

Water has a high specific heat capacity, which means it can absorb a large amount of heat energy with only a small increase in temperature.

This property helps organisms regulate their internal temperature and prevents abrupt changes in temperature, providing a stable environment for biological

processes.

Latent Heat of Vaporization:

Water has a high latent heat of vaporization, which means it requires a significant amount of heat energy to change from a liquid to a gas.

This property is important for cooling mechanisms in organisms, such as sweating in humans, where heat is absorbed from the body to evaporate water from the skin, helping to maintain body temperature.

3 Enzymes (8)

3.1 Mode of action of enzymes

1. state that enzymes are globular proteins that catalyse reactions inside cells (intracellular enzymes) or are secreted to catalyse reactions outside cells (extracellular enzymes)

2. explain the mode of action of enzymes in terms of an active site, enzyme–substrate complex, lowering of activation energy and enzyme specificity, including the lock-and-key hypothesis and the induced-fit hypothesis

Lock-and-Key Hypothesis:

The lock-and-key hypothesis suggests that the active site of an enzyme is rigid and has a fixed shape that is complementary to the substrate, similar to a key fitting into a lock.

According to this hypothesis, the substrate fits into the active site like a key into a lock, and the enzyme does not change its shape significantly upon binding.

Induced-Fit Hypothesis:

The induced-fit hypothesis suggests that the active site of an enzyme is flexible and can change its shape slightly to accommodate the substrate.

When the substrate binds, the enzyme undergoes a conformational change to form a more precise fit with the substrate.

This hypothesis implies that the binding of the substrate induces a change in the enzyme's shape, leading to optimal catalytic activity.

3. investigate the progress of enzyme-catalysed reactions by measuring rates of formation of products using catalase and rates of disappearance of substrate using amylase

Catalase (measuring rates of formation of products):

Catalase catalyzes the breakdown of hydrogen peroxide (H_2O_2) into water (H_2O) and oxygen gas (O_2).

To measure the rate of this reaction, you can collect the oxygen gas produced and measure its volume over time using a gas syringe or a water displacement method.

Plotting the volume of oxygen gas produced against time gives you a graph from which you can calculate the rate of the reaction.

Amylase (measuring rates of disappearance of substrate):

Amylase catalyzes the hydrolysis of starch into smaller carbohydrate molecules such as maltose.

To measure the rate of this reaction, you can use a colorimetric assay with iodine solution.

As the starch is broken down into smaller molecules, the iodine solution will change from blue-black to a lighter color due to the formation of iodine-starch complexes.

By measuring the absorbance of the solution at a specific wavelength using a spectrophotometer over time, you can determine the rate of disappearance of the starch substrate.

4. outline the use of a colorimeter for measuring the progress of enzyme-catalysed reactions that involve colour changes

Principle:

A colorimeter measures absorbance of light by a solution.

Color changes in the reaction cause changes in absorbance.

Setup:

Prepare reaction mixture and start the reaction.

Take samples at intervals and transfer to cuvettes.

Place cuvettes in the colorimeter.

Calibration:

Calibrate using a blank sample to set absorbance to zero.

Measurement:

Measure absorbance of samples at appropriate wavelength.

Record absorbance and time elapsed.

Analysis:

Plot absorbance vs. time to track reaction progress.

Rate of reaction can be determined from the slope.

Example:

Monitor formation of colored products in enzyme-catalyzed reactions.

Absorbance changes as reaction progresses, allowing quantification of reaction rate.

3.2 Factors that affect enzyme action

1. investigate and explain the effects of the following factors on the rate of enzyme-catalysed reactions:

Effect of Temperature on Enzyme-Catalyzed Reactions:

- Low Temperatures: At low temperatures, enzyme activity is low as the molecules have less kinetic energy and move more slowly, leading to fewer collisions between enzymes and substrates.
- Optimum Temperature: Enzymes have an optimum temperature at which they function best. At this temperature, the rate of enzyme-catalyzed reactions is at its highest.
- High Temperatures: At high temperatures, enzyme activity decreases due to denaturation, where the enzyme's structure is disrupted, leading to loss of function.

Effect of pH on Enzyme-Catalyzed Reactions:

- Enzymes have an optimal pH at which they function best. Deviation from this pH can lead to a decrease in enzyme activity.
- pH affects the charge of amino acid side chains in the active site of enzymes, which can alter the enzyme's ability to bind to the substrate.
- Buffer solutions are used to maintain a constant pH and study the effect of pH on enzyme activity.

Effect of Enzyme Concentration:

- Increasing enzyme concentration generally increases the rate of reaction, as more enzyme molecules are available to catalyze the conversion of substrate to product.
- However, at a certain point, adding more enzyme will not further increase the rate, as all substrate molecules are already bound to enzyme molecules (enzyme saturation).

Effect of Substrate Concentration:

- Increasing substrate concentration generally increases the rate of reaction, as more substrate molecules are available for the enzyme to bind to and convert to product.
- However, at a certain point, adding more substrate will not further increase the rate, as all enzyme molecules are already bound to substrate molecules (enzyme saturation).

Effect of Inhibitor Concentration:

- Inhibitors are molecules that bind to enzymes and reduce their activity.
- Competitive inhibitors compete with the substrate for binding to the active site, while non-competitive inhibitors bind to a different site on the enzyme, causing a conformational change that reduces the enzyme's activity.
- Increasing inhibitor concentration will generally decrease the rate of reaction, as more inhibitor molecules are available to bind to the enzyme and reduce its activity.

2. explain that the maximum rate of reaction (V_{max}) is used to derive the Michaelis–Menten constant (K_m), which is used to compare the affinity of different enzymes fortheir substrates

   The maximum rate of reaction (Vmax) is used to derive the Michaelis-Menten constant (Km), which is used to compare the affinity of different enzymes for their substrates. Vmax is the maximum rate at which an enzyme can catalyze a reaction when all enzyme active sites are saturated with substrate. Km is the substrate concentration at which the reaction rate is half of Vmax. A lower Km indicates a higher affinity of the enzyme for its substrate.

3. explain the effects of reversible inhibit.

   Reversible inhibition occurs when an inhibitor binds to an enzyme and can later dissociate from it, allowing the enzyme to regain its activity. There are two main types of reversible inhibition: competitive and non-competitive.

   Competitive Inhibition:

   - In competitive inhibition, the inhibitor binds to the active site of the enzyme, preventing the substrate from binding.
   - This type of inhibition can be overcome by increasing the substrate concentration, as this increases the chances of substrate binding before the inhibitor.
   - The inhibitor and substrate compete for the active site, hence the name "competitive" inhibition.

   Non-Competitive Inhibition:

   - In non-competitive inhibition, the inhibitor binds to a site on the enzyme other than the active site, called the allosteric site.
   - This binding causes a conformational change in the enzyme, making the active site less effective at catalyzing the reaction.
   - Increasing substrate concentration cannot overcome non-competitive inhibition, as the inhibitor does not compete with the substrate for the active site.

4. investigate the difference in activity between an enzyme immobilised in alginate and the same enzyme free in solution, and state the advantages of using immobilised enzymes.

Difference in Activity:

- Immobilizing an enzyme in alginate can affect its activity compared to the same enzyme free in solution.
- The immobilization process may alter the enzyme's microenvironment, affecting its conformation and therefore its activity.
- However, immobilization can also stabilize the enzyme, making it more resistant to denaturation and extending its lifespan.

Advantages of Using Immobilized Enzymes:

Reusability: Immobilized enzymes can be reused multiple times, reducing the need for frequent enzyme replenishment.

Operational Stability: Immobilized enzymes often exhibit greater stability under a variety of conditions (pH, temperature, etc.) compared to free enzymes.

Easy Separation: Immobilized enzymes can be easily separated from the reaction mixture, simplifying downstream processing.

Enhanced Control: Immobilization allows for better control of enzyme concentration and activity in a reaction.

Improved Product Purity: Immobilized enzymes can lead to higher product purity by reducing the risk of enzyme contamination in the final product.

Cost-Effectiveness: While the initial immobilization process may incur additional costs, the ability to reuse immobilized enzymes can lead to cost savings in the long run.

4 . Cell membranes and transport (10)

4.1 Fluid mosaic membranes

1. describe the fluid mosaic model of membrane structure with reference to the hydrophobic and hydrophilic interactions that account for the formation of the phospholipid bilayer and the arrangement of proteins

   The fluid mosaic model describes cell membranes as a dynamic structure composed of a lipid bilayer with embedded proteins. The hydrophobic interactions between the fatty acid tails of phospholipids drive the formation of the bilayer, with hydrophilic heads facing outward and inward toward water. Proteins, both integral and peripheral, are embedded or attached to the membrane, performing various functions. Cholesterol helps regulate membrane fluidity. This model emphasizes the dynamic nature of membranes, with molecules constantly moving and interacting.

2. describe the arrangement of cholesterol, glycolipids and glycoproteins in cell surfacemembranes

   Cholesterol: Cholesterol is interspersed within the phospholipid bilayer. Its hydroxyl group interacts with the polar head groups of phospholipids, while its hydrophobic tail interacts with the fatty acid tails of phospholipids. Cholesterol helps regulate membrane fluidity by preventing the phospholipid tails from packing too closely together (which would decrease fluidity) or too far apart (which would increase fluidity).

   Glycolipids: Glycolipids are located in the outer leaflet of the membrane, with their carbohydrate portions extending into the extracellular space. The hydrophobic portion of glycolipids integrates into the lipid bilayer, while the hydrophilic carbohydrate portion faces outward, where it can interact with other cells or molecules. Glycolipids are involved in cell recognition and cell signaling processes.

Glycoproteins: Glycoproteins are integral membrane proteins with carbohydrate chains attached to their extracellular domains. These proteins are embedded within the lipid bilayer, with their hydrophobic regions interacting with the lipid tails of phospholipids. The carbohydrate chains extend into the extracellular space, where they can participate in cell-cell recognition, signaling, and immune responses.

3. describe the roles of phospholipids, cholesterol, glycolipids, proteins and glycoproteins in cell surface membranes, with reference to stability, fluidity, permeability, transport (carrier proteins and channel proteins), cell signalling (cell surface receptors) and cell recognition (cell surface antigens – see11.1.2)

Phospholipids: Form the basic structure of the membrane, providing a barrier that separates the inside and outside of the cell. They contribute to membrane fluidity and flexibility.

Cholesterol: Regulates membrane fluidity by preventing phospholipids from packing too closely together (which would decrease fluidity) or too far apart (which would increase fluidity). It also stabilizes the membrane.

Glycolipids: Located in the outer layer of the membrane, they help maintain stability and play a role in cell recognition.

Proteins:

Transport Proteins (Carrier and Channel Proteins): Regulate the movement of molecules across the membrane, facilitating the transport of ions, nutrients, and waste products.

Cell Surface Receptors: Bind to specific molecules outside the cell and initiate a cellular response, such as cell signaling pathways.

Enzymes: Catalyze specific chemical reactions at the cell surface.

Structural Proteins: Help maintain the shape of the cell and stabilize the membrane.

Glycoproteins: Involved in cell recognition and communication. They can act as cell surface antigens, which are important for immune responses and self-recognition.

4. outline the main stages in the process of cell signalling leading to specific responses:

·**Secretion of Specific Chemicals (Ligands) from Cells**:

·Cells release signaling molecules, known as ligands, in response to internal or external stimuli.

·Ligands can be hormones, neurotransmitters, growth factors, or cytokines, among others.

·**Transport of Ligands to Target Cells:**

·Ligands travel through the extracellular fluid to reach target cells.

·Some ligands may be released into the bloodstream for systemic effects, while others act locally.

·**Binding of Ligands to Cell Surface Receptors on Target Cells:**

·Ligands bind to specific receptors on the surface of target cells.

·Receptors are often proteins that undergo conformational changes upon ligand binding.

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第四章

4.2 Movement into and out of cells

1. describe and explain the processes of ：

Simple Diffusion:

Description: The passive movement of molecules from an area of higher concentration to an area of lower concentration across a semipermeable membrane.

Explanation: This occurs due to the random motion of molecules. No energy is required, and the process continues until equilibrium is reached.

Facilitated Diffusion:

Description: Similar to simple diffusion but requires specific carrier proteins or channel proteins to facilitate the movement of molecules across the membrane.

Explanation: Molecules move down their concentration gradient, and the rate of diffusion is limited by the number of available transport proteins.

Osmosis:

Description: The diffusion of water molecules across a semipermeable membrane from an area of lower solute concentration to an area of higher solute concentration.

Explanation: Water moves to equalize the concentration of solutes on both sides of the membrane, balancing the osmotic pressure.

Active Transport:

Description: The movement of molecules against their concentration gradient, requiring energy in the form of ATP.

Explanation: This process is facilitated by specific carrier proteins (pumps) that bind to the molecule to be transported and use ATP to change shape and move the molecule across the membrane.

Endocytosis:

Description: The process by which cells engulf large molecules, particles, or other cells by wrapping the cell membrane around the material to form a vesicle.

Explanation: There are two main types: phagocytosis (cell eating) and pinocytosis (cell drinking), both of which require energy.

Exocytosis:

Description: The process by which cells expel waste products or secrete substances by fusing a vesicle containing the material with the cell membrane, releasing its contents outside the cell.

Explanation: This process is also energy-dependent and is used for various purposes, such as secretion of hormones, neurotransmitters, or enzymes.

2. investigate simple diffusion and osmosis using plant tissue and non-living materials,including dialysis (Visking) tubing and agar

Materials Needed:

Plant tissue (e.g., potato or beetroot slices)

Dialysis (Visking) tubing or agar

Solutions of different sucrose concentrations

Water

Beakers

Knife and cutting board

Procedure:

Prepare plant tissue slices and dialysis tubing.

Place plant tissue in sucrose solutions, observe changes.

Place tubing in water and then in sucrose solution, observe changes.

Observations and Analysis:

Record changes in plant tissue and tubing.

Compare rates of diffusion and osmosis.

Conclusion:

Discuss findings on diffusion and osmosis in plants.

3. illustrate the principle that surface area to volume ratios decrease with increasing size by calculating surface areas and volumes of simple 3-D shapes (as shown in theMathematical requirements)

Cube:

Side length (s) = 1 unit (for simplicity)

Surface Area (SA) = 6s^2

Volume (V) = s^3

For a cube with side length 1 unit:

Surface Area = 6(1)^2 = 6 units^2

Volume = (1)^3 = 1 unit^3

Surface Area to Volume Ratio = 6/1 = 6 units^-1

Sphere:

Radius (r) = 1 unit (for simplicity)

Surface Area (SA) = 4πr^2

Volume (V) = (4/3)πr^3

For a sphere with radius 1 unit:

Surface Area = 4π(1)^2 ≈ 12.57 units^2

Volume = (4/3)π(1)^3 ≈ 4.19 units^3

Surface Area to Volume Ratio ≈ 12.57/4.19 ≈ 3 units^-1

Cylinder:

Radius (r) = 1 unit (for simplicity)

Height (h) = 1 unit (for simplicity)

Surface Area (SA) = 2πrh + 2πr^2

Volume (V) = πr^2h

For a cylinder with radius 1 unit and height 1 unit:

Surface Area = 2π(1)(1) + 2π(1)^2 ≈ 8.57 units^2

Volume = π(1)^2(1) ≈ 3.14 units^3

Surface Area to Volume Ratio ≈ 8.57/3.14 ≈ 2.73 units^-1

As we can see, as the shapes increase in size, the surface area to volume ratio decreases. This principle has implications in biology, affecting factors such as heat exchange, nutrient absorption, and metabolic rates in organisms.

4. investigate the effect of changing surface area to volume ratio on diffusion usingagar blocks of different sizes

Materials:

Agar powder, water, food coloring, knife, ruler, beakers, stopwatch.

Procedure:

- Prepare agar blocks of different sizes.
- Fill a beaker with colored water.
- Place each agar block in the beaker and time how long it takes for the color to diffuse.
- Record the results.

Observations:

Smaller agar blocks with larger surface area to volume ratios diffuse color faster.

Conclusion:

Surface area to volume ratio affects diffusion rate, with higher ratios allowing faster diffusion.

5. investigate the effects of immersing plant tissues in solutions of different waterpotentials, using the results to estimate the water potential of the tissues

Materials Needed:

Plant tissues (e.g., potato slices)

Solutions of different sucrose concentrations (to create different water potentials)

Distilled water

Balance

Beakers

Paper towels

Stopwatch

Procedure:

Prepare solutions of different sucrose concentrations (e.g., 0.2M, 0.4M, 0.6M, 0.8M, 1.0M).

Cut plant tissues into uniform slices.

Blot the slices with a paper towel to remove excess water.

Weigh and record the initial mass of each slice.

Place each slice in a different sucrose solution.

Allow the slices to equilibrate for a set period (e.g., 30 minutes).

Remove the slices from the solutions, blot them gently, and reweigh.

Calculate the percentage change in mass for each slice.

Plot the percentage change in mass against the concentration of the sucrose

solution.

Determine the concentration at which there is no change in mass (isotonic point).

Calculations:

The point at which there is no change in mass corresponds to the water potential of the plant tissue.

Use the data to estimate the water potential of the plant tissues using a suitable formula or graph.

Observations and Analysis:

Higher sucrose concentrations result in greater water loss from the plant tissues, leading to decreased mass.

The isotonic point represents the sucrose concentration at which the water potential of the solution is equal to the water potential of the plant tissue.

Conclusion:

The experiment demonstrates the relationship between water potential and the movement of water in and out of plant tissues.

The water potential of the plant tissues can be estimated based on the isotonic point.

5. The mitotic cell cycle (8)

5.1 Replication and division of nuclei and cells

1. describe the structure of a chromosome, limited to:

   DNA: Chromosomes are primarily made up of DNA, which is a long, double-stranded molecule that carries genetic instructions. DNA is tightly coiled and condensed to fit within the nucleus of a cell.

   Histone Proteins: DNA is wrapped around histone proteins to form a structure called a nucleosome. Histones help in packaging and organizing DNA, and they play a role in gene regulation.

   Sister Chromatids: Each chromosome consists of two identical chromatids called sister chromatids, which are joined together at a region called the centromere. Sister chromatids are produced during DNA replication and are separated during cell division.

   Centromere: The centromere is a specialized region of a chromosome that holds the sister chromatids together. It is essential for the proper alignment and segregation of chromosomes during cell division.

   Telomeres: Telomeres are repetitive DNA sequences located at the ends of chromosomes. They protect the ends of the chromosomes from deterioration and fusion with other chromosomes. Telomeres also play a role in regulating the lifespan of cells.

2. explain the importance of mitosis in the production of genetically identical daughtercells during:

Growth of Multicellular Organisms:

During growth, cells in the body divide through mitosis to increase the overall number of cells.

Mitosis ensures that each new cell receives an identical copy of the genetic material (DNA) present in the parent cell, leading to the formation of genetically identical daughter cells.

This process allows multicellular organisms to grow in a controlled and organized manner, maintaining the integrity of their genetic information.

Replacement of Damaged or Dead Cells:

Cells in the body undergo wear and tear or may be damaged due to injury or disease.

Mitosis plays a vital role in replacing these damaged or dead cells with new, healthy cells.

The daughter cells produced through mitosis are genetically identical to the parent cell, ensuring that the replacement cells function correctly and maintain the organism's overall health.

Repair of Tissues by Cell Replacement:

In response to injury or damage, tissues may need to be repaired through cell replacement.

Mitosis allows for the rapid division of cells to replace damaged tissue.

The new cells produced through mitosis are identical to the existing cells, ensuring that the repaired tissue functions properly.

Asexual Reproduction:

In some organisms, mitosis is the primary method of reproduction, leading to the production of genetically identical offspring.

Mitosis ensures that each offspring receives an exact copy of the genetic material from the parent organism, maintaining genetic continuity.

3. outline the mitotic cell cycle, including:

Interphase:

- G1 Phase (Gap 1): The cell grows and carries out its normal functions. It synthesizes proteins and other molecules needed for DNA replication.
- S Phase (Synthesis): DNA replication occurs, resulting in the duplication of the genetic material (chromosomes). Each chromosome now consists of two sister chromatids held together by a centromere.
- G2 Phase (Gap 2): The cell continues to grow and prepares for cell division. It synthesizes additional proteins and organelles needed for mitosis.

Mitosis:

- Prophase: Chromosomes condense, becoming visible under a microscope. The nuclear envelope breaks down, and the mitotic spindle, composed of microtubules, begins to form.
- Metaphase: Chromosomes line up along the metaphase plate, an imaginary plane equidistant from the two spindle poles.
- Anaphase: Sister chromatids separate and move toward opposite spindle poles, pulled by the shortening of microtubules.
- Telophase: Chromatids arrive at opposite poles and decondense into chromatin. A new nuclear envelope forms around each set of chromosomes, and the mitotic spindle breaks down.

Cytokinesis:

- Cytokinesis typically begins in late anaphase or telophase and involves the division of the cytoplasm to form two daughter cells.
- In animal cells, a cleavage furrow forms and deepens, eventually pinching the cell into two.
- In plant cells, a new cell wall called the cell plate forms between the two daughter nuclei, eventually leading to the formation of two separate daughter cells.

4. outline the role of telomeres in preventing the loss of genes from the ends of chromosomes during DNA replication

   Telomeres are repetitive DNA sequences at chromosome ends. They protect genes from degradation during DNA replication, preventing loss of genetic information and maintaining chromosome stability.

5. outline the role of stem cells in cell replacement and tissue repair by mitosis

   Stem cells are undifferentiated cells that can divide and differentiate into specialized cell types. They play a crucial role in tissue regeneration and repair by replacing damaged or dead cells through mitosis. This process helps maintain the integrity and function of various tissues in the body, contributing to overall health and healing.

6. explain how uncontrolled cell division can result in the formation of a tumour

   Uncontrolled cell division leads to tumor formation by disrupting normal cell cycle regulation. Mutated cells divide uncontrollably, forming a mass. Malignant tumors invade surrounding tissues and spread, aided by angiogenesis and immune evasion, disrupting organ function.

5.2 Chromosome behaviour in mitosis

1. describe the behaviour of chromosomes in plant and animal cells during the mitoticcell cycle and the associated behaviour of the nuclear envelope, the cell surface membrane and the spindle (names of the main stages of mitosis are expected: prophase, metaphase, anaphase and telophase)

   Prophase:

   Chromosomes condense and become visible as distinct structures.

   The nuclear envelope breaks down, allowing the spindle fibers to interact with the chromosomes.

   The spindle apparatus, consisting of microtubules, forms and extends between the two centrosomes located at opposite ends of the cell.

   Metaphase:

   Chromosomes align along the metaphase plate, an imaginary plane equidistant from the two spindle poles.

   The spindle fibers attach to the centromeres of the chromosomes, ensuring that each chromatid will be pulled to opposite poles during anaphase.

   Anaphase:

   Sister chromatids separate at the centromere and move towards opposite spindle poles.

   The spindle fibers shorten, pulling the separated chromatids toward the poles.

   At the end of anaphase, each pole has a complete set of chromosomes.

   Telophase:

   Chromatids reach the spindle poles and begin to decondense into chromatin.

   The nuclear envelope reforms around each set of chromosomes, forming two

separate nuclei.

The spindle apparatus disassembles, and the cell prepares for cytokine

2. interpret photomicrographs, diagrams and microscope slides of cells in differentstages of the mitotic cell cycle and identify the main stages of mitosis

Interphase:

Cells appear normal in size and shape, with a prominent nucleus and nucleolus.

Chromosomes are not visible as distinct structures, and the nuclear envelope is intact.

Prophase:

Chromosomes condense and become visible as distinct, thread-like structures.

The nuclear envelope begins to break down, and the nucleolus disappears.

The spindle apparatus, including the centrosomes and microtubules, becomes visible.

Metaphase:

Chromosomes align along the metaphase plate, a plane located equidistant from the two spindle poles.

Chromosomes are fully condensed and attached to spindle fibers at their centromeres.

Anaphase:

Sister chromatids separate at the centromere and move towards opposite spindle poles.

The cell elongates as the spindle fibers pull the chromatids apart.

Telophase:

Chromatids reach the spindle poles and begin to decondense into chromatin.

The nuclear envelope reforms around each set of chromosomes, and the nucleolus reappears.

The spindle apparatus disassembles, and the cell prepares for cytokinesis.

Cytokinesis:

In animal cells, a cleavage furrow forms and deepens, eventually pinching the cell into two daughter cells.

In plant cells, a cell plate forms between the two nuclei, eventually developing into a new cell wall dividing the two daughter cells.

6. Nucleic acids and protein synthesis (12)

6.1 Structure of nucleic acids and replication of DNA

1. describe the structure of nucleotides, including the phosphorylated nucleotide ATP(structural formulae are not expected)

   The structure of nucleotides can be described as follows:

   Nitrogenous Base: Nucleotides contain one of five nitrogenous bases: adenine (A), guanine (G), cytosine (C), thymine (T) (in DNA), or uracil (U) (in RNA). The base is attached to the sugar molecule.

   Five-Carbon Sugar: In DNA, the sugar is deoxyribose, while in RNA, it is ribose. The sugar is bonded to the nitrogenous base and forms the backbone of the nucleotide chain.

   Phosphate Group(s): Nucleotides can have one, two, or three phosphate groups attached to the sugar molecule. The phosphate groups are attached to the 5' carbon of the sugar in a nucleotide chain.

   Adenosine triphosphate (ATP) is a nucleotide that plays a critical role in cellular energy transfer. It consists of the nitrogenous base adenine, the five-carbon sugar ribose, and three phosphate groups. The presence of three phosphate groups makes ATP a high-energy molecule that can release energy when the bond between the last two phosphate groups is broken, converting ATP to adenosine diphosphate (ADP) and releasing energy for cellular processes.

2. state that the bases adenine and guanine are purines with a double ring structure,and that the bases cytosine, thymine and uracil are pyrimidines with a single ring structure (structural formulae for bases are not expected)

The bases adenine (A) and guanine (G) are purines, which have a double-ring structure. The bases cytosine (C), thymine (T) (in DNA), and uracil (U) (in RNA) are pyrimidines, which have a single-ring structure

第六章

3. describe the structure of a DNA molecule as a double helix, including:

   The DNA molecule is a double helix with two antiparallel strands. Complementary base pairing between the 5' to 3' and 3' to 5' strands ensures specific hydrogen bonding between adenine (A) and thymine (T) (or uracil (U) in RNA), as well as between cytosine (C) and guanine (G). Cytosine and guanine form three hydrogen bonds, while adenine and thymine form two, contributing to the stability of the DNA molecule. Nucleotides are linked by phosphodiester bonds between the 3' carbon of one sugar molecule and the 5' carbon of the next, forming a sugar-phosphate backbone.

4. describe the semi-conservative replication of DNA during the S phase of the cellcycle, including:

   Initiation: The DNA double helix is unwound by an enzyme called helicase, creating two template strands.

   Primer Binding: Primase synthesizes a short RNA primer on each template strand, providing a starting point for DNA synthesis.

   Elongation - Leading Strand: DNA polymerase III synthesizes the leading strand continuously in the 5' to 3' direction, following the helicase as it unwinds the DNA. Since DNA polymerase can only add nucleotides in the 5' to 3' direction, the leading strand is synthesized continuously.

   Elongation - Lagging Strand: The lagging strand is synthesized discontinuously in short fragments called Okazaki fragments. Primase synthesizes RNA primers, and DNA polymerase III synthesizes short stretches of DNA in the 5' to 3' direction away from the replication fork. This results in the formation of Okazaki fragments.

   Okazaki Fragment Processing: DNA polymerase I removes the RNA primers and replaces them with DNA, while DNA ligase joins the Okazaki fragments on the lagging strand, forming a continuous daughter strand.

   Termination: The replication process continues until the entire DNA molecule is replicated. Telomeres, repetitive DNA sequences at the ends of chromosomes, are replicated by a special enzyme called telomerase to prevent the loss of genetic information during replication.

5. describe the structure of an RNA molecule, using the example of messenger RNA(mRNA)

Nucleotides: Like DNA, RNA is composed of nucleotides, each consisting of a nitrogenous base, a five-carbon sugar (ribose in RNA), and a phosphate group.

Nitrogenous Bases: RNA contains four nitrogenous bases: adenine (A), cytosine (C), guanine (G), and uracil (U). Uracil replaces thymine (T) found in DNA and pairs with adenine via two hydrogen bonds.

Sugar-Phosphate Backbone: The nucleotides in an RNA molecule are linked together by phosphodiester bonds between the 3' carbon of one sugar and the 5' carbon of the next sugar, forming a sugar-phosphate backbone.

Structure: mRNA molecules are typically single-stranded and can fold into complex secondary structures due to complementary base pairing within the molecule. This folding is important for the function of mRNA in protein synthesis

6.2 Protein synthesis

1. state that a polypeptide is coded for by a gene and that a gene is a sequence of nucleotides that forms part of a DNA molecule

2. describe the principle of the universal genetic code in which different triplets of DNAbases either code for specific amino acids or correspond to start and stop codons

   The universal genetic code is a set of rules that specifies how DNA and RNA sequences are translated into proteins. It is universal because it is the same in all organisms, from bacteria to humans. The code is based on codons, which are sequences of three nucleotides (triplets) that specify a particular amino acid or signal the start or end of protein synthesis.

   In the genetic code, each codon corresponds to either one of the 20 standard amino acids used in protein synthesis or one of the three stop codons that signal the end of translation. The start codon, AUG (encoding the amino acid methionine), initiates protein synthesis, while the stop codons (UAA, UAG, and UGA) signal the termination of translation.

   The specificity of the genetic code ensures that the same codons encode the same amino acids across different organisms. This universality is essential for the accurate translation of genetic information into proteins and underlies the fundamental processes of life.

3. describe how the information in DNA is used during transcription and translation toconstruct polypeptides, including the roles of:

Transcription:

RNA Polymerase: RNA polymerase is an enzyme that catalyzes the synthesis of RNA from a DNA template. It binds to the promoter region of a gene on the DNA strand and unwinds the DNA double helix to expose the template strand.

Messenger RNA (mRNA): mRNA is the RNA molecule synthesized during transcription that carries the genetic information from the DNA in the nucleus to the ribosomes in the cytoplasm. It is complementary to the DNA template strand and serves as a template for translation.

Codons: Codons are three-nucleotide sequences in mRNA that code for specific amino acids or signal the start or end of translation. Each codon corresponds to a specific amino acid or a stop signal.

Translation:

Transfer RNA (tRNA): tRNA molecules are adaptor molecules that carry amino acids to the ribosome during translation. Each tRNA molecule has an anticodon that is complementary to a specific mRNA codon and carries the corresponding amino acid.

Anticodons: Anticodons are three-nucleotide sequences in tRNA that are complementary to the codons in mRNA. They allow tRNA to recognize and bind to the corresponding codons in mRNA.

Ribosomes: Ribosomes are cellular structures where protein synthesis occurs. They consist of two subunits (large and small) and contain binding sites for mRNA and tRNA. Ribosomes catalyze the formation of peptide bonds between amino acids, resulting in the synthesis of a polypeptide chain.

4. state that the strand of a DNA molecule that is used in transcription is called the transcribed or template strand and that the other strand is called the non-transcribed strand

4. explain that, in eukaryotes, the RNA molecule formed following transcription (primary transcript) is modified by the removal of non-coding sequences (introns) andthe joining together of coding sequences (exons) to form mRNA

This primary transcript undergoes a process called RNA processing or RNA splicing, where non-coding sequences called introns are removed, and the coding sequences called exons are joined together to form mature messenger RNA (mRNA).

Introns and Exons: Introns are non-coding sequences found within genes that do not code for proteins. Exons, on the other hand, are coding sequences that contain the genetic information for protein synthesis.

RNA Splicing: The process of RNA splicing involves the removal of introns and the joining together of exons to produce a mature mRNA molecule. This process is carried out by a complex called the spliceosome, which recognizes specific sequences at the boundaries between introns and exons.

Alternative Splicing: In some cases, alternative splicing can occur, where different combinations of exons are joined together, leading to the production of multiple protein isoforms from a single gene.

Formation of Mature mRNA: After RNA splicing, the mature mRNA molecule is exported from the nucleus to the cytoplasm, where it serves as a template for protein synthesis during translation.

6. state that a gene mutation is a change in the sequence of base pairs in a DNA molecule that may result in an altered polypeptide
6. explain that a gene mutation is a result of substitution or deletion or insertion of nucleotides in DNA and outline how each of these types of mutation may affect thepolypeptide produced **Substitution:** In a substitution mutation, one nucleotide is replaced with a different nucleotide. This can lead to three possible outcomes: Silent Mutation: The substitution does not change the amino acid coded for by the mRNA codon, so there is no change in the polypeptide. Missense Mutation: The substitution results in a different amino acid being incorporated into the polypeptide, which can alter its structure and function. The impact of a missense mutation depends on the specific amino acid change and its location in the protein. Nonsense Mutation: The substitution changes a codon that codes for an amino acid into a stop codon, prematurely terminating translation. This results in a truncated, usually nonfunctional polypeptide. **Deletion:** In a deletion mutation, one or more nucleotides are deleted from the DNA sequence. This can lead to a frameshift mutation, where the reading frame of the mRNA is shifted, altering the entire sequence of codons downstream of the mutation. The resulting polypeptide is usually nonfunctional due to the extensive changes in amino acid sequence. **Insertion:** In an insertion mutation, one or more nucleotides are inserted into the DNA sequence. Like deletion, insertion can also cause a frameshift mutation, affecting the entire sequence of codons downstream of the insertion. The resulting polypeptide is often nonfunctional due to the altered amino acid

sequence.

第六章

7. Transport of Plant (12)

7.1 Structure of transport tissues

1. draw plan diagrams of transverse sections of stems, roots and leaves of herbaceousdicotyledonous plants from microscope slides and photomicrographs.

   Here's a general guide:

   Stem: The stem of a s dicotyledonous plant typically consists of several tissues, including epidermis, cortex, vascular bundles, and pith. Start by drawing a circle to represent the epidermis, then add layers for the cortex and pith. Inside the stem, draw several oval-shaped vascular bundles arranged in a circle. Label each part accordingly.

   Root: The root of a dicotyledonous plant has a similar structure to the stem but lacks pith and has a central vascular cylinder instead. Draw a circle for the epidermis, then add layers for the cortex and vascular cylinder. Inside the vascular cylinder, draw several x-shaped structures to represent the xylem and phloem. Label each part accordingly.

   Leaf: The leaf of a dicotyledonous plant consists of several layers, including epidermis, mesophyll, and vascular bundles. Draw a long oval shape to represent the leaf. Inside the leaf, draw two layers for the upper and lower epidermis. Between the epidermal layers, draw the mesophyll, which consists of palisade and spongy parenchyma. Add vascular bundles in the mesophyll, connecting to the veins. Label each part accordingly.

2. describe the distribution of xylem and phloem in transverse sections of stems, rootsand leaves of herbaceous dicotyledonous plants.

Stems:

Stem Cross-Section: In stems, the xylem and phloem are arranged in vascular bundles. These bundles are scattered throughout the stem, forming a pattern known as the vascular cylinder or vascular bundle system.

Xylem and Phloem: Xylem is located toward the center of the vascular bundle, while phloem is located toward the outer edge. This arrangement helps in the efficient transport of water and nutrients throughout the plant.

Roots:

Root Cross-Section: In roots, the xylem and phloem are arranged in the center of the root, forming a structure known as the vascular cylinder or stele.

Xylem and Phloem: Similar to stems, xylem is located toward the center of the vascular cylinder, while phloem is located toward the outer edge. This arrangement allows for the efficient uptake of water and nutrients from the soil.

Leaves:

Leaf Cross-Section: In leaves, the xylem and phloem are arranged in vascular bundles that run through the leaf, primarily in the midrib and veins.

Xylem and Phloem: Xylem is typically located on the upper side of the vascular bundle, closer to the upper epidermis, while phloem is located on the lower side, closer to the lower epidermis. This arrangement helps in the transport of water and nutrients from the roots to the leaves and other parts of the plant.

3. draw and label xylem vessel elements, phloem sieve tube elements and companioncells from microscope slides, photomicrographs and electron micrographs

Here's a general guide:

Xylem Vessel Elements:

Draw elongated cells with thick walls and perforations (or pits) in the walls.

Label the thick walls as lignified and the perforations as pits.

Add labels for primary and secondary walls, as well as the lumen.

Phloem Sieve Tube Elements:

Draw elongated cells with thin walls and sieve plates at the ends.

Label the thin walls and the sieve plates.

Add labels for the lumen and the cytoplasm.

Companion Cells:

Draw small, elongated cells adjacent to the sieve tube elements.

Label the cells as companion cells.

Add labels for the nucleus, cytoplasm, and cell wall.

4. relate the structure of xylem vessel elements, phloem sieve tube elements andcompanion cells to their functions

Xylem Vessel Elements:

- Structure: Xylem vessel elements are elongated cells with lignified walls and perforations called pits. These elements are stacked end-to-end, forming vessels that transport water and minerals from roots to shoots.
- Function: The lignified walls provide strength and support, allowing the vessel to withstand the tension created by water movement. The pits allow water to move laterally between vessel elements, ensuring efficient water transport.

Phloem Sieve Tube Elements:

- Structure: Phloem sieve tube elements are elongated cells with thin walls and sieve plates at the ends. These elements are interconnected to form sieve tubes that transport sugars and other organic nutrients throughout the plant.
- Function: The thin walls of sieve tube elements allow for efficient nutrient transport. The sieve plates facilitate the movement of nutrients between adjacent sieve tube elements. However, sieve tube elements lack a nucleus, ribosomes, and a distinct vacuole, relying on companion cells for metabolic functions.

Companion Cells:

- Structure: Companion cells are small, elongated cells located adjacent to sieve tube elements. They have a nucleus, abundant ribosomes, and a large central vacuole.

- Function: Companion cells are metabolically active and provide energy and nutrients to maintain the function and integrity of sieve tube elements. They are involved in loading sugars into the sieve tubes and in regulating the movement of substances between the sieve tubes and surrounding cells.

7.2 Transport mechanisms

1. state that some mineral ions and organic compounds can be transported within plants dissolved in water

3. describe the transport of water from the soil to the xylem through the:

Apoplast Pathway:

- Description: In the apoplast pathway, water moves through the cell walls and intercellular spaces without entering the cell cytoplasm. It is a continuous network of cell walls and extracellular spaces that extends throughout the plant.
- Key Features: The cell walls in the apoplast pathway are composed of lignin and cellulose, which provide structural support and prevent collapse of the cell walls under tension. Lignin is particularly important for its hydrophobic properties, which help in water movement.
- Function: Water moves rapidly through the apoplast pathway, facilitated by the cohesive and adhesive properties of water molecules. However, water must eventually cross the plasma membrane to enter the symplast pathway and reach the xylem.

Symplast Pathway:

- Description: In the symplast pathway, water moves through the cytoplasm of cells via plasmodesmata, which are channels that connect the cytoplasm of adjacent cells. This pathway allows for controlled movement of water and solutes between cells.
- Key Features: The endodermis, a specialized layer of cells in the root cortex, plays a crucial role in regulating water and solute movement in the symplast pathway. The endodermal cells are characterized by the presence of a Casparian strip, which is a band of suberin (a waxy substance) in their cell walls.
- Function: The Casparian strip is impermeable to water and ions, forcing water and solutes to cross the plasma membrane of endodermal cells to enter the symplast pathway. This selective barrier allows the plant to control the uptake of water and nutrients from the soil.

4. explain that transpiration involves the evaporation of water from the internalsurfaces of leaves followed by diffusion of water vapour to the atmosphere

   During transpiration, water molecules evaporate from the moist surfaces of the cells in the leaf, particularly from the spongy mesophyll and the surface of the cells in the stomatal pores. These water molecules then diffuse through the stomata into the surrounding air, where they become water vapor and are carried away by air currents.

   The evaporation of water from the internal surfaces of leaves creates a negative pressure (tension) in the leaf cells, which pulls water from the roots through the xylem vessels. This process, known as cohesion-tension theory, relies on the cohesive properties of water molecules and the tensile strength of water columns in the xylem.

5. explain how hydrogen bonding of water molecules is involved with movement ofwater in the xylem by cohesion-tension in transpiration pull and by adhesion to cellulose in cell walls

Cohesion-Tension:

Cohesion: Water molecules are cohesive, meaning they are attracted to each other. This cohesion is due to hydrogen bonding between water molecules. As water evaporates from the leaves during transpiration, it creates tension (negative pressure) in the xylem.

Tension: The tension created by transpiration pull is transmitted through the water column in the xylem, from the leaves to the roots. This tension is maintained by the cohesive forces between water molecules, which allow them to form a continuous column in the xylem.

Adhesion to Cellulose:

Adhesion: Water molecules also adhere (stick) to the cellulose molecules in the cell walls of xylem vessels. This adhesion helps counter the force of gravity, allowing water to move upwards in the xylem.

Capillary Action: The adhesion of water to cellulose, combined with cohesion between water molecules, allows for capillary action, where water is drawn up narrow tubes (such as xylem vessels) against gravity. This helps water move from the roots to the leaves.

6. make annotated drawings of transverse sections of leaves from xerophytic plants toexplain how they are adapted to reduce water loss by transpiration.

Thick Cuticle: Draw a thick, waxy layer on the outer surface of the leaf. Label it as "Thick Cuticle." This layer helps reduce water loss by providing a barrier to transpiration.

Sunken Stomata: Draw stomata that are sunken into pits or grooves in the leaf surface. Label them as "Sunken Stomata." This adaptation helps reduce water loss by creating a more humid microclimate around the stomata, reducing the rate of transpiration.

Reduced Number of Stomata: Draw fewer stomata compared to leaves of non-xerophytic plants. Label this adaptation as "Reduced Stomata." This reduces the surface area available for transpiration.

Hairy Surface: Draw hairs (trichomes) on the leaf surface. Label them as "Hairs." These hairs create a boundary layer of still air around the leaf, reducing the rate of transpiration by slowing down air movement.

Rolled or Curled Leaves: Draw leaves that are rolled or curled. Label this adaptation as "Rolled Leaves." This reduces the surface area exposed to the air, reducing transpiration.

Additional Adaptations: You can also include other adaptations such as thickened epidermis, smaller leaf size, and succulence (water storage tissue) if relevant to the xerophytic plant you are illustrating.

6. state that assimilates dissolved in water, such as sucrose and amino acids, move from sources to sinks in phloem sieve tubes.

7. explain how companion cells transfer assimilates to phloem sieve tubes, withreference to proton pumps and cotransporter proteins

Loading of Assimilates: Assimilates are actively transported into the companion cells from surrounding cells or from the apoplast. This process requires energy in the form of ATP and is facilitated by proton pumps located in the plasma membrane of companion cells.

Proton Pump Activity: Proton pumps actively transport protons (H+) from the cytoplasm of the companion cell into the cell wall or apoplast. This creates a concentration gradient of protons, with a higher concentration outside the cell than inside.

Cotransport with Protons: Cotransporter proteins are embedded in the plasma membrane of companion cells. These cotransporters facilitate the transport of assimilates, such as sucrose, along with protons. The protons move down their concentration gradient back into the companion cell, while the assimilates are transported against their concentration gradient into the sieve tube.

Transfer to Phloem Sieve Tubes: Once inside the companion cell, assimilates move through plasmodesmata (channels connecting companion cells and sieve tubes) into the sieve tubes. The movement of assimilates into the sieve tubes is driven by the high concentration of assimilates in the companion cell.

Mass Flow in Phloem: The movement of assimilates along with water through the sieve tubes is driven by a pressure gradient between source and sink tissues. This mass flow, known as translocation, allows assimilates

to be transported efficiently over long distances within the plant.

第七章

8. explain mass flow in phloem sieve tubes down a hydrostatic pressure gradient fromsource to sink

Loading at Source: Assimilates are actively transported into the sieve tubes at source regions, such as mature leaves or storage organs, by companion cells. This loading process creates a high concentration of assimilates in the sieve tubes at the source.

Pressure Build-Up: As assimilates are loaded into the sieve tubes, the concentration of solutes (primarily sugars) increases, creating a higher solute potential in the sieve tubes compared to the surrounding cells. This leads to the uptake of water by osmosis, increasing the pressure inside the sieve tubes.

Pressure Gradient: The increase in pressure at the source creates a pressure gradient along the phloem pathway, with higher pressure at the source and lower pressure at the sink. This pressure gradient drives the flow of assimilates through the sieve tubes.

Translocation: Assimilates, along with water, flow through the sieve tubes from regions of high pressure (source) to regions of low pressure (sink). This mass flow of assimilates is driven by the pressure gradient and is a relatively rapid process, allowing for efficient transport over long distances.

Unloading at Sink: At the sink, assimilates are actively unloaded from the sieve tubes by companion cells and used for growth, storage, or other metabolic processes. This unloading reduces the pressure in the sieve tubes at the sink.

Return Flow: Some of the water that entered the sieve tubes at the source is recirculated back to the xylem via the phloem for reuse in the plant.

8 Transport in mammals (17)

8.1 The circulatory system

1. state that the mammalian circulatory system is a closed double circulation consisting of a heart, blood and blood vessels including arteries, arterioles, capillaries, venules and veins

2. describe the functions of the main blood vessels of the pulmonary and systemic circulations, limited to pulmonary artery, pulmonary vein, aorta and vena cava.

Pulmonary Artery:

- Function: Carries deoxygenated blood from the right ventricle of the heart to the lungs for oxygenation.
- Oxygen Exchange: In the lungs, carbon dioxide is removed from the blood, and oxygen is taken up by the red blood cells, converting deoxygenated blood into oxygenated blood.

Pulmonary Vein:

- Function: Returns oxygenated blood from the lungs to the left atrium of the heart.
- Oxygenated Blood: After exchanging carbon dioxide for oxygen in the lungs, blood in the pulmonary veins is rich in oxygen and ready to be pumped to the rest of the body.

Aorta:

- Function: The largest artery in the body, it carries oxygenated blood from the left ventricle of the heart to the systemic circulation.
- Systemic Circulation: The aorta branches into smaller arteries that deliver oxygenated blood to all parts of the body, providing oxygen and nutrients to tissues.

Vena Cava:

- Function: The superior and inferior vena cava return deoxygenated blood from the body to the right atrium of the heart.
- Deoxygenated Blood: After delivering oxygen to the tissues, blood returns to the heart through the vena cava to be pumped to the lungs for oxygenation again.

3. recognise arteries, veins and capillaries from microscope slides, photomicrographs and electron micrographs and make plan diagrams showing the structure of arteries and veins in transverse section (TS) and longitudinal section (LS).

Arteries:

- Transverse Section: Arteries have thick walls with three distinct layers: the tunica intima (innermost layer), tunica media (middle layer), and tunica externa (outer layer). The tunica media is particularly thick and contains smooth muscle cells.
- Longitudinal Section: In a longitudinal section, arteries appear as vessels with a circular or oval shape, depending on the degree of constriction. The three layers can be seen, with the tunica media appearing as a prominent layer.

Veins:

- Transverse Section: Veins have thinner walls compared to arteries and lack a well-defined tunica media. They have a larger lumen relative to their diameter.
- Longitudinal Section: In a longitudinal section, veins appear as vessels with a more irregular shape compared to arteries. The walls are thinner, and the lumen is larger. Valves may also be visible in larger veins.

4. explain how the structure of muscular arteries, elastic arteries, veins and capillaries are each related to their functions.

Muscular Arteries:

- Structure: Muscular arteries have a thick tunica media composed of smooth muscle cells. They also have a well-defined tunica intima and tunica externa.
- Function: The thick muscular layer allows these arteries to regulate blood flow by constricting or dilating in response to changes in blood pressure and tissue demand. They help distribute blood to various parts of the body.

Elastic Arteries:

- Structure: Elastic arteries have a large number of elastic fibers in their tunica media, giving them a more elastic and stretchable nature. They also have well-defined tunica intima and tunica externa.
- Function: The elastic fibers allow these arteries to expand and recoil in response to each heartbeat, helping maintain a continuous blood flow and dampening the pulsatile nature of blood flow from the heart.

Veins:

- Structure: Veins have thinner walls compared to arteries, with a less pronounced tunica media and fewer elastic fibers. They have a larger lumen relative to their diameter and may contain valves to prevent backflow of blood.
- Function: Veins carry blood back to the heart under lower pressure. Their thin walls and larger lumens allow them to accommodate a larger volume of blood. Valves prevent the backflow of blood and assist in the return of blood to the heart, especially against gravity in the lower limbs.

Capillaries:

- Structure: Capillaries consist of a single layer of endothelial cells, which are thin and permeable. They lack tunica media and tunica externa.
- Function: Capillaries are the site of exchange of nutrients, gases, and wastes between the blood and tissues. Their thin walls allow for easy diffusion of substances. Their large surface area facilitates efficient exchange.

5. recognise and draw red blood cells, monocytes, neutrophils and lymphocytes from microscope slides, photomicrographs and electron micrographs

Red Blood Cells (Erythrocytes):

- Appearance: Circular, biconcave disc shape without a nucleus.
- Function: Carry oxygen from the lungs to the rest of the body and transport carbon dioxide back to the lungs.

Monocytes:

- Appearance: Larger cells with a kidney-shaped nucleus and abundant cytoplasm.
- Function: Phagocytize pathogens, dead cells, and debris. They can differentiate into macrophages in tissues.

Neutrophils:

- Appearance: Multi-lobed nucleus (usually 3-5 lobes) with fine, pale lilac granules in the cytoplasm.
- Function: Phagocytosis of bacteria and fungi, especially in the early stages of infection.

Lymphocytes:

- Appearance: Variable in size with a large, round nucleus that occupies most of the cell. Little cytoplasm visible around the nucleus.
- Function: Play a key role in the immune response, including the production of antibodies and the destruction of infected or cancerous cells.

6. state that water is the main component of blood and tissue fluid and relate the properties of water to its role in transport in mammals, limited to solvent action and high specific heat capacity

1. **Solvent Action**: Water is known as the universal solvent because of its ability to dissolve a wide variety of solutes. In blood, water acts as a solvent for gases (such as oxygen and carbon dioxide), nutrients (such as glucose and amino acids), waste products (such as urea), and ions (such as sodium and potassium). This allows for the efficient transport of these substances in the bloodstream to and from cells.
2. **High Specific Heat Capacity**: Water has a high specific heat capacity, meaning it can absorb and release large amounts of heat with minimal change in temperature. In the circulatory system, water helps regulate body temperature by absorbing excess heat generated during metabolic processes and releasing it when needed. This is important for maintaining a stable internal environment (homeostasis) in mammals.

7. state the functions of tissue fluid and describe the formation of tissue fluid in a capillary network

Functions of tissue fluid:

- Nutrient delivery
- Waste removal
- Gas exchange
- Fluid balance
- Immune response

Formation of tissue fluid in a capillary network occurs through a process called filtration. Here's how it works:

Hydrostatic Pressure: Blood pressure in the capillaries (hydrostatic pressure) is higher than the pressure in the surrounding tissues. This pressure difference forces water and small solutes out of the capillaries into the interstitial space (the space between cells).

Osmotic Pressure: As fluid leaves the capillaries, the concentration of proteins and other solutes in the capillaries increases. This creates an osmotic pressure, drawing some of the fluid back into the capillaries.

Balance: Filtration and osmotic pressure are balanced in normal conditions, maintaining a relatively stable level of tissue fluid. Any excess fluid is collected by lymphatic vessels and returned to the bloodstream as lymph.

8.2 Transport of oxygen and carbon dioxide

1. describe the role of red blood cells in transporting oxygen and carbon dioxide withreference to the roles of:

Haemoglobin:

- Oxygen Transport: Haemoglobin, a protein found in red blood cells, binds to oxygen in the lungs, forming oxyhaemoglobin. This binding is facilitated by iron ions (Fe^2+) in the haemoglobin molecule.
- Carbon Dioxide Transport: Haemoglobin also binds to carbon dioxide, mainly in the form of carbaminohaemoglobin. This helps transport carbon dioxide from tissues to the lungs for removal.

Carbonic Anhydrase:

- Carbon Dioxide Transport: Inside red blood cells, carbonic anhydrase catalyzes the conversion of carbon dioxide and water into carbonic acid (H2CO3), which then dissociates into bicarbonate ions (HCO3-) and hydrogen ions (H+). This reaction allows for the transport of carbon dioxide in the form of bicarbonate ions, which are more soluble and can be transported in the blood plasma.

Formation of Haemoglobinic Acid:

- Haemoglobinic acid is formed when carbon dioxide (CO_2) reacts with deoxygenated haemoglobin (HHb) in the red blood cells.
- The reaction is as follows: $CO_2 + HHb \rightarrow HbCO_2$ (haemoglobinic acid) + H^+.
- Haemoglobinic acid helps transport carbon dioxide from tissues to the lungs for removal.

Formation of Carbaminohaemoglobin:

- Carbaminohaemoglobin is formed when carbon dioxide reacts directly with amino groups of haemoglobin.
- The reaction is as follows: $CO_2 + Hb\text{-}NH_2 \rightarrow Hb\text{-}NHCOOH$ (carbaminohaemoglobin).
- Carbaminohaemoglobin also helps transport carbon dioxide from tissues to the lungs for removal.

2. describe the chloride shift and explain the importance of the chloride shift

Description:

- In tissues where carbon dioxide (CO_2) is produced, CO_2 diffuses into RBCs and reacts with water to form carbonic acid (H_2CO_3) with the help of carbonic anhydrase enzyme.
- Carbonic acid then dissociates into bicarbonate ions (HCO_3^-) and hydrogen ions (H^+).
- To maintain electrical neutrality and prevent an excess buildup of negative charges inside the RBC, chloride ions (Cl^-) move into the RBC from the plasma via a chloride-bicarbonate exchanger known as the band 3 protein.
- In the lungs, where CO_2 is exhaled, the process is reversed. Chloride ions move out of the RBCs back into the plasma, and bicarbonate ions move back into the RBCs.

Importance:

- The chloride shift helps maintain the ionic balance in red blood cells, preventing excessive buildup of negative charges inside the cell.
- It plays a crucial role in the transportation of carbon dioxide in the blood. By converting CO_2 into bicarbonate ions in the tissues and then converting them back into CO_2 in the lungs, the chloride shift assists in the transport of CO_2 from tissues to lungs for elimination.
- The process also helps maintain the pH balance of the blood. Excessive CO_2 in the

blood can lead to the formation of carbonic acid and a decrease in pH. The chloride shift helps regulate these changes in pH by buffering the excess hydrogen ions produced during carbon dioxide transport.

3. describe the role of plasma in the transport of carbon dioxide

   plasma plays a crucial role in the transport of CO_2 in the blood by carrying dissolved CO_2, bicarbonate ions, and carbaminohaemoglobin. These mechanisms ensure the efficient removal of CO_2 from tissues to the lungs for exhalation.

4. describe and explain the oxygen dissociation curve of adult haemoglobin

   Low pO_2 (Tissues):

   In tissues with low pO_2, haemoglobin releases oxygen due to the Bohr effect (increased acidity and high carbon dioxide levels).

   This facilitates oxygen unloading to tissues for cellular respiration.

   Mid-range pO_2 (Lungs):

   In the lungs with moderate pO_2, haemoglobin binds oxygen, transitioning to the R-state (relaxed state).

   This allows for efficient loading of oxygen in the lungs where pO_2 is high.

   High pO_2 (Lungs):

   At high pO_2, haemoglobin is almost fully saturated with oxygen.

   The steep part of the curve indicates that a small change in pO_2 results in a large change in oxygen saturation, facilitating efficient oxygen uptake in the lungs.

   Cooperative Binding:

   The sigmoidal shape results from cooperative binding, where the binding of one oxygen molecule enhances the binding of subsequent molecules.

   This allows for efficient loading and unloading of oxygen, adapting to varying oxygen demands in tissues.

5. explain the importance of the oxygen dissociation curve at partial pressures ofoxygen in the lungs and in respiring tissues

   The importance of the oxygen dissociation curve lies in its role in facilitating the efficient transport and delivery of oxygen by haemoglobin to tissues throughout the body. It allows haemoglobin to bind oxygen in the lungs, where oxygen levels are high, and release it in tissues with lower oxygen levels, where it is needed for cellular respiration. The sigmoidal shape of the curve indicates cooperative binding, ensuring that oxygen is readily available when and where it is needed most. This adaptability is crucial for supporting aerobic metabolism and overall physiological function in humans and other organisms.

6. describe the Bohr shift and explain the importance of the Bohr shift

   The Bohr shift describes how the binding of oxygen to haemoglobin is affected by changes in acidity (pH) and carbon dioxide (CO_2) levels in the blood. When acidity increases or CO_2 levels rise, haemoglobin has a lower affinity for oxygen, meaning it releases oxygen more readily. This is important because it allows haemoglobin to unload oxygen more easily in tissues with high levels of CO_2 and low pH, where oxygen is needed for cellular respiration. This shift in the oxygen dissociation curve helps ensure that oxygen is delivered to tissues efficiently, matching oxygen delivery with metabolic demand.

8.3 The heart

1. describe the external and internal structure of the mammalian heart

External Structure:

- Size and Shape: The heart is roughly the size of a fist and has a conical shape, with the apex pointing downward and to the left.
- Coverings: The heart is enclosed in a double-layered membrane called the pericardium, which protects and anchors the heart in the chest cavity.
- Chambers: The heart has four chambers—two atria (upper chambers) and two ventricles (lower chambers). The atria receive blood, while the ventricles pump blood out of the heart.
- Blood Vessels: The heart is connected to major blood vessels—the superior and inferior vena cava bring deoxygenated blood from the body to the right atrium, and the pulmonary arteries carry deoxygenated blood from the right ventricle to the lungs for oxygenation.
- Coronary Vessels: The heart is supplied with blood by the coronary arteries, which branch off the aorta and provide oxygenated blood to the heart muscle.

Internal Structure:

- Valves: The heart has four valves—tricuspid valve and mitral valve between the atria and ventricles, and pulmonary valve and aortic valve between the ventricles and major blood vessels. These valves ensure one-way blood flow through the heart.
- Septum: The heart is divided into right and left sides by a muscular wall called the septum. This prevents oxygenated and deoxygenated blood from mixing.
- Muscle Tissue: The walls of the heart are made up of cardiac muscle tissue, which contracts to pump blood. The myocardium is the thickest layer, providing the force needed for pumping.
- Conduction System: The heart has its own electrical conduction system, including the sinoatrial (SA) node, atrioventricular (AV) node, and bundle of His, which coordinate the heart's rhythmic contractions.

2 explain the differences in the thickness of the walls of the:

Atria and Ventricles:

- The walls of the atria are thinner compared to the ventricles.
- This is because the atria only need to pump blood a short distance to the ventricles, which have thicker walls to pump blood to the lungs (right ventricle) and the rest of the body (left ventricle).

Left Ventricle and Right Ventricle:

- The left ventricle has a much thicker wall compared to the right ventricle.
- This is because the left ventricle needs to pump blood to the entire body against higher resistance, requiring more forceful contractions and a thicker myocardium.
- In contrast, the right ventricle only needs to pump blood to the lungs, which have lower resistance, so it does not need to generate as much force and has a thinner wall.

2. describe the cardiac cycle, with reference to the relationship between blood pressurechanges during systole and diastole and the opening and closing of valves

   Diastole:

   - Atria Filling (Atrial Diastole): The heart is relaxed. Blood flows passively from the veins into the atria, causing them to fill.
   - Ventricular Filling (Ventricular Diastole): As the atria contract (atrial systole), blood is pushed into the ventricles. This phase accounts for about 70-80% of ventricular filling.
   - Atrioventricular (AV) Valves Open: The pressure in the atria is higher than in the ventricles, so the AV valves (tricuspid and mitral) open, allowing blood to flow from the atria into the ventricles.
   - Pressure Changes: Blood pressure is lower during diastole as the heart relaxes.

Systole:

- Atrial Contraction (Atrial Systole): The atria contract, completing the filling of the ventricles.
- Ventricular Contraction (Ventricular Systole): The ventricles contract, increasing pressure and forcing the AV valves to close to prevent backflow of blood into the atria.
- Semilunar Valves Open: When ventricular pressure exceeds arterial pressure, the semilunar valves (aortic and pulmonary) open, allowing blood to be ejected into the aorta and pulmonary artery.
- Pressure Changes: Blood pressure is higher during systole as the heart contracts to pump blood out to the body and lungs.

Complete Cycle:

- The cardiac cycle is completed when the ventricles relax, and the pressure in the aorta and pulmonary artery closes the semilunar valves.
- The cycle then repeats with the onset of diastole as the atria fill again.

4. explain the roles of the sinoatrial node, the atrioventricular node and the Purkyne tissue in the cardiac cycle (knowledge of nervous and hormonal control is not expected)

Sinoatrial Node (SAN):

- The SA node, located in the right atrium, is often referred to as the heart's natural pacemaker.
- It generates electrical impulses spontaneously, initiating each heartbeat.
- The electrical impulses from the SA node spread across the atria, causing them to contract and push blood into the ventricles.

Atrioventricular Node (AVN):

- The AV node is located at the junction between the atria and ventricles.
- It serves as a relay station, delaying the electrical impulses for a brief moment to allow the atria to finish contracting before the ventricles contract.
- This delay ensures that blood is effectively pumped from the atria to the ventricles before the ventricles contract.

Purkyne Fibers:

- The Purkyne fibers are specialized fibers that rapidly conduct the electrical impulses from the AV node to the ventricles.
- They ensure that the ventricles contract in a synchronized manner, starting from the apex of the heart and moving upward, effectively pumping blood out of the heart.

9 Gas exchange (7)

9.1 The gas exchange system

1. describe the structure of the human gas exchange system, limited to:

Lungs:

The lungs are the main organs of the respiratory system and are responsible for gas exchange.

They are located in the chest cavity and are divided into lobes.

The lungs are surrounded by a double-layered membrane called the pleura, which helps protect and cushion the lungs.

Trachea:

The trachea, or windpipe, is a tube that connects the larynx to the bronchi.

It is lined with cilia and mucus that help trap and remove foreign particles and pathogens from the air.

Bronchi:

The trachea branches into two bronchi, each of which leads to a lung.

The bronchi further divide into smaller bronchioles.

Bronchioles:

Bronchioles are smaller branches of the bronchi that lead to the alveoli.

They are lined with smooth muscle and are capable of constricting or dilating to regulate airflow.

Alveoli:

Alveoli are tiny air sacs in the lungs where gas exchange occurs.

They are surrounded by a network of capillaries and have thin walls that allow for the diffusion of oxygen and carbon dioxide.

Capillary Network:

Capillaries are small blood vessels that surround the alveoli.

They have thin walls that allow for the exchange of gases between the blood and the alveoli.

3. describe the distribution in the gas exchange system of

Cartilage:

- Cartilage is found in the trachea and larger bronchi.
- It provides structural support and prevents collapse of these airways during breathing.

Ciliated Epithelium:

- Ciliated epithelium lines the trachea, bronchi, and larger bronchioles.
- The cilia beat in a coordinated manner to move mucus and trapped particles up towards the pharynx, where they can be swallowed or expelled.

Goblet Cells:

- Goblet cells are scattered among the ciliated epithelium.
- They secrete mucus, which helps trap dust, pathogens, and other particles, and keeps the respiratory surfaces moist.

Squamous Epithelium of Alveoli:

- The alveoli are lined with a thin layer of squamous epithelium, also known as type I alveolar cells.
- These cells are extremely thin to facilitate the rapid diffusion of gases between the alveoli and the capillaries.

Smooth Muscle:

- Smooth muscle is present in the walls of the bronchioles.
- Contraction and relaxation of smooth muscle regulate the diameter of the bronchioles, controlling airflow into the alveoli.

Capillaries:

- Capillaries form a dense network around the alveoli.
- They allow for the exchange of gases between the air in the alveoli and the blood in the capillaries.

3. recognise cartilage, ciliated epithelium, goblet cells, squamous epithelium of alveoli, smooth muscle and capillaries in microscope slides, photomicrographs and electron micrographs

Cartilage:

- Look for a firm, flexible tissue with cells (chondrocytes) embedded in a matrix.
- Cartilage appears as a bluish-white, smooth tissue in slides.
- In electron micrographs, cartilage shows a lacunae matrix with chondrocytes.

Ciliated Epithelium:

- Look for a layer of epithelial cells with cilia on their apical surface.
- Ciliated epithelium often lines the respiratory tract, where the cilia are visible as hair-like projections.
- The cells themselves are often columnar or cuboidal in shape.

Goblet Cells:

- Goblet cells are often found interspersed among the epithelial cells.
- They are typically larger than surrounding cells and contain mucus vesicles, giving them a clear appearance in slides.

Squamous Epithelium of Alveoli:

- In photomicrographs or electron micrographs, look for a thin layer of flattened cells lining the alveoli.
- These cells appear very thin and delicate, allowing for efficient gas exchange.

Smooth Muscle:

- Smooth muscle appears as elongated cells with a single nucleus.

- In slides, smooth muscle may appear more densely packed compared to other tissues.

Capillaries:

- Capillaries are small blood vessels with thin walls.
- Look for structures with a lumen (central space) surrounded by a single layer of endothelial cells.
- In electron micrographs, capillaries appear as thin-walled structures with red blood cells inside.

4. recognise trachea, bronchi, bronchioles and alveoli in microscope slides, photomicrographs and electron micrographs and make plan diagrams of transverse sections of the walls of the trachea and bronchus

Trachea:

- Look for a tubular structure lined with pseudostratified ciliated columnar epithelium.
- The tracheal wall contains cartilage rings, which appear as C-shaped rings of hyaline cartilage in slides.
- In electron micrographs, the trachea shows ciliated columnar cells, goblet cells, and the cartilage rings in the submucosa.

Bronchi:

- Bronchi are larger airways branching from the trachea and have similar features to the trachea but with fewer cartilage rings.
- Look for pseudostratified ciliated columnar epithelium, goblet cells, smooth muscle, and cartilage in the bronchial wall.

Bronchioles:

- Bronchioles are smaller airways that lack cartilage and have a thinner wall compared to bronchi.
- Look for a simple columnar or cuboidal epithelium with fewer cilia and goblet cells.
- Smooth muscle in the bronchiolar wall helps regulate airflow.

Alveoli:

- Alveoli are tiny air sacs where gas exchange occurs.
- They appear as small, round structures clustered together.
- Each alveolus is lined by squamous epithelial cells (type I alveolar cells) for gas exchange and supported by scattered cuboidal cells (type II alveolar cells) that secrete surfactant.

5. describe the functions of ciliated epithelial cells, goblet cells and mucous glands in maintaining the health of the gas exchange system

Ciliated epithelial cells: Move mucus and trapped particles upwards towards the pharynx.

Goblet cells: Produce mucus to trap and immobilize particles, including pathogens and irritants.

Mucous glands: Produce mucus to lubricate and protect the respiratory tract.

6.describe the functions in the gas exchange system of cartilage, smooth muscle,elastic fibres and squamous epithelium

Cartilage: Provides structural support and prevents collapse of the airways.

Smooth muscle: Regulates the diameter of the airways, controlling airflow into the alveoli.

Elastic fibers: Help the airways expand and recoil during breathing.

Squamous epithelium: Facilitates the rapid diffusion of gases between the alveoli and the capillaries.

6. describe gas exchange between air in the alveoli and blood in the capillaries

Oxygen Exchange:

Oxygen (O_2) from the inhaled air diffuses across the moist, thin walls of the alveoli into the surrounding capillaries.

The concentration of oxygen is higher in the alveoli than in the blood, so oxygen moves down its concentration gradient into the blood.

Carbon Dioxide Exchange:

Carbon dioxide (CO_2), which is produced as a waste product of cellular respiration, diffuses from the blood in the capillaries into the alveoli.

The concentration of carbon dioxide is higher in the blood than in the alveoli, so carbon dioxide moves down its concentration gradient into the alveoli to be exhaled.

Transport of Gases:

Oxygen that has diffused into the blood binds to hemoglobin molecules in red blood cells, forming oxyhemoglobin.

Oxyhemoglobin is carried by the bloodstream to the body's tissues, where oxygen is released from hemoglobin and diffuses into the cells.

Carbon dioxide produced by the cells diffuses into the bloodstream and is transported back to the lungs to be exhaled.

10 Infectious diseases (6)

10.1 Infectious diseases

1. state that infectious diseases are caused by pathogens and are transmissible

2. state the name and type of pathogen that causes each of the following diseases:

- cholera – caused by the bacterium Vibrio cholerae
- malaria – caused by the protoctists Plasmodium falciparum, Plasmodium malariae, Plasmodium ovale and Plasmodium vivax
- tuberculosis (TB) – caused by the bacteria Mycobacterium tuberculosis and M terium bovis.
- HIV/AIDS – caused by the human immunodeficiency virus (HIV)

4. explain how cholera, malaria, TB and HIV are transmitted

   Cholera: Cholera is caused by the bacterium Vibrio cholerae, which is typically transmitted through contaminated water or food. Ingesting contaminated food or water can lead to severe diarrhea and dehydration.

   Malaria: Malaria is caused by Plasmodium parasites, which are transmitted to humans through the bites of infected female Anopheles mosquitoes. These mosquitoes typically bite between dusk and dawn, and the parasites multiply in the liver before infecting red blood cells.

   Tuberculosis (TB): TB is caused by the bacterium Mycobacterium tuberculosis, which is spread through the air when an infected person coughs or sneezes. People inhale the bacteria and may develop an active TB infection, especially if their immune system is compromised.

   HIV/AIDS: HIV (Human Immunodeficiency Virus) is transmitted through contact with certain body fluids, such as blood, semen, vaginal fluids, and breast milk, from an infected person. HIV attacks the immune system, leading to AIDS (Acquired Immunodeficiency Syndrome) if left untreated.

4. discuss the biological, social and economic factors that need to be considered in the prevention and control of cholera, malaria, TB and HIV (details of the life cycle of the malarial parasite are not expected)

Biological Factors:

- Understanding the biology and transmission of each disease is crucial.
- Developing vaccines, improving sanitation, and using insecticide-treated bed nets are important biological strategies.

Social Factors:

- Poverty, inadequate sanitation, and limited healthcare access contribute to disease transmission.
- Health education, community engagement, and improving living conditions are vital social interventions.

Economic Factors:

- Economic factors impact access to prevention and treatment.
- Investing in infrastructure and ensuring affordable access to drugs are key economic strategies.

10.2 Antibiotics

1. outline how penicillin acts on bacteria and why antibiotics do not affect viruses

Cell Wall Synthesis Inhibition:

- Bacteria have a cell wall that provides structural support and protection.
- Penicillin interferes with the formation of the bacterial cell wall by inhibiting the enzyme involved in cross-linking the peptidoglycan molecules in the cell wall.
- Without a functional cell wall, bacteria are unable to maintain their structure and integrity, leading to cell lysis and death.

Antibiotics and Viruses:

- Antibiotics like penicillin are ineffective against viruses.
- Viruses are different from bacteria in that they are not complete cells and do not have cell walls.
- Viruses replicate inside host cells using the host cell's machinery, making it difficult to target them without harming the host cell.
- Since antibiotics target specific bacterial functions like cell wall synthesis, they have no effect on viruses.

2. discuss the consequences of antibiotic resistance and the steps that can be taken to reduce its impact

Consequences:

- Infections become harder to treat, leading to prolonged illness, increased mortality, and higher healthcare costs.
- Common infections may become untreatable, potentially leading to increased morbidity and mortality rates.
- The effectiveness of medical procedures that rely on antibiotics, such as surgeries and chemotherapy, may be compromised due to the risk of infection.

Steps to Reduce Impact:

- Antibiotic Stewardship: Promote the responsible use of antibiotics by healthcare providers and patients to prevent overuse and misuse.
- Improved Diagnostics: Develop rapid diagnostic tests to identify the specific

bacteria causing an infection and determine the most effective antibiotic treatment.

- Vaccination: Increase vaccination rates to prevent infections and reduce the need for antibiotics.
- Research and Development: Invest in the development of new antibiotics and alternative treatments to combat resistant bacteria.
- Public Education: Educate the public about the importance of using antibiotics appropriately and completing the prescribed course of treatment.
- Global Cooperation: Coordinate efforts internationally to address antibiotic resistance and implement strategies to combat it effectively.

11 Immunity (10)

11.1 The immune system

1. describe the mode of action of phagocytes (macrophages and neutrophils)

   Chemotaxis: When a pathogen invades the body or there is tissue damage, chemicals released by the damaged cells attract phagocytes to the site of infection or injury. This process is known as chemotaxis.

   Recognition: Phagocytes recognize pathogens through various receptors that bind to specific molecules on the surface of the pathogen. Once recognized, the phagocyte adheres to the pathogen's surface.

   Engulfment: The phagocyte extends pseudopodia (temporary projections of the cell membrane) to surround and engulf the pathogen, forming a phagosome.

   Phagosome Formation: The engulfed pathogen is contained within the phagosome, a vesicle inside the phagocyte.

   Phagolysosome Formation: The phagosome fuses with lysosomes, which are organelles containing digestive enzymes. This forms a phagolysosome, where the pathogen is broken down by the enzymes.

   Destruction: The pathogen is destroyed by the enzymes and other antimicrobial substances within the phagolysosome.

   Exocytosis: After digestion, the waste material is expelled from the phagocyte through exocytosis, and the phagocyte is ready to engulf another pathogen.

2. explain what is meant by an antigen (see 4.1.3) and state the difference between self-antigens and non-self-antigens

An antigen is a molecule that is capable of eliciting an immune response in the body. It can be a protein, a polysaccharide, a glycoprotein, or any other type of molecule that the immune system recognizes as foreign or non-self.

Origin:

- Self Antigens: Self antigens are molecules naturally present in the body's cells and tissues. They are derived from the individual's own cells and are recognized as "self" by the immune system.
- Non-Self Antigens: Non-self antigens are molecules that are foreign to the body. They are derived from external sources such as pathogens (e.g., bacteria, viruses, fungi), toxins, or other foreign substances.

Recognition by the Immune System:

- Self Antigens: The immune system is tolerant to self antigens and does not normally mount an immune response against them. This tolerance is essential to prevent the immune system from attacking the body's own cells and tissues (autoimmunity).
- Non-Self Antigens: Non-self antigens are recognized as foreign by the immune system, which triggers an immune response to eliminate them. This response includes the production of antibodies and activation of immune cells to target and destroy the foreign invaders.

3. describe the sequence of events that occurs during a primary immune response with reference to the roles of:

Recognition of Antigen:

Antigens from pathogens are engulfed and processed by macrophages, which then display fragments of the antigens on their surface.

Activation of T-Helper Cells:

T-helper cells recognize the antigen fragments presented by macrophages and become activated.

Activated T-helper cells secrete cytokines, which stimulate the proliferation and activation of other immune cells, including B-lymphocytes and T-killer cells.

Activation of B-Lymphocytes:

B-lymphocytes that have encountered the antigen become activated.

Activated B-lymphocytes differentiate into plasma cells, which produce and secrete specific antibodies against the antigen.

Antibody Production:

Antibodies are released into the bloodstream and lymphatic system, where they bind to the antigen and mark it for destruction.

Antibodies can neutralize pathogens directly, or they can enhance phagocytosis by macrophages and other phagocytes through a process called opsonization.

Activation of T-Killer Cells:

T-killer cells are activated by cytokines released by T-helper cells.

Activated T-killer cells directly attack and destroy infected cells or cells displaying antigens on their surface.

Resolution of the Infection:

The combined action of antibodies, T-killer cells, and other immune cells leads to the elimination of the pathogen.

Some activated B-lymphocytes and T-lymphocytes differentiate into memory cells, which provide long-lasting immunity against future infections by the same pathogen.

4. explain the role of memory cells in the secondary immune response and in long-term immunity

Secondary Immune Response:

- Memory B-lymphocytes and memory T-lymphocytes are long-lived cells that remain in the body after the primary immune response.
- If the same pathogen re-infects the body, memory cells recognize the antigen quickly and mount a faster, stronger, and more effective immune response compared to the primary response.
- Memory B-lymphocytes quickly differentiate into plasma cells that produce large quantities of specific antibodies, helping to eliminate the pathogen more rapidly.

Long-Term Immunity:

- Memory cells provide long-lasting immunity against specific pathogens.
- Memory B-lymphocytes and memory T-lymphocytes persist in the body for years or even a lifetime, ready to respond rapidly to re-infection.
- This long-term immunity is the basis for the effectiveness of vaccines, which stimulate the production of memory cells without causing the disease itself.

11.2 Antibodies and vaccination

1. relate the molecular structure of antibodies to their functions

Y-Shaped Structure:

- Antibodies are made up of four polypeptide chains: two heavy chains and two light chains, which are connected by disulfide bonds.
- The Y-shaped structure allows antibodies to bind to antigens with high specificity.

Variable Regions:

- The tips of the Y-shaped antibodies contain variable regions, which are highly variable in amino acid sequence.
- These variable regions enable antibodies to recognize and bind to a wide range of antigens with high specificity.

Constant Regions:

- The stem of the Y-shaped antibodies contains constant regions, which are more conserved in amino acid sequence.
- The constant regions determine the class (isotype) of the antibody and its functional properties, such as activating complement or binding to immune cells.

Antigen Binding:

- The variable regions of the antibody form the antigen-binding site, which binds to specific regions (epitopes) on the antigen.
- This binding is highly specific and allows antibodies to recognize and neutralize pathogens or mark them for destruction by other immune cells.

2. outline the hybridoma method for the production of monoclonal antibodies

Immunization:

An animal (usually a mouse) is immunized with the antigen of interest to stimulate an immune response.

B-lymphocytes in the spleen of the immunized animal produce antibodies against the antigen.

Isolation of B-lymphocytes:

The spleen cells containing the B-lymphocytes producing the desired antibodies are isolated from the immunized animal.

Fusion with Myeloma Cells:

The isolated B-lymphocytes are fused with myeloma cells (cancerous B-lymphocytes that can be grown indefinitely in culture).

The fusion is typically achieved using a technique involving polyethylene glycol (PEG).

Selection of Hybridoma Cells:

After fusion, the mixture of cells contains unfused myeloma cells, unfused B-lymphocytes, and fused hybridoma cells.

Selection techniques (e.g., culture media containing a selective agent) are used to isolate the hybridoma cells.

Cloning:

Single hybridoma cells are isolated and grown into separate colonies, each producing antibodies against the specific antigen.

This process ensures that each colony consists of cells producing a single type of antibody (monoclonal).

Screening and Expansion:

The monoclonal antibodies produced by the different hybridoma cell colonies are screened for their specificity and affinity to the antigen.

Selected hybridoma cell lines are expanded in culture to produce larger quantities of monoclonal antibodies.

Harvesting Monoclonal Antibodies:

Monoclonal antibodies are harvested from the culture supernatant of the selected hybridoma cell lines.

The antibodies can be purified for use in research, diagnostics, and therapy.

3. outline the principles of using monoclonal antibodies in the diagnosis of disease andin the treatment of disease

Diagnosis:

- Finding Disease Markers: Monoclonal antibodies are used to find specific markers that indicate a disease, like antigens on viruses or cancer cells.
- Tests: They're used in tests (like ELISA) to check for these markers in blood or tissue samples.
- Imaging: In some tests, they're used to help see inside the body and find diseases, like cancer.

Treatment:

- Targeting Specific Cells: Monoclonal antibodies can be made to attach to certain cells, like cancer cells, helping to treat them.
- Boosting Immune System: They can also help the immune system fight diseases better, like in some cancer treatments.
- Reducing Inflammation: For diseases where the immune system attacks the body (like in some types of arthritis), monoclonal antibodies can help calm down the immune response.

4. describe the differences between active immunity and passive immunity andbetween natural immunity and artificial immunity

Active Immunity vs. Passive Immunity:

- Active Immunity: Occurs when the body's immune system produces its own antibodies in response to an antigen (e.g., from a vaccine or natural infection). It provides long-lasting protection because memory cells are produced.
- Passive Immunity: Involves the transfer of antibodies from one individual to another. This can be naturally acquired, such as through maternal antibodies passed to a fetus during pregnancy, or artificially acquired, such as through the injection of antibodies (e.g., antivenom).

Natural Immunity vs. Artificial Immunity:

- Natural Immunity: Occurs through natural exposure to pathogens or antigens. For example, when someone gets sick with a disease and then develops immunity to it.
- Artificial Immunity: Results from deliberate exposure to antigens, such as through vaccination. It is a way to induce immunity without causing the disease itself.

5. explain that vaccines contain antigens that stimulate immune responses to providelong-term immunity

   Vaccines are made from weakened or killed germs or parts of germs. When you get a vaccine, these tiny bits of germs stimulate your immune system, which is like your body's defense force, to produce antibodies. These antibodies are like soldiers that can recognize and fight off the specific germ if you are exposed to it later. The vaccine also helps your immune system develop memory cells, which remember how to fight the germ in the future. This way, if you are ever exposed to the real germ, your immune system can quickly recognize and destroy it, protecting you from getting sick. Vaccines are an important tool in preventing infectious diseases and keeping communities healthy.

6. explain how vaccination programmes can help to control the spread of infectious diseases.

Direct Protection: Vaccines protect individuals from getting sick by stimulating their immune systems to produce antibodies against specific pathogens. This reduces the likelihood of an individual becoming infected and spreading the disease.

Herd Immunity: When a large portion of a population is vaccinated, it creates a "herd immunity" effect. This means that even those who are not vaccinated or who cannot be vaccinated (due to age, health conditions, or other reasons) are protected because the disease has little opportunity to spread within the community.

Break the Chain of Transmission: Vaccination programs help break the chain of transmission of infectious diseases. By reducing the number of susceptible individuals in a population, the likelihood of an infected person coming into contact with someone who is susceptible is greatly reduced.

Prevent Outbreaks and Epidemics: High vaccination rates can prevent outbreaks and epidemics of vaccine-preventable diseases. Even if a few cases occur, the disease is less likely to spread widely in a vaccinated population.

Protect Vulnerable Populations: Vaccination programs protect vulnerable populations, such as infants, the elderly, and those with weakened immune systems, who are at higher risk of severe complications from infectious diseases.

Cost-Effective Public Health Intervention: Vaccination is a cost-effective public health intervention. The cost of vaccinating a population is often much lower than the cost of treating the disease and dealing with its consequences