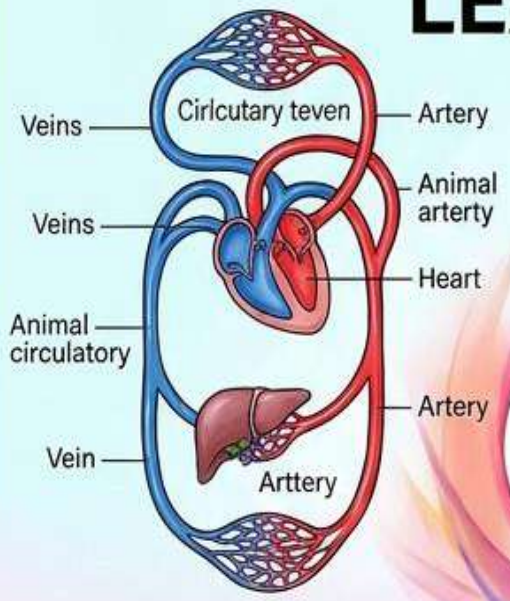
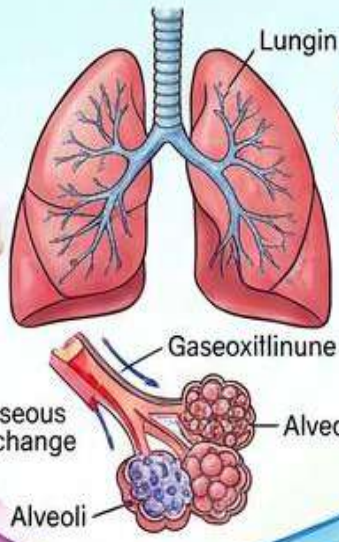
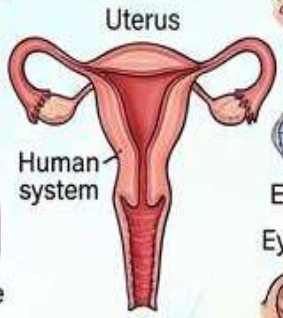
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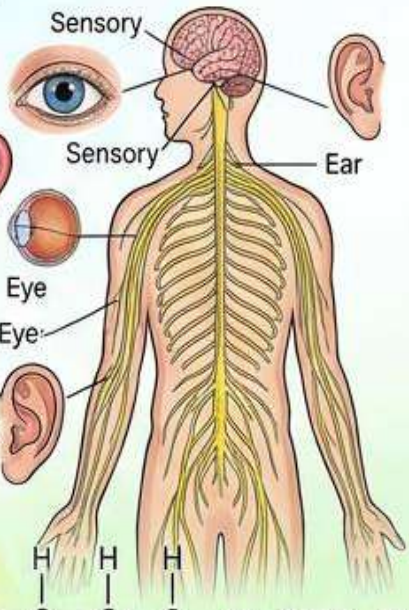
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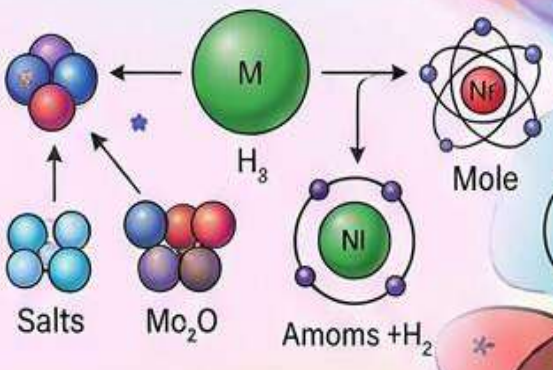
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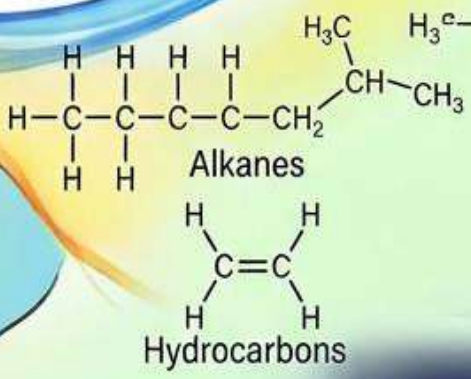


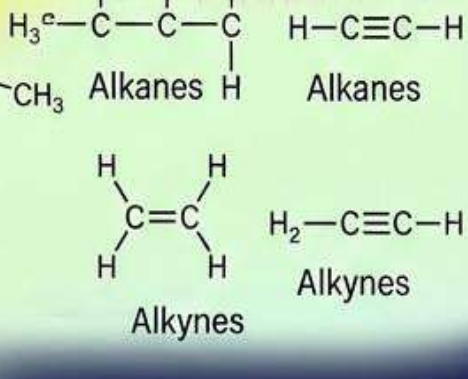


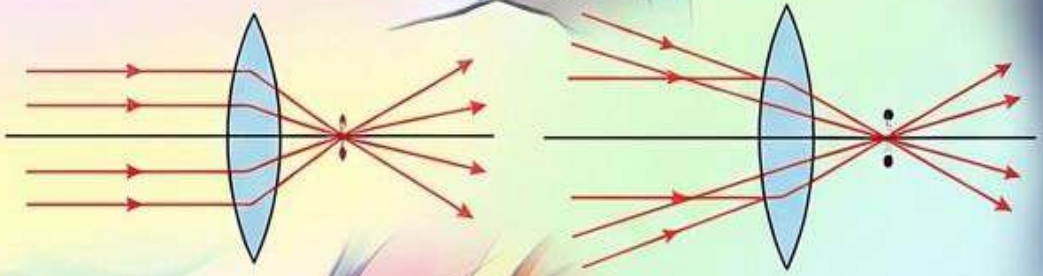


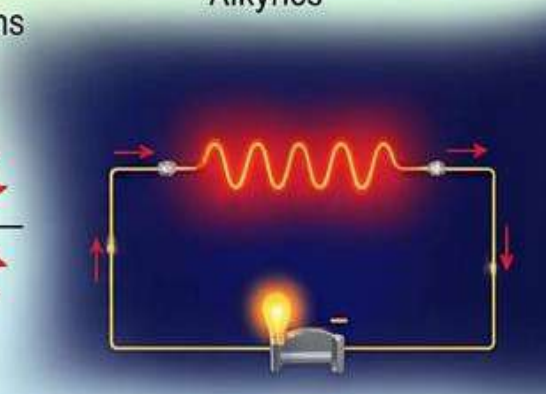


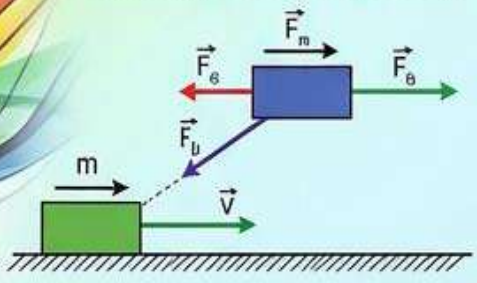














SUB-STRAND 1.1: TRANSPORT IN ANIMALS

1.0 INTRODUCTION TO TRANSPORT IN ANIMALS

1.1 Meaning of transport in animals

Transport in animals refers to the movement of substances from one part of the body to another to ensure that all body cells receive the materials they need and that waste products are removed.

Animals require a continuous supply of essential substances for growth, repair, energy production and other life processes.

In human beings, transport is mainly carried out by the **circulatory system**, which consists of the heart, blood vessels and blood.

1.2 Importance of transport in animals

The transport system performs the following functions:

1. **Transportation of oxygen:** Carries oxygen from the lungs to body cells for cellular respiration.
2. **Transportation of nutrients:** Moves digested food substances such as glucose, amino acids and fatty acids from the digestive system to body cells.
3. **Removal of waste products:** Transports carbon dioxide from body cells to the lungs for removal.
4. **Transportation of hormones:** Carries hormones from endocrine glands to their target organs.
5. **Distribution of heat:** Helps distribute heat throughout the body to maintain a relatively constant body temperature.
6. **Defence against infections:** Transports white blood cells and antibodies that protect the body against disease-causing microorganisms.
7. **Blood clotting:** Helps prevent excessive blood loss when blood vessels are damaged.
8. **Maintenance of internal balance:** Helps regulate water levels, pH and the concentration of substances in body fluids.

1.3 Why do animals need a transport system?

- Most animals have large bodies with many cells.
- Many cells are located far away from the external environment.
- Diffusion alone is too slow to transport sufficient materials over long distances.
- Cells require a continuous supply of oxygen and nutrients.
- Waste products must be removed before they accumulate to harmful levels.

Example: In human beings, oxygen absorbed into the blood in the lungs is transported to muscles during physical activities such as running, playing football and cycling.

1.4 The human circulatory system

The human circulatory system is a transport system responsible for circulating blood throughout the body.

It is a **closed, double circulatory system** because:

- Blood flows inside blood vessels.
- During one complete circulation, blood passes through the heart twice.

There are three major components of the human circulatory system:

1. The heart.
2. Blood vessels.
3. Blood.

2.0 COMPONENTS OF THE HUMAN CIRCULATORY SYSTEM

2.1 The heart

The heart is a hollow, muscular organ located in the thoracic cavity (chest), between the lungs, slightly towards the left side.

It is approximately the size of a person's closed fist.

The heart acts as a muscular pump that maintains the continuous circulation of blood throughout the body.

Main functions of the heart

1. Pumps deoxygenated blood to the lungs for oxygenation.
2. Pumps oxygenated blood to all parts of the body.
3. Maintains blood pressure necessary for blood circulation.
4. Ensures continuous delivery of oxygen and nutrients to body tissues.
5. Helps maintain efficient removal of metabolic waste products.

2.2 Structure of the human heart

The human heart consists of four chambers:

- Right atrium.
- Left atrium.
- Right ventricle.
- Left ventricle.

The atria are the upper chambers, while the ventricles are the lower chambers.

A. Right atrium

- It is the upper chamber on the right side of the heart.
- Receives deoxygenated blood from different parts of the body.
- Blood enters through the superior and inferior vena cava.
- It passes blood into the right ventricle through the tricuspid valve.

B. Left atrium

- It is the upper chamber on the left side of the heart.
- Receives oxygenated blood from the lungs.
- Blood enters through the pulmonary veins.
- It pumps blood into the left ventricle through the bicuspid (mitral) valve.

C. Right ventricle

- It is the lower chamber on the right side of the heart.
- Receives deoxygenated blood from the right atrium.
- Pumps blood to the lungs through the pulmonary artery.

- Its muscular wall is thicker than that of the atria because it pumps blood over a greater distance.

D. Left ventricle

- It is the lower chamber on the left side of the heart.
- Receives oxygenated blood from the left atrium.
- Pumps blood to all parts of the body through the aorta.
- Has the thickest muscular wall because it pumps blood at high pressure throughout the body.

2.3 Other important structures of the heart

Structure	Description and function
Septum	Muscular wall separating the right and left sides of the heart; prevents mixing of oxygenated and deoxygenated blood.
Tricuspid valve	Prevents backflow of blood from the right ventricle into the right atrium.
Bicuspid valve	Prevents backflow of blood from the left ventricle into the left atrium.
Pulmonary valve	Prevents backflow of blood from the pulmonary artery into the right ventricle.
Aortic valve	Prevents backflow of blood from the aorta into the left ventricle.
Aorta	Carries oxygenated blood from the left ventricle to the body.
Pulmonary artery	Carries deoxygenated blood from the right ventricle to the lungs.
Pulmonary veins	Carry oxygenated blood from the lungs to the left atrium.
Vena cava	Returns deoxygenated blood from the body to the right atrium.
Coronary arteries	Supply oxygenated blood and nutrients to the heart muscle.

2.4 Functions of the valves

Valves are flap-like structures that ensure blood flows in one direction.

Their functions include:

1. Preventing backward flow of blood.
2. Maintaining one-way circulation.
3. Ensuring efficient pumping of blood.
4. Maintaining the pressure needed for blood circulation.

Importance: When heart valves fail to function properly, blood may flow backwards, reducing the efficiency of the heart.

2.5 Adaptations of the heart to its functions

The human heart has several structural features that enable it to pump blood efficiently.

Adaptation	How it helps the heart
Thick muscular walls	Generate sufficient force to pump blood.
Four chambers	Allow separation of oxygenated and deoxygenated blood.
Valves	Prevent backward flow of blood.
Septum	Prevents mixing of oxygenated and deoxygenated blood.
Thick left ventricular wall	Produces high pressure to pump blood throughout the body.
Coronary arteries	Supply the heart muscle with oxygen and nutrients.
Cardiac muscle	Contracts and relaxes continuously without tiring easily.
Pacemaker tissue	Initiates and regulates the heartbeat.

2.6 The cardiac cycle

The cardiac cycle refers to the sequence of events involving contraction and relaxation of the heart chambers during one heartbeat.

It consists of three main stages.

A. Atrial systole

- Both atria contract.
- Blood is pushed into the ventricles.
- The atrioventricular valves remain open.
- The ventricles fill with blood.

B. Ventricular systole

- Both ventricles contract.
- The tricuspid and bicuspid valves close.
- The pulmonary and aortic valves open.
- Blood is pumped to the lungs and the rest of the body.

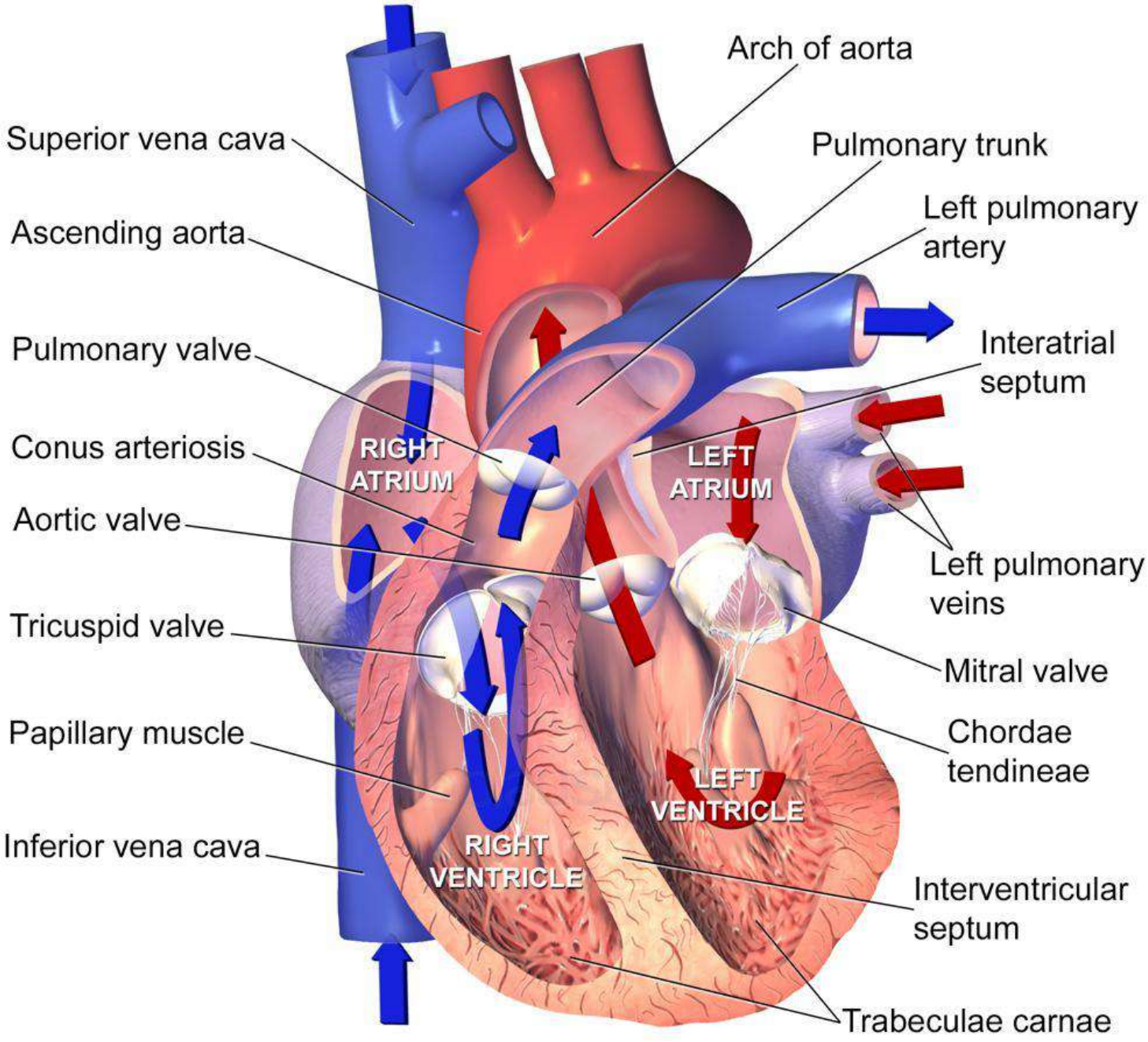
C. Complete cardiac diastole

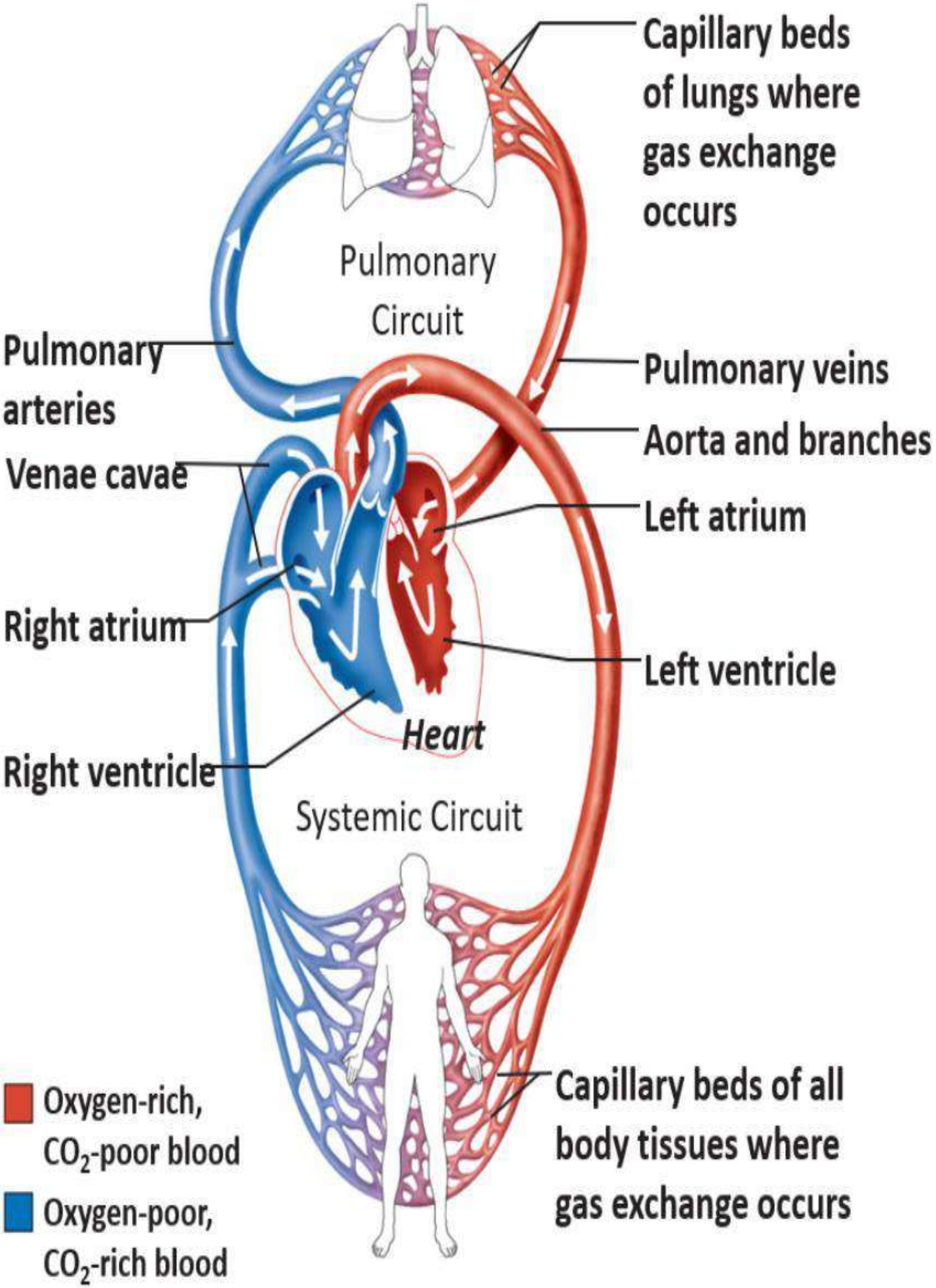
- Both atria and ventricles relax.
- Blood enters the atria from the veins.
- Blood flows into the ventricles.
- The heart prepares for another heartbeat.

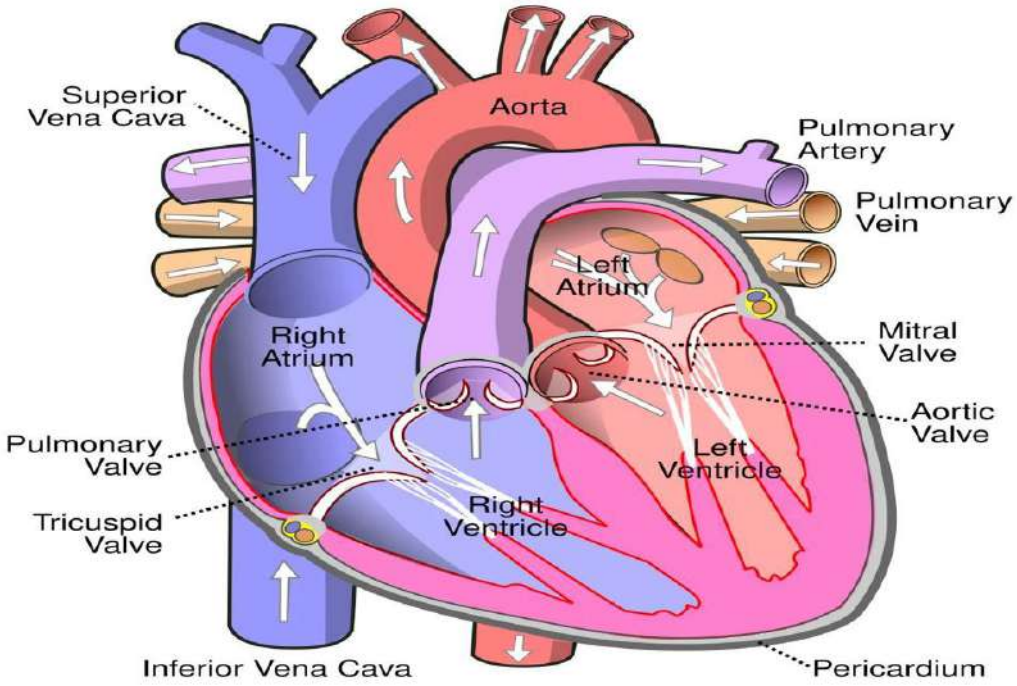
Heart rate

Heart rate refers to the number of heartbeats per minute.

- It is commonly measured by feeling the pulse.
- It varies with age, physical activity, emotions and health.
- During exercise, heart rate increases to supply working muscles with more oxygen and nutrients.


Arch of aorta
Superior vena cava
Pulmonary trunk
Left pulmonary artery
Ascending aorta
Interatrial septum
Pulmonary valve
RIGHT ATRIUM
LEFT ATRIUM
Conus arteriosis
Aortic valve
Left pulmonary veins
Tricuspid valve
Mitral valve
Papillary muscle
Chordae tendineae
LEFT VENTRICLE
RIGHT VENTRICLE
Inferior vena cava
Interventricular septum
Trabeculae carnae


Capillary beds of lungs where gas exchange occurs
Pulmonary Circuit
Pulmonary arteries
Pulmonary veins
Aorta and branches
Venae cavae
Left atrium
Right atrium
Left ventricle
Heart
Right ventricle
Systemic Circuit
Capillary beds of all body tissues where gas exchange occurs
Oxygen-rich, CO_2-poor blood
Oxygen-poor, CO_2-rich blood



2.7 Pathway of blood through the heart

Blood follows a definite pathway through the heart, lungs and body.

The pathway is:

1. Deoxygenated blood from body tissues enters the superior and inferior vena cava.
2. Blood flows into the right atrium.
3. It passes through the tricuspid valve into the right ventricle.
4. The right ventricle pumps blood through the pulmonary artery to the lungs.
5. In the lungs, blood releases carbon dioxide and receives oxygen.
6. Oxygenated blood returns to the left atrium through the pulmonary veins.
7. It passes through the bicuspid valve into the left ventricle.
8. The left ventricle pumps blood through the aorta.
9. The aorta distributes oxygenated blood to all parts of the body.

Important scientific fact: The pulmonary artery carries deoxygenated blood, while the pulmonary veins carry oxygenated blood. These are exceptions to the usual oxygen content of arteries and veins.

3.0 BLOOD VESSELS: STRUCTURE AND FUNCTIONS

3.1 Meaning of blood vessels

Blood vessels are tube-like structures through which blood flows between the heart and different parts of the body.

They form an extensive network throughout the human body.

There are three main types of blood vessels:

1. Arteries.
2. Veins.
3. Capillaries.

3.2 Arteries

Arteries are blood vessels that carry blood away from the heart to different parts of the body.

Characteristics of arteries

- Have thick, muscular walls.
- Have many elastic fibres in their walls.
- Have relatively narrow internal spaces called lumens.
- Carry blood under high pressure.
- Usually carry oxygenated blood, except the pulmonary artery.
- Generally do not have valves along their lengths.

Functions of arteries

1. Transport blood away from the heart.
2. Distribute oxygenated blood to body tissues.
3. Maintain blood pressure through their elastic and muscular walls.
4. Supply blood to organs through smaller branches called arterioles.

Adaptations of arteries to their functions

Adaptation	Importance
Thick muscular walls	Withstand high blood pressure.
Elastic fibres	Allow stretching and recoil as blood is pumped.
Narrow lumen	Helps maintain high blood pressure.
Smooth inner lining	Reduces friction as blood flows.

3.3 Veins

Veins are blood vessels that carry blood towards the heart from different parts of the body.

Characteristics of veins

- Have relatively thin walls.
- Have less muscular and elastic tissue than arteries.
- Have wider lumens than arteries.
- Carry blood under low pressure.
- Contain valves that prevent backward flow of blood.
- Usually carry deoxygenated blood, except the pulmonary veins.

Functions of veins

1. Return blood from body tissues to the heart.
2. Transport deoxygenated blood to the heart.
3. Help maintain blood circulation.
4. Act as blood reservoirs because they can accommodate large volumes of blood.

Adaptations of veins to their functions

Adaptation	Importance
Thin walls	Suitable for carrying blood under low pressure.
Wide lumen	Reduces resistance to blood flow.
Valves	Prevent backward flow of blood.
Smooth inner lining	Reduces friction.

3.4 Capillaries

Capillaries are very small blood vessels that connect arterioles to venules.

They form networks within body tissues and are the main sites of exchange between blood and body cells.

Characteristics of capillaries

- Have extremely thin walls consisting of a single layer of endothelial cells.
- Have very narrow lumens.
- Form extensive networks in body tissues.
- Allow substances to move between blood and surrounding cells.

Functions of capillaries

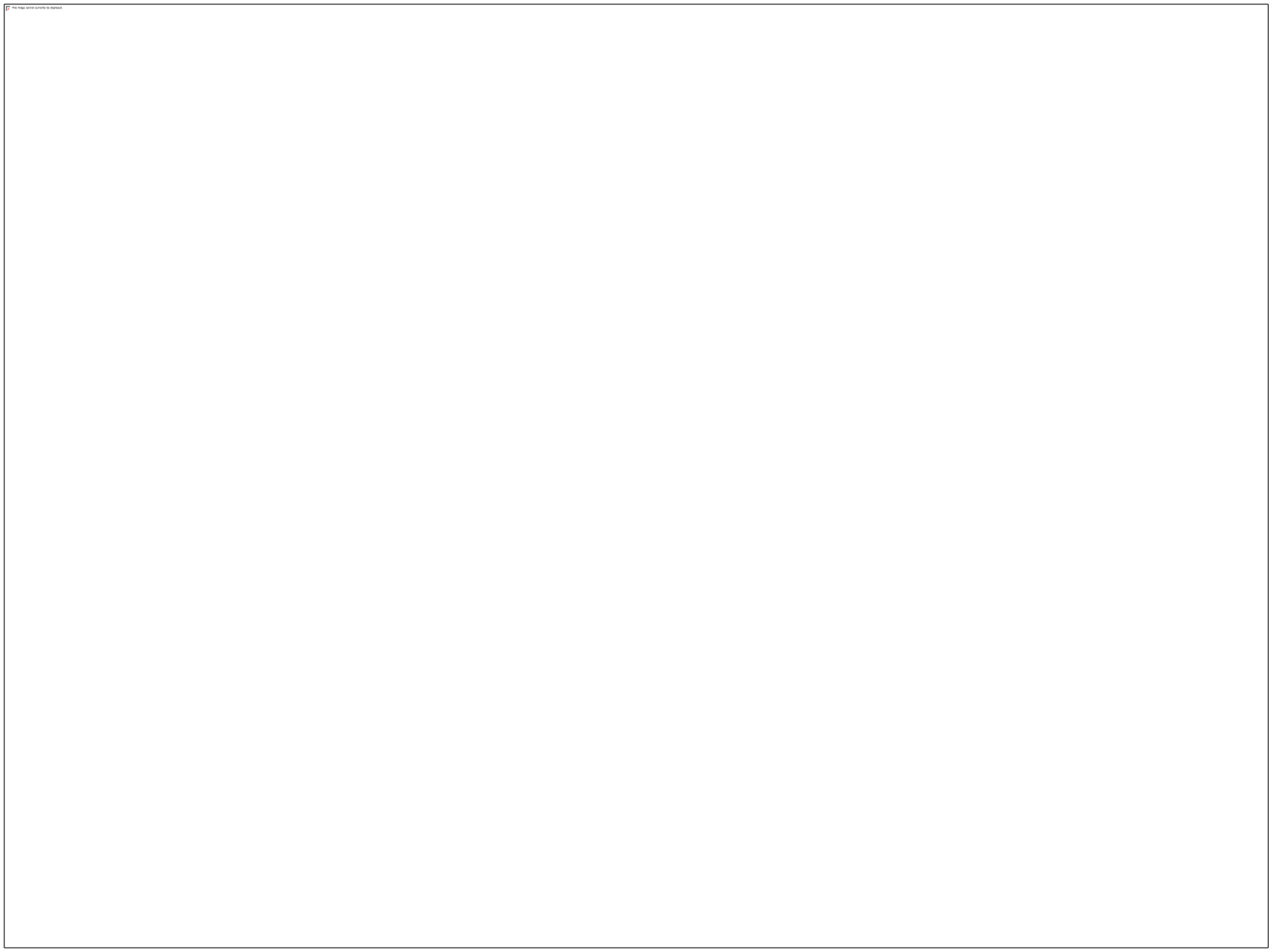
1. Allow oxygen to diffuse from blood into body cells.
2. Allow carbon dioxide to diffuse from body cells into blood.
3. Allow nutrients to move from blood into body tissues.
4. Allow waste products to enter the blood.
5. Facilitate the exchange of water and dissolved substances between blood and tissues.

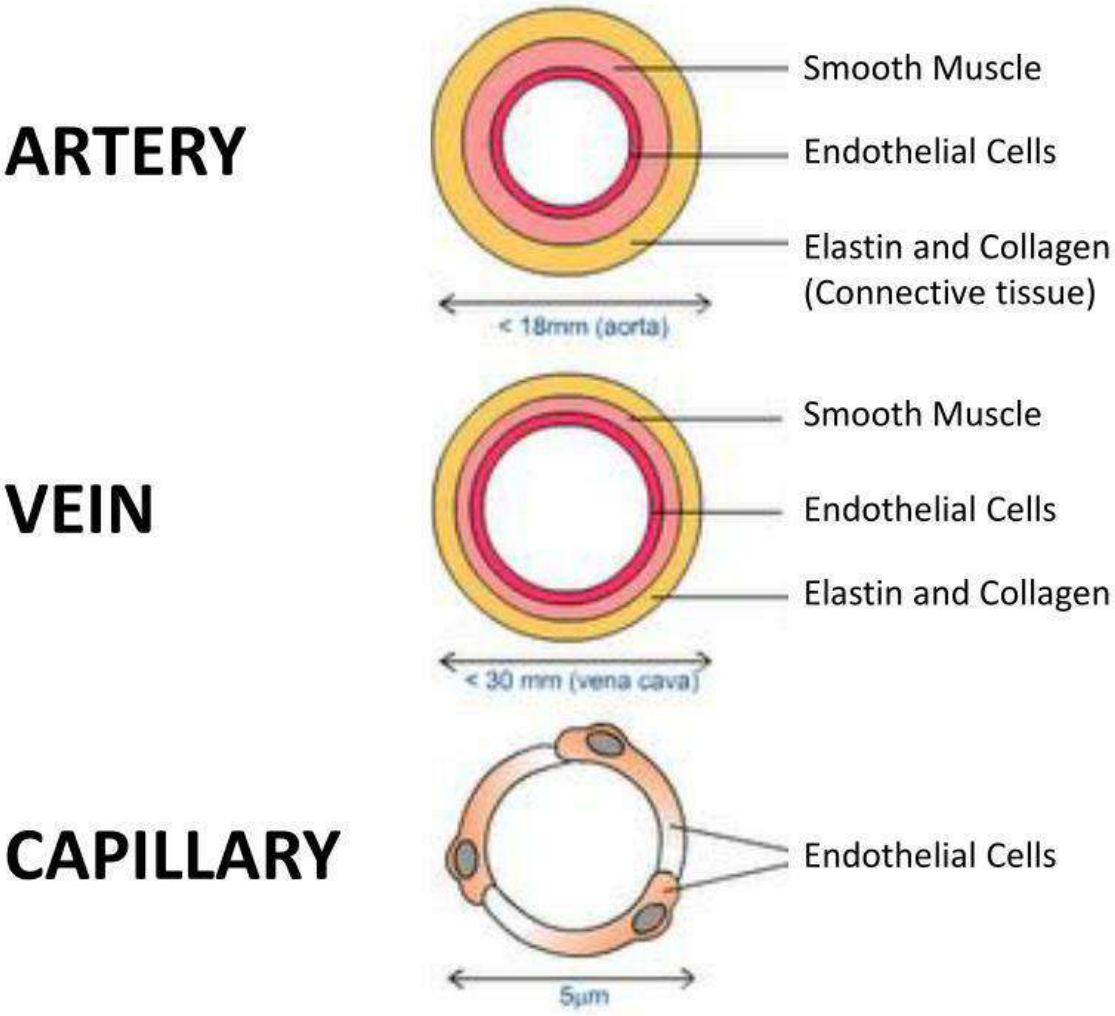
Adaptations of capillaries to their functions

Adaptation	Importance
Walls are one cell thick	Allow rapid diffusion of substances.
Extensive network	Provides a large surface area for exchange.
Narrow lumen	Slows blood flow, allowing sufficient time for exchange.
Close contact with body cells	Reduces the distance substances travel.

3.5 Differences between arteries, veins and capillaries

Feature	Arteries	Veins	Capillaries
Direction of blood flow	Away from heart	Towards heart	Between arterioles and venules
Wall thickness	Thick	Thin	One cell thick
Lumen	Narrow	Wide	Very narrow
Blood pressure	High	Low	Relatively low
Valves	Generally absent	Present in many veins	Absent
Main function	Transport blood from heart	Return blood to heart	Exchange substances
Oxygen content	Usually oxygenated	Usually deoxygenated	Varies along the capillary





3.6 Pulse and its relationship with blood circulation

A pulse is the rhythmic expansion and recoil of an artery caused by the pressure of blood pumped from the heart.

Common pulse points in the human body

- Wrist (radial artery).
- Neck (carotid artery).
- Temple (temporal artery).
- Inside the elbow (brachial artery).
- Groin (femoral artery).

How to measure the pulse rate

1. Allow the person to rest comfortably.
2. Place the index and middle fingers on the wrist or neck.
3. Apply gentle pressure until the pulse is felt.
4. Count the beats for 60 seconds.
5. Record the number of beats per minute.

Note: The thumb should not be used because it has its own detectable pulse.

Factors affecting pulse rate

- Physical exercise.
- Age.
- Emotional excitement.
- Fever.
- Stress.
- General health.
- Certain medicines.

3.7 Comparison of blood pressure in different blood vessels

Blood pressure is the force exerted by circulating blood against the walls of blood vessels.

- It is highest in the arteries close to the heart.
- It decreases as blood moves through smaller arteries and capillaries.
- It is lowest in the large veins returning blood to the heart.

In adults, a commonly used reference blood pressure is approximately 120/80 mmHg, although healthy readings vary between individuals.

4.0 BLOOD: STRUCTURE AND FUNCTIONS

4.1 Meaning of blood

Blood is a specialised fluid connective tissue that circulates throughout the body, transporting substances and protecting the body against diseases.

It consists of two major components:

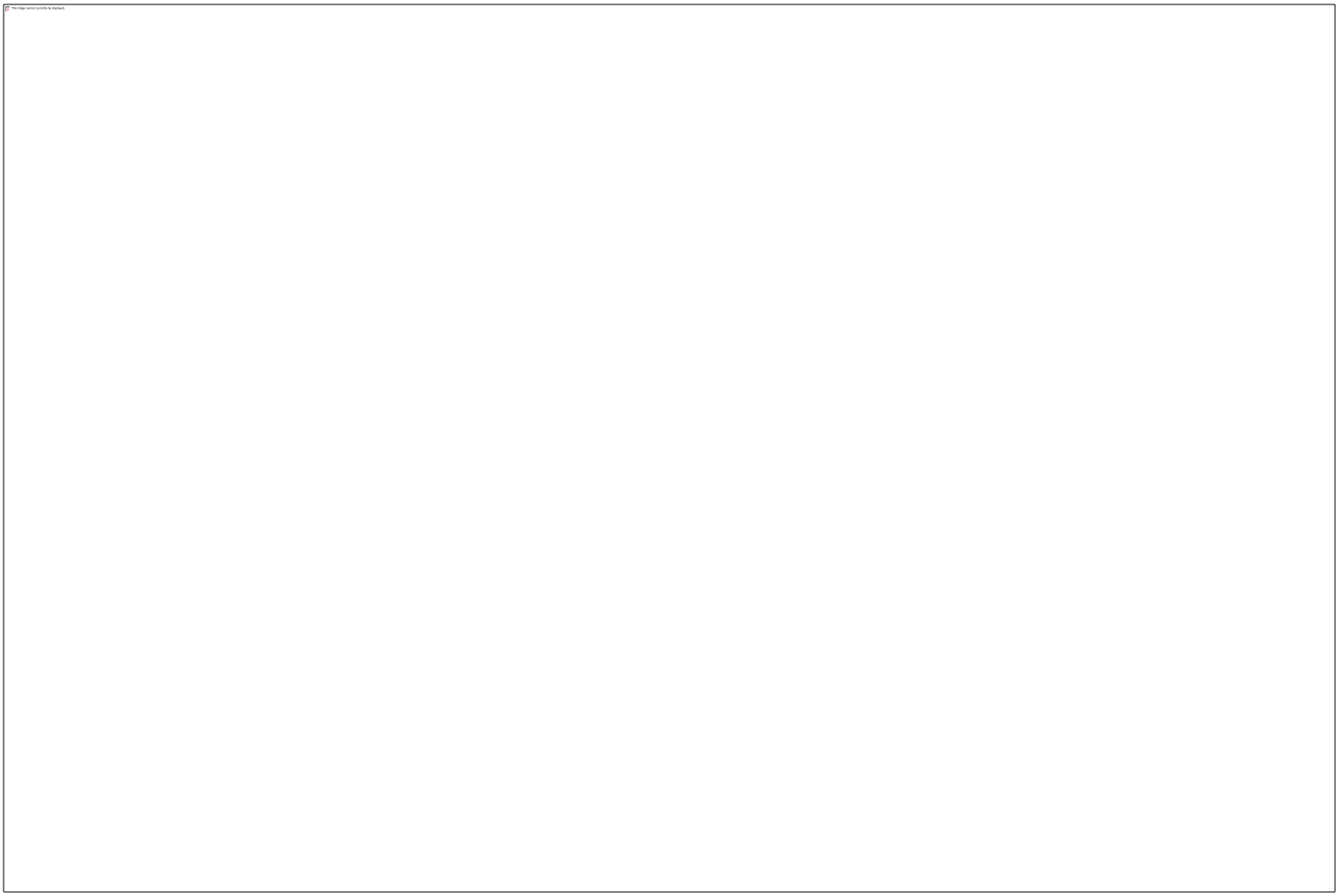
1. Plasma – the liquid component.
2. Blood cells and cell fragments – the formed elements.

Blood accounts for approximately 7–8% of an adult's body mass.

4.2 Components of blood

The four major components of blood are:

1. Red blood cells.
2. White blood cells.
3. Platelets.
4. Plasma.



4.3 Red blood cells (erythrocytes)

Red blood cells are specialised blood cells responsible for transporting oxygen from the lungs to body tissues.

Structure of red blood cells

- They are small and circular.
- They have a biconcave disc shape.
- Mature human red blood cells lack a nucleus.
- They contain a red pigment called haemoglobin.
- They are flexible, enabling them to pass through narrow capillaries.

Functions of red blood cells

1. Transport oxygen from the lungs to body tissues.
2. Assist in transporting some carbon dioxide from body tissues to the lungs.
3. Help maintain the acid-base balance of blood.

Adaptations of red blood cells to their functions

Adaptation	Importance
Biconcave shape	Provides a large surface area for gaseous exchange.
Lack of nucleus when mature	Creates more space for haemoglobin.
Presence of haemoglobin	Enables oxygen to be transported.
Flexible cell membrane	Allows movement through narrow capillaries.
Small size	Enables movement through tiny blood vessels.

Haemoglobin

Haemoglobin is an iron-containing red pigment found in red blood cells that combines reversibly with oxygen.

In the lungs:

- Oxygen combines with haemoglobin.
- Oxyhaemoglobin is formed.

In body tissues:

- Oxyhaemoglobin releases oxygen.
- Oxygen diffuses into body cells.

Equation:

Hb+O2⇌HbO2*Hb*+*O*2⇌*Hb*O2

Where:

- Hb = Haemoglobin.
- O_2 = Oxygen.
- HbO_2 = Oxyhaemoglobin.

4.4 White blood cells (leucocytes)

White blood cells are blood cells responsible for protecting the body against disease-causing microorganisms and foreign substances.

Characteristics of white blood cells

- They are generally larger than red blood cells.
- They have nuclei.
- They lack haemoglobin.
- They are usually fewer in number than red blood cells.
- Some can change their shape.
- Some can move through blood vessel walls into body tissues.

Types of white blood cells

The major types include:

A. Phagocytes

Phagocytes are white blood cells that protect the body by engulfing and destroying pathogens through a process called phagocytosis.

Functions:

1. Engulf bacteria and other foreign particles.
2. Digest harmful microorganisms.
3. Remove dead and damaged cells.
4. Help prevent the spread of infections.

B. Lymphocytes

Lymphocytes are white blood cells involved in specific immune responses.

There are two major types:

- B lymphocytes.
- T lymphocytes.

Functions of B lymphocytes:

1. Produce antibodies.
2. Help recognise specific antigens.
3. Form memory cells that provide long-term immunity.

Functions of T lymphocytes:

1. Destroy infected body cells.
2. Coordinate immune responses.
3. Help regulate the activity of other immune cells.

4.5 Platelets (thrombocytes)

Platelets are small cell fragments in the blood that help in blood clotting.

They are produced in the bone marrow from large cells called megakaryocytes.

Functions of platelets

1. Help stop bleeding when blood vessels are damaged.
2. Form a temporary plug at the site of injury.
3. Release substances that promote blood clotting.
4. Assist in wound healing.

The process of blood clotting

Blood clotting is the process by which blood changes from a liquid into a semi-solid clot to prevent excessive blood loss.

The process involves the following stages:

1. A blood vessel is damaged.
2. Platelets gather at the injured area and form a temporary plug.
3. Clotting factors are activated.
4. Prothrombin is converted into thrombin.
5. Thrombin converts soluble fibrinogen into insoluble fibrin.
6. Fibrin forms a network of fibres that traps blood cells and platelets.
7. A blood clot forms and seals the wound.

The process can be summarised as:

Prothrombin→ThrombinProthrombin→Thrombin

Fibrinogen→FibrinFibrinogen→Fibrin

Calcium ions and vitamin K are important in normal blood clotting.

4.6 Plasma

Plasma is the pale-yellow liquid component of blood in which blood cells and platelets are suspended.

It makes up approximately 55% of the total blood volume.

Composition of plasma

Plasma contains:

- Water (approximately 90–92%).
- Plasma proteins.
- Mineral salts.
- Nutrients.
- Hormones.
- Dissolved gases.
- Waste products.

Functions of plasma

1. Transports digested nutrients to body cells.
2. Carries hormones from endocrine glands to target organs.
3. Transports carbon dioxide and other waste products.
4. Distributes heat throughout the body.
5. Maintains blood volume.
6. Helps maintain blood pH.
7. Contains antibodies that help fight infections.
8. Contains clotting proteins such as fibrinogen.

Major plasma proteins

Protein	Function
Albumin	Maintains osmotic pressure and helps regulate fluid balance.
Globulins	Include antibodies involved in body defence.
Fibrinogen	Participates in blood clotting.

4.7 Summary of blood components

Component	Main function
Red blood cells	Transport oxygen.
White blood cells	Defend the body against infections.
Platelets	Help in blood clotting.
Plasma	Transports dissolved substances and distributes heat.

4.8 Importance of blood in human beings

Blood performs several essential functions:

1. Transports oxygen and nutrients.
2. Removes metabolic waste products.
3. Protects the body against infections.
4. Prevents excessive blood loss through clotting.
5. Regulates body temperature.
6. Maintains fluid and chemical balance.

7. Transports hormones.
8. Supports communication between different body organs.

5.0 ABO BLOOD GROUPS AND BLOOD TRANSFUSION

5.1 Meaning of blood groups

Blood groups are classifications of blood based on the presence or absence of specific antigens on the surface of red blood cells.

The ABO blood group system classifies human blood into four major groups:

- Group A.
- Group B.
- Group AB.
- Group O.

5.2 Meaning of antigens and antibodies

Antigens: These are substances, usually proteins or carbohydrates on the surface of cells, that can trigger an immune response.

In the ABO system, the important antigens are A and B.

Antibodies: These are specialised proteins produced by the immune system that recognise and bind to specific antigens.

The ABO blood group system involves anti-A and anti-B antibodies.

5.3 Classification of ABO blood groups

Blood group	Antigens on red blood cells	Antibodies in plasma
A	A antigen	Anti-B
B	B antigen	Anti-A
AB	A and B antigens	Neither anti-A nor anti-B
O	Neither A nor B	Anti-A and anti-B

Explanation of the four blood groups

A. Blood group A

- Has A antigens on red blood cells.
- Has anti-B antibodies in plasma.
- Can receive compatible red blood cells from groups A and O.

B. Blood group B

- Has B antigens on red blood cells.
- Has anti-A antibodies in plasma.
- Can receive compatible red blood cells from groups B and O.

C. Blood group AB

- Has both A and B antigens.
- Does not have anti-A or anti-B antibodies in plasma.
- Can receive compatible red blood cells from all four ABO groups, provided other compatibility requirements are met.
- Is known as the universal ABO red-cell recipient.

D. Blood group O

- Has neither A nor B antigens on red blood cells.
- Has both anti-A and anti-B antibodies in plasma.
- Can receive compatible red blood cells from group O only.
- Group O negative is commonly referred to as the universal red-cell donor in emergency settings, but proper testing is still required.

BLOOD GROUP	A	B	AB	O
RED BLOOD CELL TYPE				
ANTIGENES IN RED BLOOD CELLS	 A ANTIGEN	 B ANTIGEN	 A AND B ANTIGEN	NONE
ANTIBODIES IN PLASMA	 ANTI-B	 ANTI-A	NONE	 ANTI-B ANTIGEN

5.4 Blood transfusion

Blood transfusion is the medical procedure of transferring blood or blood components from a donor to a recipient through a vein.

It is commonly used to replace blood lost through accidents, surgery, childbirth or certain medical conditions.

Reasons why a person may require a blood transfusion

1. Severe blood loss following an accident.
2. Excessive bleeding during childbirth.
3. Blood loss during major surgery.
4. Severe anaemia.
5. Certain blood disorders.
6. Some cancer treatments.
7. Severe internal bleeding.

5.5 Blood transfusion compatibility

Blood transfusion compatibility refers to the ability of donor blood to be safely received by a recipient without causing a harmful immune reaction.

For red blood cell transfusion, donor red-cell antigens must be compatible with the recipient's antibodies.

ABO red blood cell compatibility table

Recipient blood group	Compatible donor ABO groups
A	A and O
B	B and O
AB	A, B, AB and O
O	O only

What happens during an incompatible blood transfusion?

If incompatible blood is transfused:

1. Antibodies in the recipient's plasma recognise foreign antigens on donor red blood cells.
2. Antibodies attach to the red blood cells.
3. Red blood cells may clump together in a process called agglutination.
4. The cells may break down through haemolysis.
5. This can cause serious complications, including kidney damage, shock and death.

5.6 The Rhesus (Rh) blood group system

The Rhesus blood group system is another important blood classification system.

It is mainly determined by the presence or absence of the Rh(D) antigen on red blood cells.

- Rh-positive (Rh+) blood has the D antigen.
- Rh-negative (Rh−) blood lacks the D antigen.

A person's blood group can therefore be described using both ABO and Rh systems, for example:

- A+.
- A−.
- B+.
- B−.
- AB+.
- AB−.
- O+.
- O−.

Importance of the Rh system

- It is important when matching donor and recipient blood.
- It helps prevent transfusion reactions.
- It is important during pregnancy.

5.7 Rhesus incompatibility during pregnancy

Rhesus incompatibility can occur when an Rh-negative mother carries an Rh-positive baby.

During pregnancy or childbirth, some fetal red blood cells may enter the mother's bloodstream.

The mother's immune system may become sensitised and produce anti-D antibodies.

In a subsequent pregnancy involving an Rh-positive baby, these antibodies may cross the placenta and destroy the baby's red blood cells, causing haemolytic disease of the fetus and newborn.

Prevention:

- Rh-negative mothers at risk are given anti-D immunoglobulin at appropriate times.

- Blood group testing is done during antenatal care.
- Appropriate medical monitoring is provided during pregnancy.

5.8 Procedures followed before blood transfusion

1. Determine the blood group of the donor and recipient.
2. Test for Rh compatibility.
3. Carry out cross-matching to check compatibility.
4. Screen donated blood for transfusion-transmissible infections.
5. Ensure the blood is properly stored.
6. Use sterile equipment.
7. Monitor the recipient during and after transfusion.

Ethical considerations in blood transfusion

- Informed consent should be obtained.
- Donated blood should be collected voluntarily and safely.
- Donor and recipient information should remain confidential.
- Blood should be screened to protect recipients.
- Discrimination based on blood group should be avoided.
- Blood should be distributed fairly according to medical need.
- Religious and cultural concerns should be handled respectfully while prioritising patient safety and informed medical decision-making.

6.0 IMMUNITY IN HUMAN BEINGS

6.1 Meaning of immunity

Immunity is the ability of the human body to resist and defend itself against infections and harmful foreign substances.

It is provided by the immune system, which consists of specialised cells, tissues, organs and protective substances.

The immune system protects the body against pathogens such as:

- Bacteria.
- Viruses.
- Fungi.
- Protozoa.
- Parasitic worms.

6.2 Importance of immunity

1. Protects the body against disease-causing microorganisms.
2. Destroys harmful pathogens.
3. Identifies and removes infected body cells.
4. Produces antibodies against specific antigens.
5. Provides protection against repeated infections.
6. Helps the body recover from diseases.

7. Removes abnormal or damaged cells.
8. Maintains overall health.

6.3 Types of immunity

Immunity is broadly classified into two major types:

1. Innate immunity.
2. Acquired immunity.

A. Innate immunity (natural immunity)

Innate immunity is the body's natural defence mechanism that is present from birth.

It provides immediate, general protection against pathogens without targeting a particular pathogen.

Examples and components of innate immunity

1. Skin – forms a physical barrier that prevents pathogens from entering the body.
2. Mucus – traps microorganisms in the respiratory and digestive systems.
3. Tears – contain substances such as lysozyme that help destroy bacteria.
4. Stomach acid – destroys many microorganisms entering through food.
5. Phagocytes – engulf and destroy invading microorganisms.
6. Inflammation – attracts immune cells to areas of infection or injury.
7. Cilia – help remove trapped particles from the respiratory tract.

B. Acquired immunity (adaptive immunity)

Acquired immunity is the specific defence mechanism that develops after exposure to particular antigens.

It involves lymphocytes and the production of specific antibodies or immune responses.

It can develop naturally or through medical intervention.

Acquired immunity is divided into:

- Active immunity.
- Passive immunity.

6.4 Active immunity

Active immunity develops when the body produces its own antibodies and immune memory cells after exposure to an antigen.

There are two types:

A. Naturally acquired active immunity

- Develops after a person becomes infected by a pathogen.
- The immune system responds by producing antibodies and memory cells.
- It may provide long-lasting protection.

Example: A person develops immunity after recovering from certain infections.

B. Artificially acquired active immunity

- Develops after vaccination.
- A vaccine exposes the immune system to an antigen or instructions for producing an antigen.

- The immune system produces a protective response and memory cells.
- It helps protect against future infection or severe disease.

Examples of vaccines used in Kenya include:

- BCG vaccine.
- Polio vaccine.
- Measles-rubella vaccine.
- Human papillomavirus (HPV) vaccine.
- Tetanus-containing vaccines.

6.5 Passive immunity

Passive immunity occurs when a person receives ready-made antibodies from another source rather than producing them through their own immune response.

It provides immediate but usually temporary protection.

There are two types:

A. Naturally acquired passive immunity

- Occurs when antibodies pass from mother to baby.
- Antibodies cross the placenta during pregnancy.
- Antibodies are also transferred through breast milk, particularly colostrum.

B. Artificially acquired passive immunity

- Occurs when ready-made antibodies are administered medically.
- Provides rapid protection.
- Does not usually produce long-term immune memory.

Examples:

- Rabies immunoglobulin after certain high-risk exposures.
- Tetanus immunoglobulin in appropriate clinical situations.
- Antivenom for certain snake bites.

6.6 Differences between active and passive immunity

Active immunity	**Passive immunity**
Body produces its own antibodies.	Ready-made antibodies are received.
Develops relatively slowly.	Provides immediate protection.
Usually lasts longer.	Usually lasts for a shorter period.
Produces immune memory.	Does not usually produce immune memory.
Occurs after infection or vaccination.	Occurs through maternal antibodies or antibody administration.

6.7 The role of antibodies in immunity

Antibodies are specialised proteins produced by B lymphocytes, particularly plasma cells, in response to specific antigens.

Functions of antibodies

1. Bind to specific antigens.

2. Neutralise certain toxins and viruses.
3. Cause pathogens to clump together.
4. Mark pathogens for destruction by phagocytes.
5. Activate other immune defence mechanisms.

Antigen-antibody reaction

An antigen-antibody reaction occurs when a specific antibody binds to its corresponding antigen.

This interaction helps the immune system recognise and eliminate harmful substances.

6.8 Vaccination and immunisation

Vaccination is the administration of a vaccine to stimulate an immune response against a particular disease.

Immunisation is the process through which a person develops protection against an infectious disease, either through vaccination or other means.

Importance of vaccination

- Prevents certain infectious diseases.
- Reduces the severity of infections.
- Reduces the spread of communicable diseases.
- Protects vulnerable individuals.
- Reduces childhood illness and deaths.
- Contributes to community protection.
- Helps control disease outbreaks.

Community (herd) immunity

Community immunity occurs when a sufficiently large proportion of a population becomes immune to an infectious disease, reducing its spread.

It helps protect people who cannot receive certain vaccines or who have weakened immune responses.

6.9 Factors affecting the immune system

The effectiveness of the immune system can be influenced by several factors.

1. Nutrition

- A balanced diet supports the production and functioning of immune cells.
- Protein is needed for the production of antibodies.
- Vitamins and minerals support normal immune functions.
- Malnutrition can weaken immune responses.

2. Age

- Infants have developing immune systems.
- Older people may experience reduced immune function.
- Immunisation helps protect vulnerable age groups.

3. Stress

- Prolonged stress can interfere with normal immune responses.

- Stress may affect sleep and general health.

4. Sleep

- Adequate sleep supports immune system functioning.
- Lack of sleep may reduce the body's ability to fight infections.

5. Physical activity

- Regular moderate exercise supports general health and immune function.
- Excessive physical strain without adequate recovery may negatively affect health.

6. HIV infection

- HIV attacks and destroys CD4 T lymphocytes.
- This weakens the immune system.
- Advanced HIV infection can progress to AIDS if untreated.

7. Chronic diseases

- Certain long-term diseases can weaken immune responses.
- Proper medical management helps reduce complications.

8. Smoking and excessive alcohol consumption

- Smoking damages protective structures in the respiratory tract.
- Excessive alcohol consumption can interfere with immune functioning.

9. Medicines

- Some medicines, such as immunosuppressants and certain cancer treatments, reduce immune activity.
- Such medicines may increase susceptibility to infections.

10. Environmental conditions

- Poor sanitation increases exposure to pathogens.
- Overcrowding may encourage the spread of infectious diseases.
- Clean water and proper waste disposal help reduce infections.

6.10 Ways of maintaining a healthy immune system

1. Eat a balanced diet.
2. Drink safe and clean water.
3. Maintain personal hygiene.
4. Get adequate sleep.
5. Exercise regularly.
6. Avoid smoking.
7. Avoid excessive alcohol consumption.
8. Follow recommended vaccination schedules.
9. Practise safe food handling.
10. Seek medical attention when necessary.
11. Maintain proper sanitation.

12. Follow prescribed treatment for chronic illnesses.

7.0 DISEASES OF THE HUMAN CIRCULATORY SYSTEM

7.1 Meaning of circulatory system diseases

Diseases of the circulatory system are conditions that affect the heart, blood vessels or blood, interfering with the normal movement of blood throughout the body.

Some circulatory diseases are associated with lifestyle choices, while others may result from genetic factors, infections, ageing or other medical conditions.

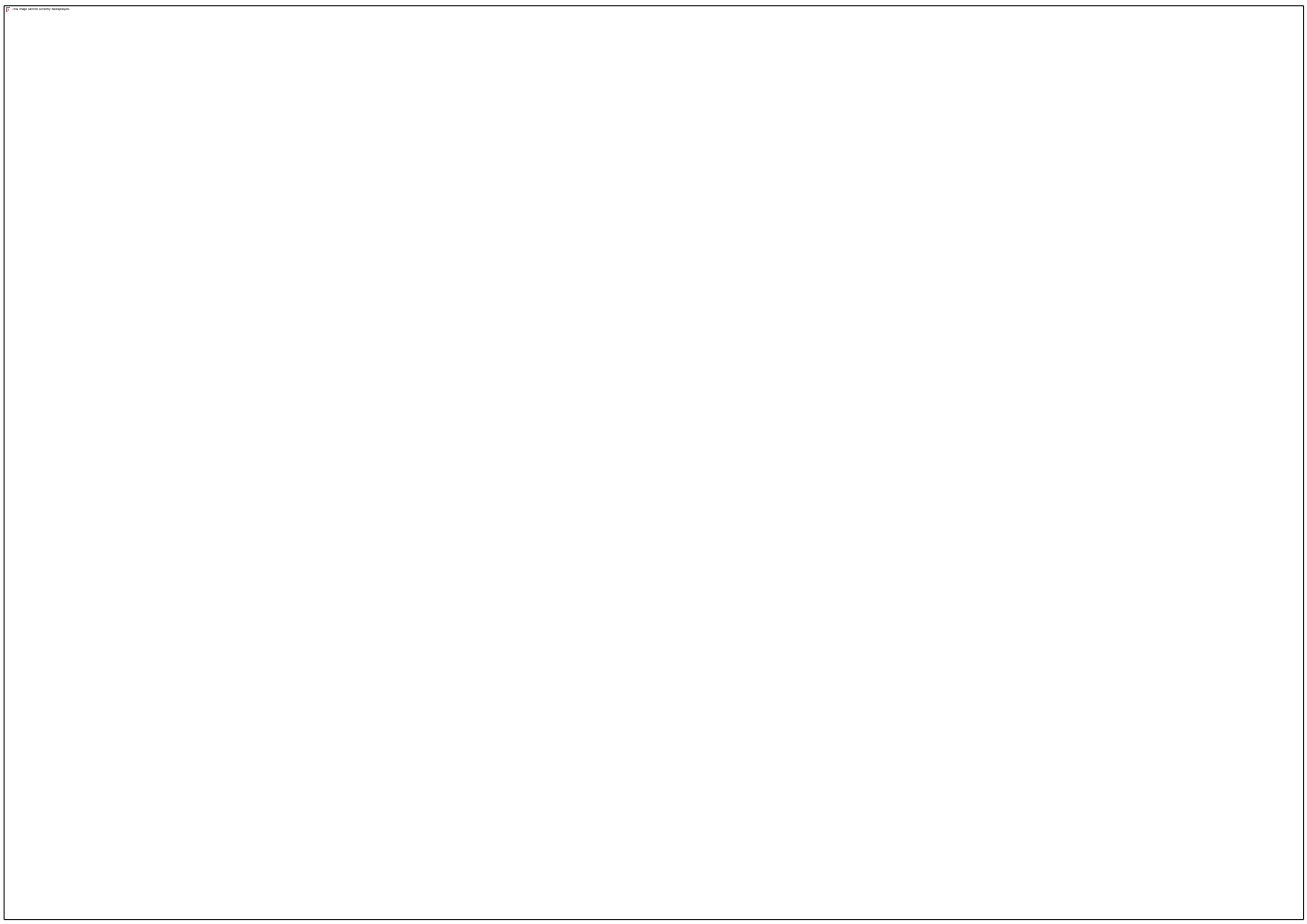
The three conditions emphasised in this sub-strand are:

1. Varicose veins.
2. Arteriosclerosis.
3. Thrombosis.

7.2 Varicose veins

Varicose veins are enlarged, twisted and swollen veins that commonly occur in the legs.

They develop when vein valves become weak or damaged, allowing blood to flow backwards and collect in the veins.



Causes and risk factors of varicose veins

1. Weak or damaged vein valves.
2. Prolonged standing or sitting.
3. Pregnancy.
4. Ageing.

5. Obesity.
6. Family history of varicose veins.
7. Reduced movement of leg muscles.

Signs and symptoms

- Swollen and twisted veins.
- Aching or heavy legs.
- Pain after prolonged standing.
- Itching around affected veins.
- Swelling of the ankles and feet.
- Skin discolouration in severe cases.

Prevention and control

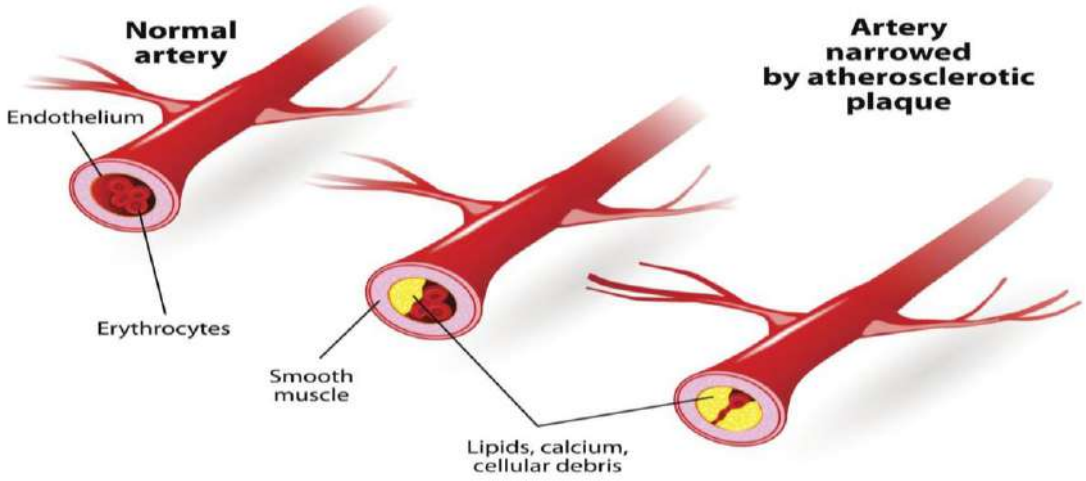
1. Exercise regularly.
2. Avoid sitting or standing for very long periods.
3. Maintain a healthy body mass.
4. Elevate the legs when resting.
5. Wear compression stockings when recommended by a healthcare professional.
6. Seek medical assessment when symptoms persist or worsen.

7.3 Arteriosclerosis

Arteriosclerosis is the thickening, hardening and loss of elasticity of arterial walls.

It makes arteries less flexible and may reduce the efficiency of blood circulation.

A common type is atherosclerosis, which involves the accumulation of fatty deposits called plaques inside arterial walls.



Causes and risk factors

1. Ageing.
2. High blood pressure.
3. High levels of LDL cholesterol.
4. Smoking.

5. Diabetes mellitus.
6. Physical inactivity.
7. Obesity.
8. Unhealthy diets high in saturated and trans fats.
9. Family history of cardiovascular disease.

Effects of arteriosclerosis

- Reduces the elasticity of arteries.
- Narrows the space through which blood flows.
- Reduces blood supply to body tissues.
- Increases the workload of the heart.
- May contribute to heart attacks and strokes.

Prevention and control

1. Eat a balanced diet.
2. Reduce excessive intake of saturated and trans fats.
3. Exercise regularly.
4. Avoid smoking.
5. Maintain a healthy body mass.
6. Control blood pressure.
7. Monitor blood cholesterol levels.
8. Manage diabetes.
9. Attend regular medical check-ups.
10. Follow prescribed medication.

7.4 Thrombosis

Thrombosis is the formation of a blood clot (thrombus) inside a blood vessel, which may partially or completely block blood flow.

Thrombosis can occur in veins or arteries.

Types of thrombosis

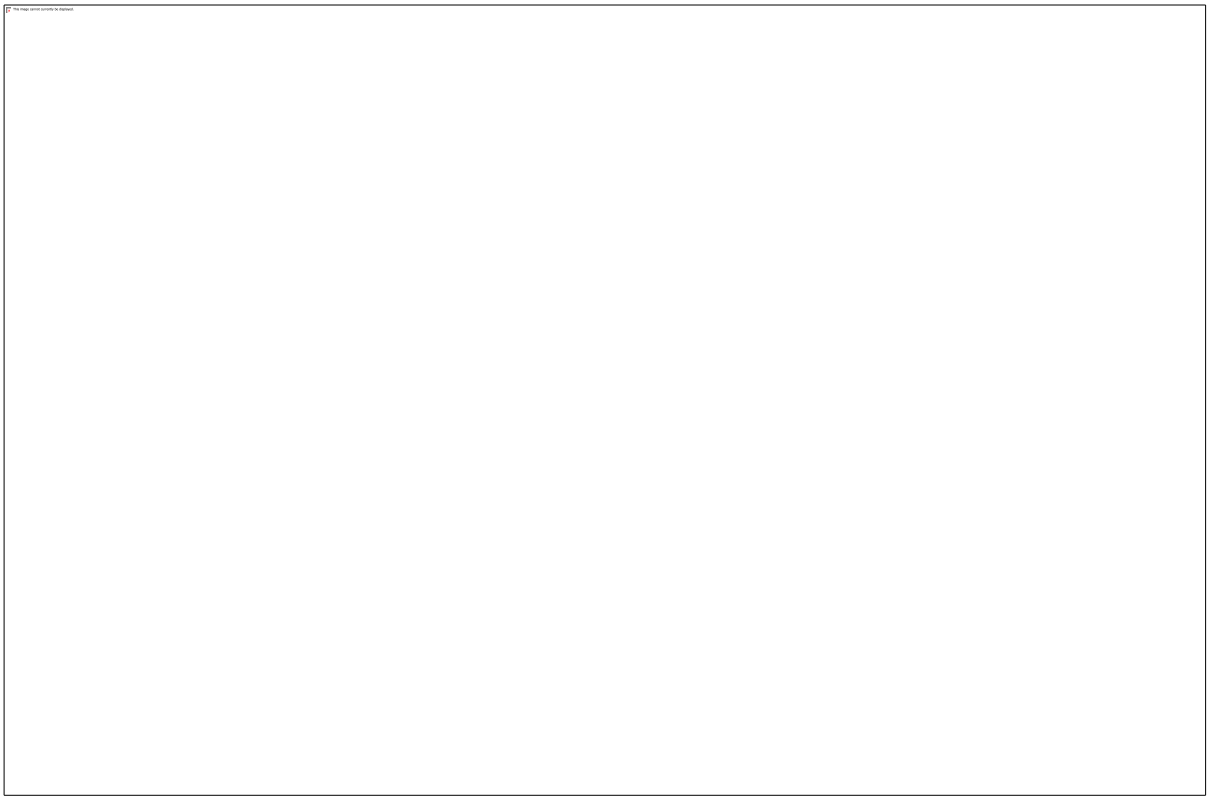
A. Deep vein thrombosis (DVT)

- Occurs when a blood clot forms in a deep vein.
- Commonly affects the lower limbs.
- May cause pain, swelling, warmth and redness in the affected leg.
- A clot may break away and travel to the lungs, causing a pulmonary embolism.

B. Arterial thrombosis

- Occurs when a blood clot forms in an artery.
- May block blood supply to important organs.
- Can cause a heart attack if it affects the coronary arteries.

- Can cause an ischaemic stroke if it blocks blood flow to the brain.



Causes and risk factors of thrombosis

1. Prolonged immobility.
2. Major surgery.
3. Injury to blood vessels.
4. Certain inherited clotting disorders.
5. Cancer and some cancer treatments.
6. Pregnancy and the period after childbirth.
7. Smoking.
8. Obesity.
9. Some hormonal medicines.

Signs and symptoms of deep vein thrombosis

- Swelling in one leg.
- Pain or tenderness in the affected leg.
- Warmth around the affected area.
- Redness or discolouration of the skin.

Medical emergency: Sudden difficulty in breathing, chest pain or coughing blood may indicate pulmonary embolism and requires immediate emergency medical attention.

Prevention and control

1. Avoid prolonged immobility.
2. Walk and move regularly.
3. Perform leg exercises during long journeys.

4. Maintain a healthy body mass.
5. Avoid smoking.
6. Use prescribed preventive medication when medically indicated.
7. Follow medical advice after surgery.
8. Seek immediate medical attention when symptoms suggest thrombosis.

7.5 Comparison of the three circulatory diseases

Disease	Main affected structure	Main problem
Varicose veins	Veins	Weak valves cause blood pooling and enlarged veins.
Arteriosclerosis	Arteries	Arterial walls become thick and less elastic.
Thrombosis	Blood vessels	Blood clot forms and blocks blood flow.

7.6 General ways of maintaining a healthy circulatory system

- Eat a balanced diet rich in fruits and vegetables.
- Exercise regularly.
- Maintain a healthy body mass.
- Drink adequate clean water.
- Avoid smoking and tobacco products.
- Avoid excessive alcohol consumption.
- Reduce excessive salt intake.
- Manage stress.
- Get adequate sleep.
- Monitor blood pressure and cholesterol.
- Manage diabetes.
- Attend regular medical check-ups.

8.0 DOUBLE CIRCULATION IN HUMAN BEINGS

8.1 Meaning of double circulation

Double circulation refers to the movement of blood through the heart twice during one complete circulation of the body.

It consists of two major pathways:

1. Pulmonary circulation.
2. Systemic circulation.

8.2 Pulmonary circulation

Pulmonary circulation is the movement of blood from the right ventricle to the lungs and back to the left atrium.

Pathway

Right ventricle → Pulmonary artery → Lungs → Pulmonary veins → Left atrium.

Functions

- Carries deoxygenated blood to the lungs.
- Allows blood to release carbon dioxide.
- Allows blood to receive oxygen.

- Returns oxygenated blood to the heart.

8.3 Systemic circulation

Systemic circulation is the movement of blood from the left ventricle to all parts of the body and back to the right atrium.

Pathway

Left ventricle → Aorta → Body tissues → Vena cava → Right atrium.

Functions

- Supplies body cells with oxygen.
- Delivers nutrients to body tissues.
- Collects carbon dioxide.
- Removes metabolic waste products.
- Returns deoxygenated blood to the heart.

8.4 Differences between pulmonary and systemic circulation

Pulmonary circulation	Systemic circulation
Takes place between the heart and lungs.	Takes place between the heart and the rest of the body.
Begins at the right ventricle.	Begins at the left ventricle.
Ends at the left atrium.	Ends at the right atrium.
Oxygenates blood.	Supplies oxygen to body tissues.
Operates at relatively lower pressure.	Operates at relatively higher pressure.

8.5 Advantages of double circulation

1. Prevents mixing of oxygenated and deoxygenated blood.
2. Ensures efficient oxygen supply to body tissues.
3. Maintains high pressure in systemic circulation.
4. Allows lower pressure in pulmonary circulation, protecting delicate lung capillaries.
5. Supports the high metabolic demands of human beings.
6. Enables efficient transport of nutrients and removal of waste products.

9.0 PRACTICAL ACTIVITIES AND LEARNING EXPERIENCES

These activities develop practical skills, observation, critical thinking, collaboration and problem-solving competencies.

Activity 1: Investigating the pulse rate

Materials: Stopwatch, notebook and pen.

Procedure:

1. Work in pairs.
2. Ask one learner to sit quietly for five minutes.
3. Locate the radial pulse at the wrist.
4. Count the pulse beats for one minute.
5. Record the result.
6. Ask the learner to perform a safe physical activity such as jogging on the spot for two minutes.

7. Measure the pulse again.
8. Compare the two readings.

Observation: The pulse rate usually increases after exercise.

Conclusion: Physical activity increases the demand for oxygen and nutrients, causing the heart to pump blood faster.

Competencies developed: Communication, collaboration, critical thinking and problem-solving.

Activity 2: Observing the effect of exercise on heart rate

Learners can investigate how exercise affects the heartbeat.

Condition	Pulse rate (beats per minute)
At rest	To be measured
Immediately after exercise	To be measured
After five minutes of rest	To be measured

Discussion questions:

1. Which condition produced the highest pulse rate?
2. Why did the pulse rate increase after exercise?
3. Why did the pulse rate gradually return towards its resting level?

Activity 3: Modelling blood circulation

Materials:

- Two plastic bottles.
- Transparent plastic tubes.
- Red and blue coloured water.
- Cardboard.
- Adhesive tape.
- Scissors.
- Labels.

Procedure:

1. Use the bottles to represent the right and left sides of the heart.
2. Connect tubes to represent major blood vessels.
3. Use blue-coloured water to represent deoxygenated blood.
4. Use red-coloured water to represent oxygenated blood.
5. Connect the model to represent blood flow to the lungs and the rest of the body.
6. Demonstrate how blood moves through the heart.

Important: The colours represent oxygen levels and are not the actual colours of blood in the body.

Activity 4: Investigating the effect of lifestyle on circulatory health

Learners discuss common lifestyle practices in their communities.

Examples:

- Consumption of highly salted foods.

- Physical inactivity.
- Smoking.
- Excessive alcohol consumption.
- Eating fruits and vegetables.
- Regular exercise.

Task: Prepare a poster showing five ways of maintaining a healthy circulatory system.

9.1 Project: Constructing a model of the human heart

Project title: Modelling the structure of the human heart and showing blood circulation.

Objective: To construct a model demonstrating the four chambers of the heart and the direction of blood flow.

Locally available materials:

- Cardboard.
- Clay.
- Plastic bottles.
- Drinking straws.
- Rubber tubes.
- Red and blue paper.
- Adhesive.
- Recycled containers.
- Paint or markers.

Procedure:

1. Research the structure of the human heart.
2. Construct a model showing four chambers.
3. Label the right atrium, left atrium, right ventricle and left ventricle.
4. Include the aorta, vena cava, pulmonary artery and pulmonary veins.
5. Show the septum separating the two sides.
6. Use red and blue colours to indicate oxygenated and deoxygenated blood.
7. Add arrows showing the direction of blood flow.
8. Present the model to classmates and explain how it works.

Expected outcome: A labelled model that accurately demonstrates the structure of the human heart and the pathway of blood circulation.

9.2 Key terms and definitions

Term	Meaning
Circulation	Movement of blood throughout the body.
Atrium	Upper chamber of the heart.
Ventricle	Lower chamber of the heart.
Systole	Contraction of heart muscles.
Diastole	Relaxation of heart muscles.
Artery	Blood vessel carrying blood away from the heart.

Vein	Blood vessel carrying blood towards the heart.
Capillary	Small blood vessel where exchange of substances occurs.
Haemoglobin	Oxygen-carrying pigment in red blood cells.
Phagocytosis	Process by which cells engulf and digest foreign particles.
Antigen	Substance that can trigger a specific immune response.
Antibody	Protein that recognises and binds to a specific antigen.
Immunity	Ability of the body to resist infections.
Vaccination	Administration of a vaccine to stimulate an immune response.
Transfusion	Transfer of blood or blood components from a donor to a recipient.
Agglutination	Clumping of red blood cells due to antigen-antibody reactions.
Thrombosis	Formation of a blood clot inside a blood vessel.
Arteriosclerosis	Thickening and hardening of arterial walls.
Varicose veins	Enlarged and twisted veins caused by faulty vein valves.
Plasma	Liquid component of blood.
Platelets	Blood cell fragments involved in clotting.
Oxyhaemoglobin	Compound formed when oxygen combines with haemoglobin.
Pulmonary circulation	Movement of blood between the heart and lungs.
Systemic circulation	Movement of blood between the heart and body tissues.

REVISION EXERCISES

SECTION A: MULTIPLE-CHOICE QUESTIONS (30 MARKS)

Instructions: Answer all questions by selecting the correct alternative from options A, B, C and D. Each question carries one mark.

1. Which of the following correctly identifies the three major components of the human circulatory system?

A. Heart, lungs and kidneys.

B. Heart, blood vessels and blood.

C. Blood, liver and lungs.

D. Arteries, lungs and kidneys.

2. Which chamber of the heart receives deoxygenated blood from the body?

A. Left atrium.

B. Left ventricle.

C. Right atrium.

D. Right ventricle.

3. The blood vessel that carries oxygenated blood from the lungs to the heart is the:

A. Pulmonary artery.

B. Pulmonary vein.

C. Aorta.

D. Vena cava.

4. Which chamber of the heart has the thickest muscular wall?

A. Right atrium.

B. Left atrium.

C. Right ventricle.

D. Left ventricle.

5. The main function of valves in the heart is to:

A. Increase blood production.

B. Prevent backward flow of blood.

C. Produce oxygen.

D. Destroy pathogens.

6. Which blood vessel carries blood away from the heart?

A. Vein.

B. Capillary.

C. Artery.

D. Venule.

7. Which adaptation makes capillaries suitable for the exchange of substances?

A. Thick muscular walls.

B. Presence of valves.

C. Walls consisting of one cell layer.

D. Wide lumen.

8. Which blood vessel normally carries deoxygenated blood from the heart to the lungs?

A. Aorta.

B. Pulmonary artery.

C. Pulmonary vein.

D. Coronary artery.

9. Which component of blood is mainly responsible for transporting oxygen?

A. Platelets.

B. Plasma.

C. White blood cells.

D. Red blood cells.

10. The red pigment found in red blood cells is called:

A. Fibrinogen.

B. Haemoglobin.

C. Insulin.

D. Antibody.

11. Which blood component is responsible for defending the body against infections?

A. Red blood cells.

B. Platelets.

C. White blood cells.

D. Plasma.

12. The main function of platelets is to:

A. Transport oxygen.

B. Fight infections.

C. Help in blood clotting.

D. Transport hormones.

13. Which component of blood makes up the largest proportion of its liquid part?

A. Haemoglobin.

B. Water.

C. Platelets.

D. Red blood cells.

14. Which plasma protein is directly involved in blood clotting?

A. Albumin.

B. Fibrinogen.

C. Haemoglobin.

D. Insulin.

15. A person with blood group A has which antigen on their red blood cells?

A. B antigen.

B. A antigen.

C. Both A and B antigens.

D. Neither A nor B antigen.

16. Which antibodies are found in the plasma of a person with blood group B?

A. Anti-A.

B. Anti-B.

C. Both anti-A and anti-B.

D. Neither anti-A nor anti-B.

17. Which ABO blood group is known as the universal red-cell recipient?

A. A.

B. B.

C. AB.

D. O.

18. Which ABO blood group can receive red blood cells from group O only?

A. AB.

B. A.

C. B.

D. O.

19. What may happen when incompatible blood groups are transfused?

A. Increased oxygen production.

B. Agglutination of red blood cells.

C. Increased digestion.

D. Improved immunity.

20. Which blood group classification is determined by the presence or absence of the D antigen?

A. ABO system.

B. Rhesus system.

C. Haemoglobin system.

D. Platelet system.

21. Immunity refers to the ability of the body to:

A. Digest food.

B. Transport oxygen.

C. Resist infections.

D. Produce hormones.

22. Which of the following is an example of innate immunity?

A. Vaccination.

B. Production of antibodies after infection.

C. Protection provided by the skin.

D. Administration of antivenom.

23. Vaccination mainly stimulates which type of immunity?

A. Artificially acquired active immunity.

B. Naturally acquired passive immunity.

C. Artificially acquired passive immunity.

D. Innate immunity.

24. Antibodies transferred from a mother to her baby through breast milk provide:

A. Artificial active immunity.

B. Natural passive immunity.

C. Artificial passive immunity.

D. Natural active immunity.

25. Which type of white blood cell produces antibodies?

A. Red blood cells.

B. Platelets.

C. B lymphocytes.

D. Neutrophils.

26. Which of the following conditions weakens the immune system by attacking CD4 T lymphocytes?

A. Malaria.

B. HIV infection.

C. Varicose veins.

D. Arteriosclerosis.

27. Varicose veins mainly develop due to:

A. Increased production of red blood cells.

B. Weak or damaged vein valves.

C. Excessive production of platelets.

D. Thickening of capillary walls.

28. Arteriosclerosis is characterised by:

A. Softening of veins.

B. Hardening and thickening of arterial walls.

C. Destruction of red blood cells.

D. Increased production of antibodies.

29. The formation of a blood clot inside a blood vessel is called:

A. Phagocytosis.

B. Agglutination.

C. Thrombosis.

D. Diastole.

30. Which of the following practices helps maintain a healthy circulatory system?

A. Smoking regularly.

B. Avoiding physical activity.

C. Eating excessive saturated fats.

D. Exercising regularly and eating a balanced diet.

SECTION B: 50 MARKS

Structured Questions

Instructions: Answer all questions. Show your understanding using well-explained points, labelled diagrams and relevant examples where necessary.

Question 1: The Human Circulatory System (8 marks)

a) Define the term circulatory system. (1 mark)

b) Name the three major components of the human circulatory system. (3 marks)

c) State four functions of the human circulatory system. (4 marks)

Question 2: Structure and Function of the Heart (8 marks)

a) Name the four chambers of the human heart. (4 marks)

b) Explain the functions of the following structures: (2 marks)

i. Septum. ii. Valves.

c) Explain why the wall of the left ventricle is thicker than that of the right ventricle. (2 marks)

Question 3: Blood Vessels and Blood (8 marks)

a) Name the three major types of blood vessels in human beings. (3 marks)

b) State two structural adaptations of capillaries to their functions. (2 marks)

c) State three functions of blood in the human body. (3 marks)

Question 4: Blood Groups and Blood Transfusion (8 marks)

a) Name the four blood groups in the ABO blood group system. (2 marks)

b) Differentiate between antigens and antibodies. (2 marks)

c) State the antibodies found in the plasma of a person with blood group O. (1 mark)

d) Explain why blood group compatibility is important during blood transfusion. (2 marks)

e) What is the meaning of Rh-positive blood? (1 mark)

Question 5: Immunity in Human Beings (9 marks)

a) Define immunity. (1 mark)

b) Differentiate between innate immunity and acquired immunity. (2 marks)

c) Explain the differences between active immunity and passive immunity. (4 marks)

d) State two factors that may weaken the human immune system. (2 marks)

Question 6: Diseases of the Circulatory System (9 marks)

a) Define the following conditions: (3 marks)

i. Varicose veins. ii. Arteriosclerosis. iii. Thrombosis.

b) State three risk factors associated with diseases of the circulatory system. (3 marks)

c) Explain three practices that can help prevent circulatory system diseases. (3 marks)

12.0 REVISION ANSWER KEY

Section A: Multiple Choice Answers

Question	Answer	Question	Answer
1	B	16	A
2	C	17	C
3	B	18	D
4	D	19	B
5	B	20	B
6	C	21	C
7	C	22	C
8	B	23	A
9	D	24	B
10	B	25	C
11	C	26	B
12	C	27	B
13	B	28	B
14	B	29	C
15	B	30	D

Section B: Suggested marking guide

Question 1

a) The system responsible for transporting blood and substances throughout the body. (1)

b) Heart, blood vessels and blood. (3)

c) Any four:

- Transport oxygen.
- Transport nutrients.
- Remove carbon dioxide.
- Transport hormones.
- Defend the body against infections.
- Regulate body temperature.
- Assist in blood clotting. (4)

Question 2

a) Right atrium, left atrium, right ventricle and left ventricle. (4)

b)

- Septum: Separates the right and left sides of the heart and prevents mixing of blood. (1)
- Valves: Prevent backward flow of blood. (1)

c) The left ventricle pumps blood to the entire body, requiring greater pressure and force than the right ventricle, which pumps blood only to the lungs. (2)

Question 3

a) Arteries, veins and capillaries. (3)

b) Any two:

- Walls are one cell thick.

- Have an extensive network.
- Have narrow lumens.
- Are close to body cells. (2)

c) Any three:

- Transport oxygen.
- Transport nutrients.
- Remove waste products.
- Defend against infections.
- Regulate body temperature.
- Assist in clotting. (3)

Question 4

a) A, B, AB and O. (2)

b)

- Antigens are substances on cell surfaces that can trigger an immune response.
- Antibodies are proteins that recognise and bind to specific antigens. (2)

c) Anti-A and anti-B. (1)

d) Compatibility prevents harmful antigen-antibody reactions, agglutination and destruction of red blood cells. (2)

e) Blood that has the D antigen on its red blood cells. (1)

Question 5

a) The ability of the body to resist and defend itself against infections. (1)

b)

- Innate immunity is natural, non-specific protection present from birth.
- Acquired immunity develops following exposure to specific antigens or vaccination. (2)

c)

- Active immunity involves the body producing its own antibodies, while passive immunity involves receiving ready-made antibodies. (2)
- Active immunity usually lasts longer and produces memory cells, while passive immunity is usually temporary and does not produce immune memory. (2)

d) Any two:

- Poor nutrition.
- HIV infection.
- Stress.
- Lack of sleep.
- Smoking.
- Chronic diseases.
- Certain medicines. (2)

Question 6

a)

- Varicose veins: Enlarged and twisted veins caused by faulty valves. (1)
- Arteriosclerosis: Thickening and hardening of arterial walls. (1)
- Thrombosis: Formation of a blood clot inside a blood vessel. (1)

b) Any three:

- Smoking.
- Obesity.
- Physical inactivity.
- High blood pressure.
- Unhealthy diet.
- Diabetes.
- Ageing. (3)

c) Any three explained:

- Regular exercise improves circulation and supports heart health.
- Balanced diets help control cholesterol and blood pressure.
- Avoiding smoking reduces damage to blood vessels.
- Maintaining healthy body mass reduces cardiovascular risk.
- Regular medical check-ups help identify health problems early.
- Reducing excessive salt intake helps control blood pressure. (3)

STRAND 1.0: LIFE SCIENCE

SUB-STRAND 1.2: GASEOUS EXCHANGE IN HUMAN BEINGS

1.0 INTRODUCTION TO GASEOUS EXCHANGE

1.1 Meaning of gaseous exchange

Gaseous exchange is the biological process through which oxygen enters the body while carbon dioxide is removed from the body.

In human beings, gaseous exchange takes place mainly in the alveoli of the lungs.

During gaseous exchange:

- Oxygen from inhaled air diffuses into the blood.
- Carbon dioxide from the blood diffuses into the alveoli.
- Carbon dioxide is removed from the body during exhalation.
- Oxygen is transported by blood to body cells for cellular respiration.

Gaseous exchange is essential because body cells require oxygen to release energy from food substances during cellular respiration.

1.2 Meaning of respiration

Respiration is the process through which living cells release energy from food substances.

In human beings, cellular respiration mainly takes place in the mitochondria.

Aerobic respiration involves the use of oxygen to break down glucose and release energy.

The equation for aerobic respiration is:

Word Equation:

Glucose + Oxygen → Carbon dioxide + Water + Energy

Balanced Chemical Equation:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$$

1.3 Difference between breathing, gaseous exchange and cellular respiration

These terms are related but have different meanings.

Process	Meaning
Breathing (ventilation)	Movement of air into and out of the lungs.
Gaseous exchange	Movement of oxygen and carbon dioxide across respiratory surfaces by diffusion.
Cellular respiration	Chemical process through which cells release energy from food.

Example: When a learner runs during a school athletics competition, breathing becomes faster, more oxygen enters the lungs, and the blood transports additional oxygen to active muscles for cellular respiration.

1.4 Importance of gaseous exchange in human beings

Gaseous exchange is important because it:

1. Supplies oxygen required for aerobic respiration.
2. Enables cells to release energy from glucose.
3. Removes carbon dioxide produced during cellular respiration.
4. Helps maintain the normal pH of blood.
5. Supports the functioning of body organs such as the brain and heart.
6. Supports physical activities such as walking, running, farming and playing football.
7. Helps maintain normal body functioning.
8. Prevents the accumulation of excessive carbon dioxide in the body.

1.5 Why do human beings need an efficient gaseous exchange system?

Human beings need an efficient gaseous exchange system because:

- They have large bodies containing millions of cells.
- Most body cells are located far from the external environment.
- Their cells require a continuous supply of oxygen.
- Cellular respiration produces carbon dioxide that must be removed.

- Diffusion alone across the external body surface cannot meet the needs of all body cells.

Key point: The respiratory system works together with the circulatory system to ensure that oxygen reaches body cells and carbon dioxide is removed.

2.0 STRUCTURE OF THE HUMAN RESPIRATORY SYSTEM

2.1 Meaning of the respiratory system

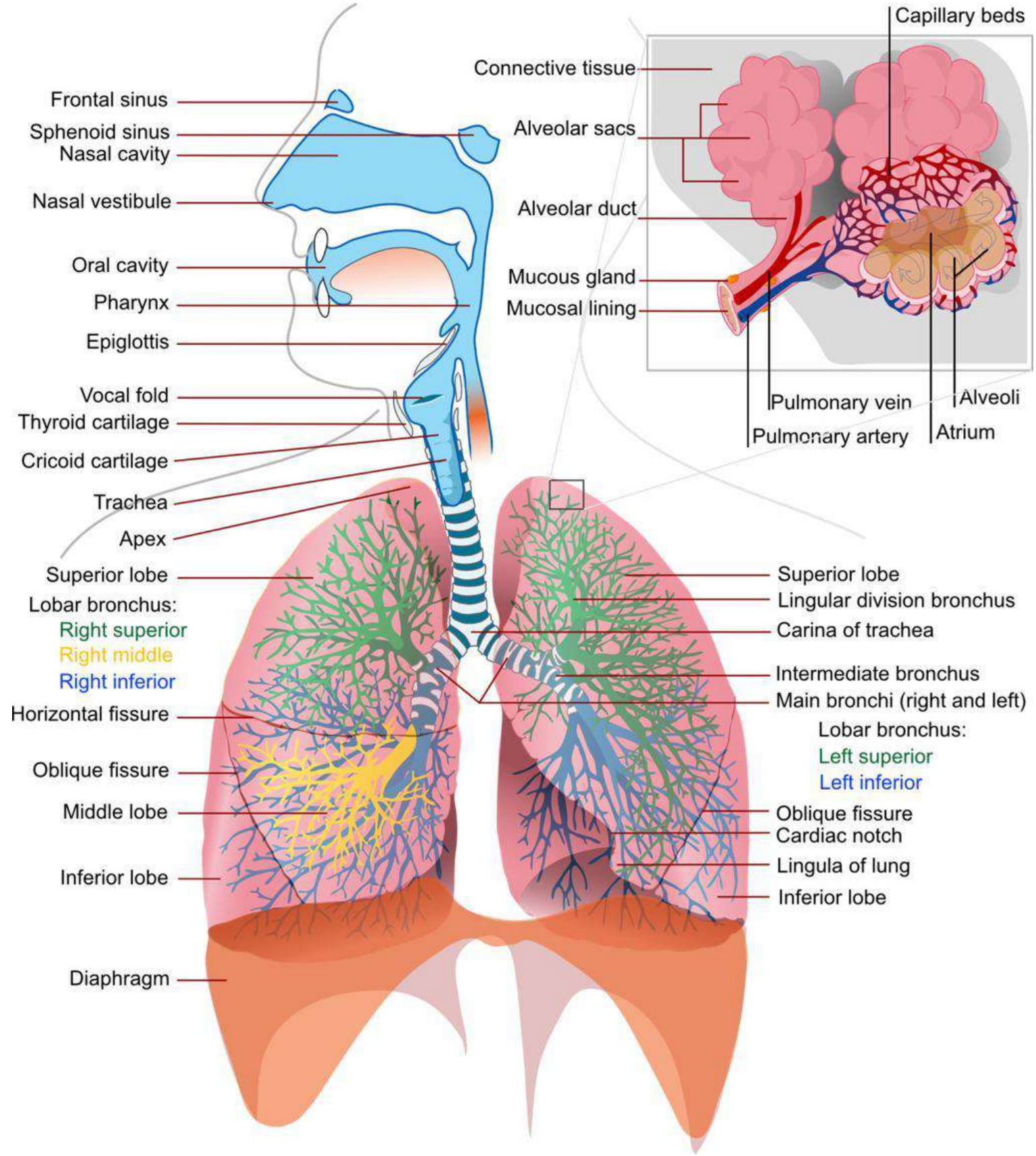
The human respiratory system is a group of organs and structures responsible for breathing and gaseous exchange between the body and the external environment.

It enables oxygen to enter the body and carbon dioxide to leave the body.

The major structures include:

1. Nostrils.
2. Nasal cavity.
3. Pharynx.
4. Larynx.
5. Trachea.
6. Bronchi.
7. Bronchioles.
8. Alveoli.
9. Lungs.
10. Diaphragm and intercostal muscles, which assist in breathing.

2.2 Diagram of the human respiratory system



2.3 Structure and functions of the respiratory system

A. Nostrils

Nostrils are the two external openings of the nose through which air enters and leaves the respiratory system.

Functions of nostrils

1. Allow air to enter and leave the respiratory system.
2. Provide the first passage through which inhaled air moves.

3. Help prevent large particles from entering the respiratory tract through nasal hairs.

Adaptations

- Contain hairs that trap dust and large particles.
- Lead into the nasal cavity, which conditions inhaled air.
- Their position allows air to enter directly from the surroundings.

B. Nasal cavity

The nasal cavity is the hollow space inside the nose through which inhaled air passes.

It is lined with a mucus membrane and contains tiny hair-like structures called cilia.

Functions of the nasal cavity

1. Filters dust and other particles from inhaled air.
2. Warms incoming air.
3. Moistens inhaled air.
4. Traps microorganisms in mucus.
5. Helps protect the delicate structures of the lungs.

Adaptations

Structure	Adaptation and function
Nasal hairs	Trap large dust particles.
Mucus membrane	Traps dust and microorganisms.
Blood capillaries	Warm incoming air.
Cilia	Move mucus containing trapped particles towards the throat.

Importance: Breathing through the nose is generally better than breathing through the mouth because the nasal cavity filters, warms and moistens the incoming air.

C. Pharynx

The pharynx is a muscular passage located behind the nasal cavity and mouth.

It is shared by the respiratory and digestive systems.

Functions

1. Provides a passage for air from the nasal cavity to the larynx.
2. Connects the nasal cavity to the lower respiratory tract.
3. Allows swallowed food to pass towards the oesophagus.

D. Larynx

The larynx is a structure located between the pharynx and trachea.

It is commonly called the voice box because it contains the vocal cords.

Functions of the larynx

1. Allows air to pass from the pharynx into the trachea.
2. Produces sound through the vibration of vocal cords.
3. Helps protect the lower respiratory tract during swallowing.

Adaptations

- Contains vocal cords for sound production.

- Has supporting cartilage that keeps the airway open.
- Contains the epiglottis, which helps prevent food from entering the trachea during swallowing.

E. Epiglottis

The epiglottis is a flap of elastic cartilage located at the entrance of the larynx.

Functions

1. Covers the entrance to the larynx during swallowing.
2. Helps prevent food and liquids from entering the trachea.
3. Directs swallowed food towards the oesophagus.

Note: The epiglottis does not normally cover the airway during breathing.

F. Trachea

The trachea is a tube that connects the larynx to the two primary bronchi.

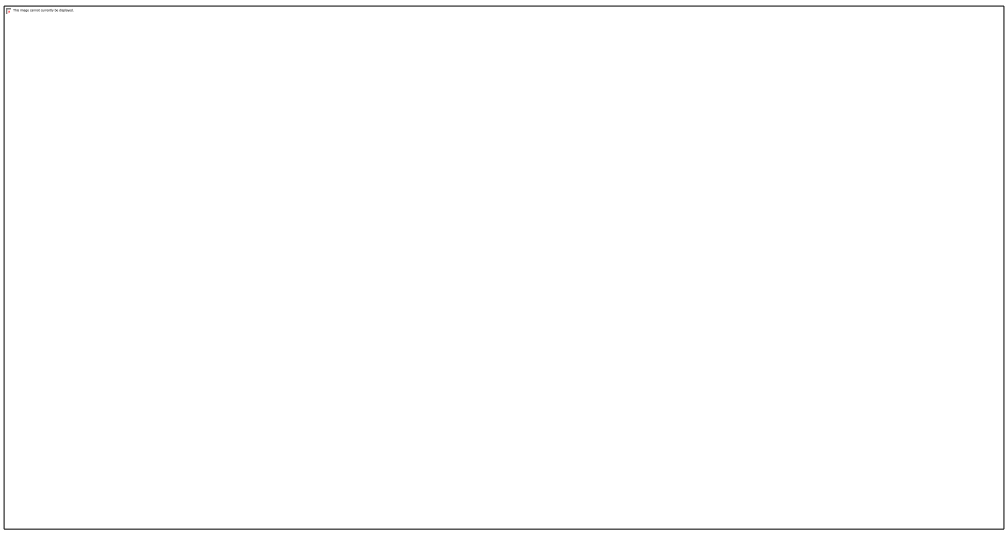
It is also known as the windpipe.

Functions of the trachea

1. Conducts air to and from the lungs.
2. Allows air to pass towards the bronchi.
3. Helps remove trapped particles through the movement of mucus and cilia.
4. Provides a passage for air during inhalation and exhalation.

Adaptations of the trachea

- Supported by C-shaped rings of cartilage that prevent it from collapsing.
- Lined with mucus-producing cells that trap dust and microorganisms.
- Contains cilia that move mucus upwards towards the pharynx.
- Has a moist lining that helps condition incoming air.



G. Bronchi

Bronchi are the two major branches of the trachea that carry air into the right and left lungs.

Each bronchus enters a lung and divides into smaller branches.

Functions of bronchi

1. Conduct air into the lungs.
2. Distribute air to different parts of the lungs.
3. Help remove dust and microorganisms through mucus and ciliary action.

Adaptations

- Have cartilage to support their walls.
- Have a mucus lining that traps particles.
- Contain cilia that help remove trapped particles.
- Have smooth muscle that helps regulate the diameter of the air passages.

H. Bronchioles

Bronchioles are smaller branches of the bronchi found within the lungs.

They eventually lead to alveolar ducts and alveolar sacs.

Functions of bronchioles

1. Distribute air throughout the lungs.
2. Conduct air towards the alveoli.
3. Regulate airflow through contraction and relaxation of smooth muscles.

Adaptations

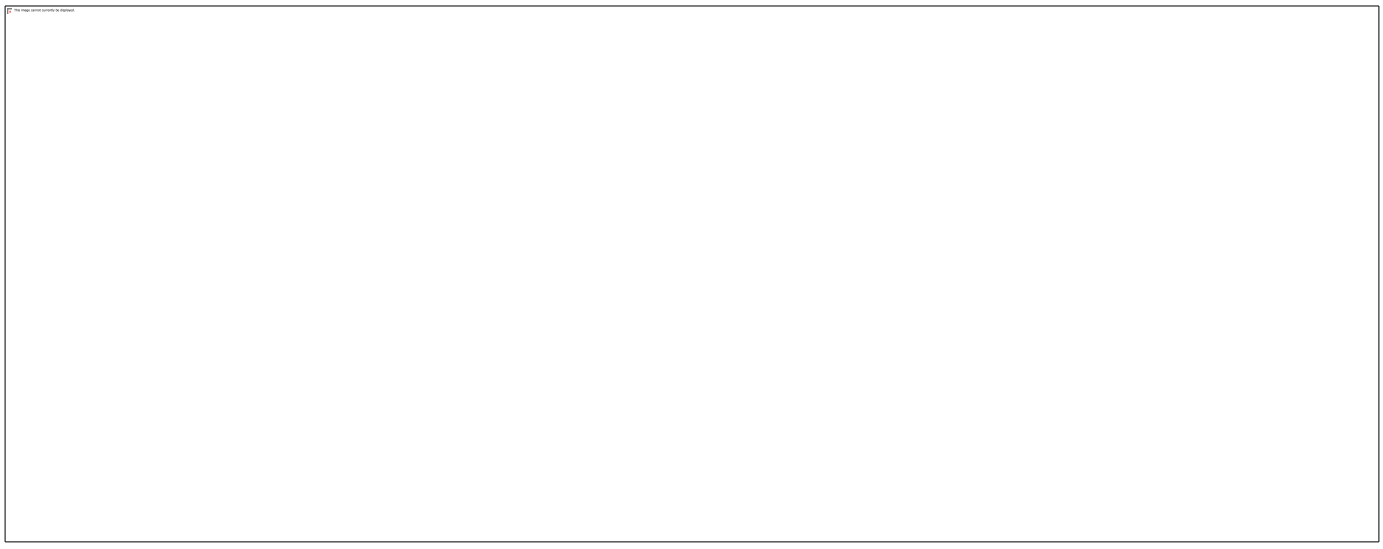
- Have smooth muscle that regulates their diameter.
- Their branching arrangement distributes air to many regions of the lungs.
- Smaller bronchioles lead towards the alveoli.
- Their walls are relatively thin compared with those of larger air passages.

I. Alveoli

Alveoli are tiny, balloon-like air sacs found at the ends of the smallest respiratory passages in the lungs.

They are the main sites of gaseous exchange in human beings.

Each lung contains millions of alveoli, providing a very large surface area for gaseous exchange.



Functions of alveoli

1. Allow oxygen to diffuse from inhaled air into the blood.

2. Allow carbon dioxide to diffuse from the blood into the alveoli.
3. Provide a large surface area for gaseous exchange.
4. Enable rapid diffusion of respiratory gases.

Adaptations of alveoli to gaseous exchange

Adaptation	Explanation
Numerous alveoli	Provide a large surface area for gaseous exchange.
Thin walls	Each alveolus has a wall one cell thick, reducing diffusion distance.
Moist lining	Allows oxygen and carbon dioxide to dissolve before diffusing.
Rich blood supply	Maintains a concentration gradient for gaseous exchange.
Close association with capillaries	Reduces the distance between air and blood.
Elastic walls	Allow expansion and recoil during breathing.
Continuous ventilation	Maintains differences in oxygen and carbon dioxide concentrations.

J. Lungs

The lungs are a pair of spongy, elastic organs located in the thoracic cavity.

They are protected by the rib cage.

The right lung normally has three lobes, while the left lung has two lobes to accommodate the heart.

Functions of the lungs

1. Provide a surface for gaseous exchange.
2. Supply oxygen to the blood.
3. Remove carbon dioxide from the blood.
4. Assist in maintaining the acid-base balance of blood.
5. Help remove water vapour during exhalation.

K. Pleural membranes

Pleural membranes are two thin membranes surrounding each lung.

The space between them contains a small amount of pleural fluid.

Functions

1. Reduce friction during breathing.
2. Allow smooth movement of the lungs against the chest wall.
3. Help maintain close contact between the lungs and chest wall during breathing movements.

L. Diaphragm

The diaphragm is a dome-shaped muscular sheet separating the thoracic cavity from the abdominal cavity.

It plays an important role in breathing.

Functions

1. Contracts and flattens during inhalation.
2. Relaxes and becomes dome-shaped during exhalation.
3. Changes the volume of the thoracic cavity.
4. Helps produce pressure changes that move air into and out of the lungs.

M. Intercostal muscles

Intercostal muscles are muscles located between the ribs.

There are two main groups:

- External intercostal muscles.
- Internal intercostal muscles.

Functions

1. Move the ribs during breathing.
2. Increase or decrease the volume of the thoracic cavity.
3. Assist in inhalation and forced exhalation.

2.4 Summary of respiratory structures and functions

Structure	Main function
Nostrils	Allow air to enter and leave the nose.
Nasal cavity	Filters, warms and moistens air.
Pharynx	Provides a passage for air.
Larynx	Conducts air and produces sound.
Epiglottis	Prevents food from entering the airway.
Trachea	Conducts air towards the bronchi.
Bronchi	Carry air into the lungs.
Bronchioles	Distribute air within the lungs.
Alveoli	Main sites of gaseous exchange.
Lungs	Contain the respiratory surfaces.
Pleural membranes	Reduce friction during breathing.
Diaphragm	Changes thoracic cavity volume.
Intercostal muscles	Move the ribs during breathing.

3.0 GASEOUS EXCHANGE ACROSS THE ALVEOLI

3.1 Meaning of gaseous exchange across the alveoli

Gaseous exchange across the alveoli is the movement of oxygen from the air inside the alveoli into the blood and the movement of carbon dioxide from the blood into the alveoli.

It occurs through a process called **diffusion**.

Diffusion is the movement of particles from a region of higher concentration to a region of lower concentration.

In the lungs:

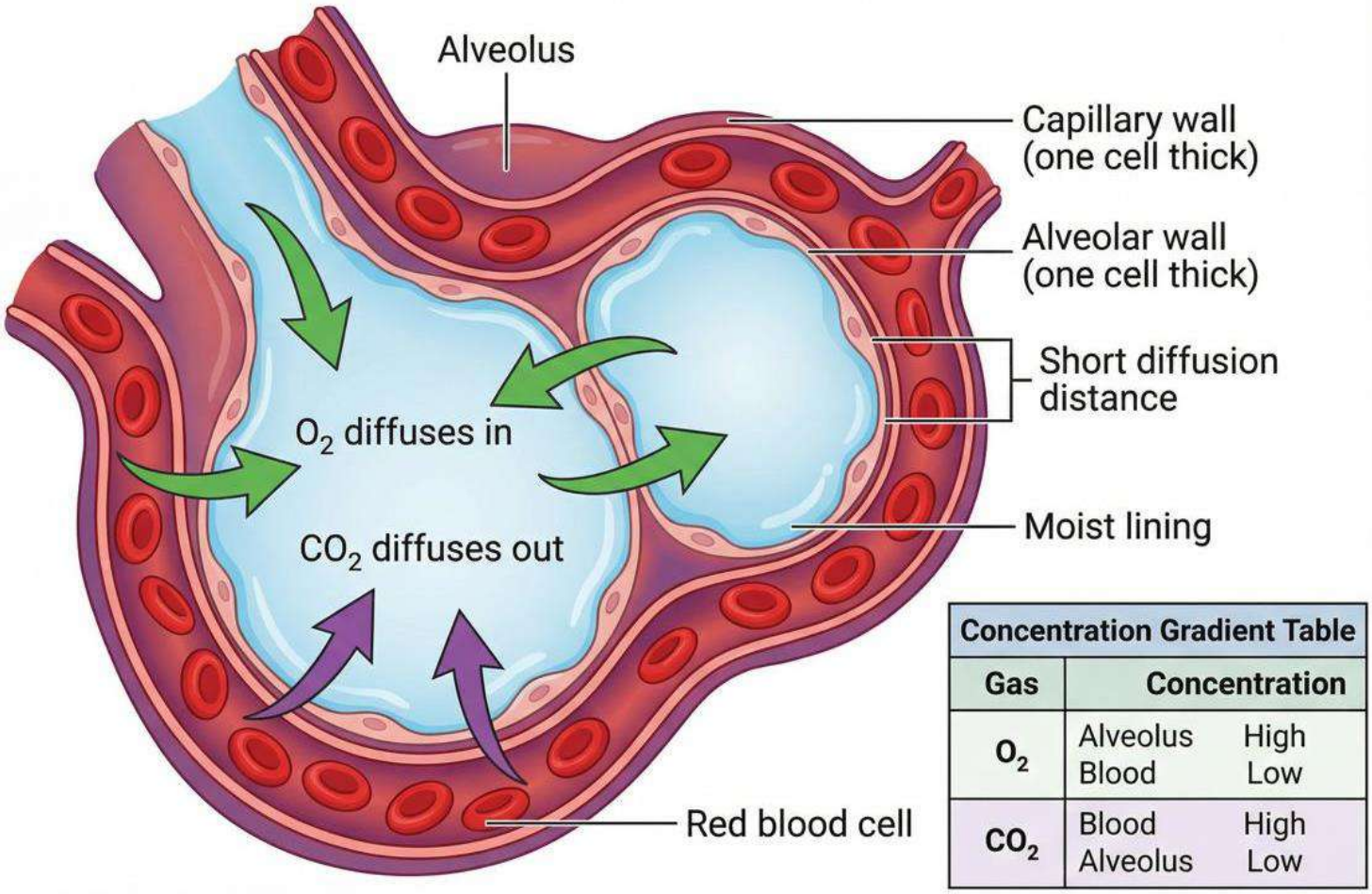
- Oxygen concentration is higher in the alveolar air than in the deoxygenated blood arriving at the lungs.
- Oxygen therefore diffuses from the alveoli into the blood.
- Carbon dioxide concentration is higher in the blood arriving at the lungs than in the alveolar air.
- Carbon dioxide therefore diffuses from the blood into the alveoli.

The carbon dioxide is then removed from the body through exhalation.

3.2 Structure of the alveolar-capillary network

Alveoli are surrounded by a dense network of blood capillaries.

The capillaries bring deoxygenated blood from the pulmonary artery branches and carry oxygenated blood away through pulmonary veins.



Concentration Gradient Table		
Gas	**Concentration**	
O_2	Alveolus	High
	Blood	Low
CO_2	Blood	High
	Alveolus	Low

Events during gaseous exchange

A. Movement of oxygen

1. Air containing oxygen enters the alveoli during inhalation.
2. Oxygen dissolves in the moist lining of the alveoli.
3. Oxygen diffuses across the thin alveolar wall.
4. It passes through the thin capillary wall into the blood.
5. Oxygen combines with haemoglobin in red blood cells to form oxyhaemoglobin.
6. Oxygenated blood is transported to the heart.
7. The heart pumps oxygenated blood to body tissues.

B. Movement of carbon dioxide

1. Carbon dioxide is produced in body cells during cellular respiration.
2. It diffuses into the blood.
3. Blood transports carbon dioxide to the lungs.
4. Carbon dioxide diffuses from the blood across the capillary and alveolar walls.
5. It enters the air inside the alveoli.
6. Carbon dioxide is removed from the body during exhalation.

3.3 How oxygen is transported in the blood

Oxygen is transported in the blood in two main ways:

1. Most oxygen is transported combined with haemoglobin in red blood cells.
2. A small amount is transported dissolved in blood plasma.

In the lungs, oxygen combines with haemoglobin to form oxyhaemoglobin.

Chemical Equation:

$$Hb + O_2 \rightleftharpoons HbO_2$$

Where:

- **Hb** – Haemoglobin
- **O_2** – Oxygen
- **HbO_2** – Oxyhaemoglobin

In body tissues, oxyhaemoglobin releases oxygen for use by cells.

3.4 How carbon dioxide is transported in the blood

Carbon dioxide is transported in the blood in three main forms:

1. Mainly as hydrogen carbonate (bicarbonate) ions in plasma.
2. Combined with haemoglobin to form carbaminohaemoglobin.
3. Dissolved directly in plasma.

The largest proportion is transported as hydrogen carbonate ions.

In the lungs, these ions are converted back into carbon dioxide, which diffuses into the alveoli and is exhaled.

3.5 Differences between inhaled and exhaled air

Inhaled air and exhaled air have different compositions because the body uses oxygen and produces carbon dioxide during cellular respiration.

Component	Inhaled air	Exhaled air
Oxygen	Approximately 21%	Approximately 16%
Carbon dioxide	Approximately 0.04%	Approximately 4%
Nitrogen and other gases	Approximately 79%	Approximately 79%
Water vapour	Variable	Usually higher

Explanation:

- Oxygen decreases because some of it is absorbed into the blood.
- Carbon dioxide increases because it is removed from the blood into the alveoli.
- Exhaled air contains more water vapour because it becomes humidified in the respiratory tract.
- Nitrogen remains approximately unchanged because the body does not use significant amounts of it during normal respiration.

3.6 Factors affecting the rate of gaseous exchange

The efficiency of gaseous exchange depends on several factors.

1. Surface area

- A large surface area allows more gases to diffuse at the same time.
- Numerous alveoli provide a large surface area.

2. Thickness of the respiratory surface

- Thin alveolar walls reduce the diffusion distance.
- This allows gases to diffuse rapidly.

3. Concentration gradient

- A large difference in oxygen and carbon dioxide concentrations increases the rate of diffusion.
- Continuous ventilation and blood circulation help maintain this gradient.

4. Moisture

- The moist lining of alveoli allows respiratory gases to dissolve before diffusion.

5. Blood supply

- A rich capillary network maintains the supply of deoxygenated blood and removes oxygenated blood.
- This helps maintain concentration gradients.

6. Ventilation

- Continuous movement of air into and out of the lungs maintains the oxygen supply in the alveoli.
- It also removes accumulated carbon dioxide.

7. Health of the lungs

- Healthy alveoli allow efficient gaseous exchange.
- Diseases that damage alveoli or cause fluid accumulation may reduce gaseous exchange.

3.7 Importance of maintaining healthy alveoli

Healthy alveoli are important because they:

1. Ensure adequate oxygen enters the blood.
2. Allow effective removal of carbon dioxide.
3. Support efficient cellular respiration.
4. Maintain normal blood gas levels.
5. Support the activities of vital organs.

4.0 MECHANISM OF BREATHING IN HUMAN BEINGS

4.1 Meaning of breathing

Breathing, also known as pulmonary ventilation, is the mechanical process through which air moves into and out of the lungs.

It consists of two main processes:

1. Inhalation (inspiration).
2. Exhalation (expiration).

Breathing involves the coordinated action of the diaphragm, intercostal muscles, ribs and thoracic cavity.

4.2 Inhalation (inspiration)

Inhalation is the process through which air enters the lungs from the external environment.

It is normally an active process because it involves muscle contraction.

Events during inhalation

1. The external intercostal muscles contract.
2. The ribs move upwards and outwards.
3. The diaphragm contracts and flattens.
4. The volume of the thoracic cavity increases.
5. The lungs expand.
6. Pressure inside the lungs decreases below atmospheric pressure.
7. Air flows into the lungs through the respiratory passages.



Changes during inhalation

Structure or condition	Change
External intercostal muscles	Contract
Ribs	Move upwards and outwards
Diaphragm	Contracts and flattens
Thoracic cavity volume	Increases
Lung volume	Increases
Pressure inside lungs	Decreases
Direction of air movement	Into the lungs

4.3 Exhalation (expiration)

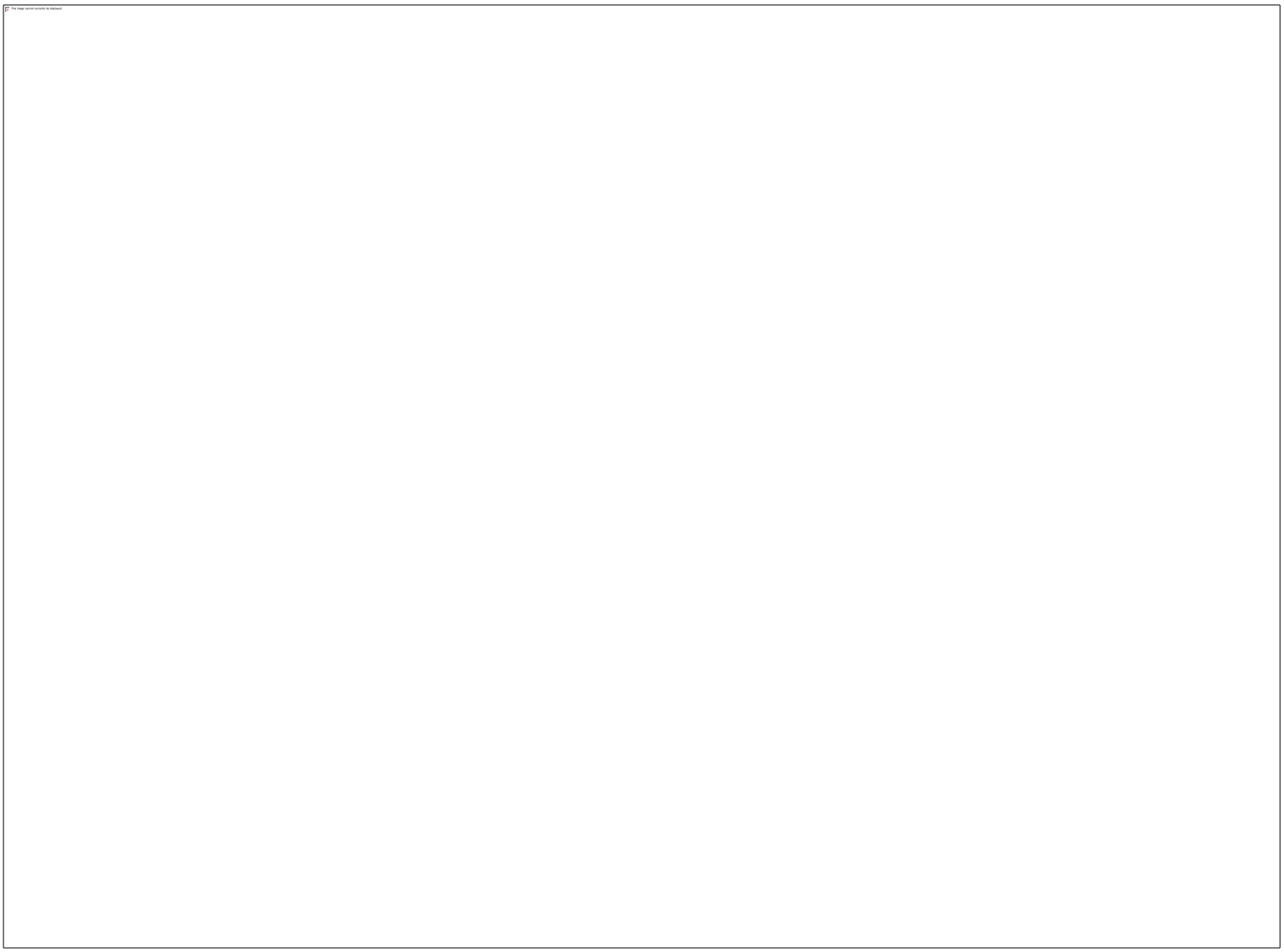
Exhalation is the process through which air is expelled from the lungs into the external environment.

During quiet breathing, exhalation is normally a passive process.

Events during exhalation

1. The external intercostal muscles relax.
2. The ribs move downwards and inwards.
3. The diaphragm relaxes and becomes dome-shaped.
4. The volume of the thoracic cavity decreases.

5. The lungs recoil due to their elastic properties.
6. Pressure inside the lungs increases above atmospheric pressure.
7. Air flows out of the lungs.



Changes during exhalation

Structure or condition	Change
External intercostal muscles	Relax
Ribs	Move downwards and inwards
Diaphragm	Relaxes and becomes dome-shaped
Thoracic cavity volume	Decreases
Lung volume	Decreases
Pressure inside lungs	Increases
Direction of air movement	Out of the lungs

4.4 Differences between inhalation and exhalation

Inhalation	Exhalation
Air enters the lungs.	Air leaves the lungs.

External intercostal muscles contract.	External intercostal muscles relax.
Ribs move upwards and outwards.	Ribs move downwards and inwards.
Diaphragm contracts.	Diaphragm relaxes.
Diaphragm flattens.	Diaphragm becomes dome-shaped.
Thoracic volume increases.	Thoracic volume decreases.
Lung pressure decreases.	Lung pressure increases.
Normally active.	Normally passive during quiet breathing.

4.5 Forced breathing

Forced breathing occurs during activities that require increased ventilation, such as strenuous exercise, coughing or blowing.

Forced inhalation

- External intercostal muscles contract more strongly.
- Accessory muscles of inspiration, such as the sternocleidomastoid and scalene muscles, may assist.
- The thoracic cavity expands further.
- More air enters the lungs.

Forced exhalation

- Internal intercostal muscles contract.
- Abdominal muscles contract.
- The ribs are pulled downwards.
- The diaphragm is pushed upwards.
- Air is expelled forcefully from the lungs.

4.6 Pressure changes during breathing

Breathing occurs because of pressure differences between the lungs and the surrounding atmosphere.

During inhalation:

- Thoracic cavity volume increases.
- Lung volume increases.
- Pressure inside the lungs decreases.
- Atmospheric pressure becomes greater than pressure inside the lungs.
- Air enters the lungs.

During exhalation:

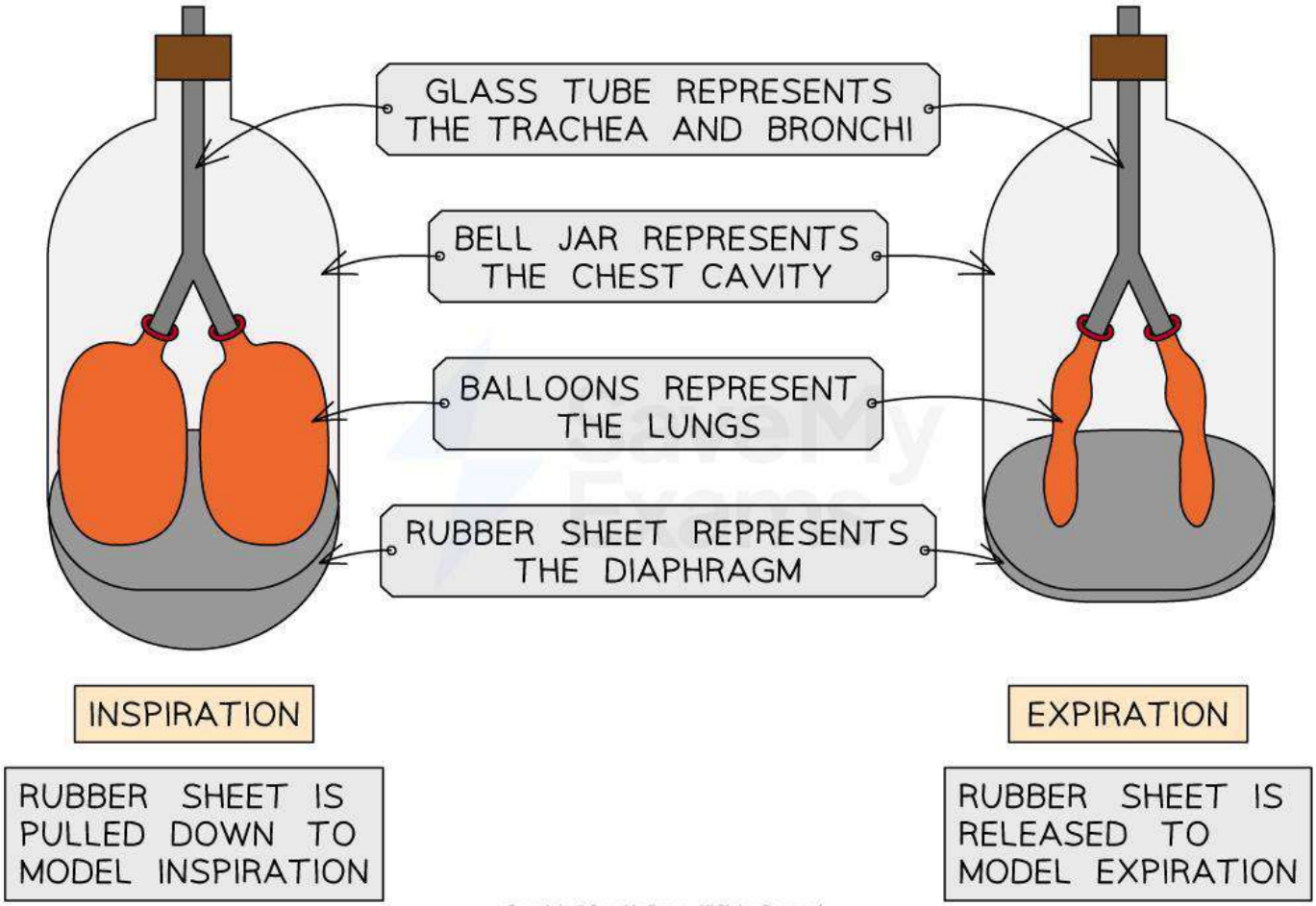
- Thoracic cavity volume decreases.
- Lung volume decreases.
- Pressure inside the lungs increases.
- Pressure inside the lungs becomes greater than atmospheric pressure.
- Air moves out of the lungs.

Scientific principle: Changes in the volume of the thoracic cavity produce corresponding changes in pressure, causing air to move into or out of the lungs.

4.7 Model demonstrating the mechanism of breathing

A simple breathing model can be made using:

- A transparent plastic bottle.
- Two small balloons.
- A Y-shaped straw.
- A larger balloon or rubber sheet.
- Rubber bands.
- Adhesive tape.



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Parts of the model and their representations

Model component	Represents
Plastic bottle	Thoracic cavity
Two small balloons	Lungs
Y-shaped tube	Trachea and bronchi
Rubber sheet	Diaphragm
Space inside bottle	Thoracic cavity

How the model works

When the rubber sheet is pulled downwards:

1. The volume inside the bottle increases.
2. Pressure inside the bottle decreases.

3. Air enters through the tube.
4. The balloons inflate.
5. This represents inhalation.

When the rubber sheet is pushed upwards:

1. The volume inside the bottle decreases.
2. Pressure inside the bottle increases.
3. Air moves out through the tube.
4. The balloons deflate.
5. This represents exhalation.

Limitation of the model: The bottle is rigid and does not show the actual movement of ribs and intercostal muscles. The rubber sheet represents the diaphragm but does not reproduce its complete structure.

5.0 REGULATION OF BREATHING IN HUMAN BEINGS

5.1 Meaning of regulation of breathing

Regulation of breathing refers to the control of the rate and depth of breathing to ensure that the body receives sufficient oxygen and removes carbon dioxide.

Breathing is controlled mainly by respiratory centres in the brainstem.

The two major regions involved are:

1. Medulla oblongata.
2. Pons.

5.2 Role of the medulla oblongata

The medulla oblongata is part of the brainstem responsible for generating the basic rhythm of breathing.

Its functions include:

- Sending nerve impulses to the diaphragm.
- Sending nerve impulses to intercostal muscles.
- Controlling the basic breathing rhythm.
- Adjusting breathing in response to changes in carbon dioxide and blood acidity.

5.3 Role of the pons

The pons is another part of the brainstem involved in modifying breathing patterns.

It helps coordinate the transition between inhalation and exhalation.

It contributes to adjusting the rate and depth of breathing.

5.4 Role of chemoreceptors in breathing regulation

Chemoreceptors are specialised receptors that detect changes in the chemical composition of blood and body fluids.

They help regulate breathing by detecting changes in:

- Carbon dioxide levels.
- Blood pH.
- Oxygen levels.

Types of chemoreceptors

A. Central chemoreceptors

- Located in the brainstem.
- Respond mainly to changes in the pH of fluid surrounding the brain.
- Indirectly detect changes in carbon dioxide levels.

B. Peripheral chemoreceptors

- Found in the carotid bodies and aortic bodies.
- Detect changes in oxygen, carbon dioxide and blood pH.
- Help increase breathing when blood oxygen becomes significantly low or carbon dioxide rises.

5.5 How carbon dioxide affects breathing rate

Carbon dioxide plays an important role in regulating breathing.

When carbon dioxide increases in the blood:

1. More carbon dioxide reacts with water to form carbonic acid.
2. Carbonic acid dissociates, increasing hydrogen ion concentration.
3. Blood and surrounding body fluids become more acidic.
4. Chemoreceptors detect the change.
5. Respiratory centres in the brainstem increase nerve impulses to respiratory muscles.
6. Breathing becomes faster and deeper.
7. More carbon dioxide is removed through the lungs.

When carbon dioxide levels decrease towards normal:

- Stimulation of respiratory centres reduces.
- Breathing rate and depth adjust accordingly.

5.6 Negative feedback in breathing regulation

Negative feedback is a control mechanism in which a change in a condition triggers responses that oppose the original change.

For example:

- Increased carbon dioxide stimulates faster and deeper breathing.
- Increased ventilation removes more carbon dioxide.
- Carbon dioxide levels move towards normal.
- The stimulation of breathing reduces.

This helps maintain a stable internal environment.

6.0 FACTORS AFFECTING THE RATE OF BREATHING

6.1 Meaning of breathing rate

Breathing rate is the number of complete breathing cycles taken in one minute.

One complete breathing cycle consists of one inhalation followed by one exhalation.

In a healthy resting adult, the normal breathing rate is commonly about 12–20 breaths per minute.

The rate varies depending on age, physical activity and health.

6.2 Factors affecting breathing rate

A. Age

Age influences the rate of breathing.

- Babies generally breathe faster than adults.
- Young children have higher breathing rates than adults.
- Adults generally have lower resting breathing rates.
- Breathing patterns may change in older people due to age-related changes in respiratory function and health.

Explanation: Children have smaller lungs and higher metabolic demands relative to their body size.

B. Physical exercise

Physical exercise increases the rate and depth of breathing.

Examples include:

- Running.
- Cycling.
- Swimming.
- Playing football.
- Climbing hills.
- Digging and other physically demanding activities.

Explanation:

1. Working muscles require more energy.
2. Cellular respiration increases.
3. More oxygen is needed.
4. More carbon dioxide is produced.
5. Chemoreceptors and respiratory centres stimulate increased ventilation.
6. Breathing becomes faster and deeper.

C. Sex

Biological sex may influence average breathing patterns.

- Adult females may have a slightly higher average resting breathing rate than adult males.
- Differences in average lung size, body dimensions and respiratory mechanics may contribute.
- However, individual variation is considerable.

D. Health condition

Health status affects breathing rate.

Examples:

- Fever may increase breathing rate.
- Pneumonia may cause rapid breathing.

- Asthma may cause difficulty in breathing.
- Heart and lung diseases may affect ventilation.
- Anaemia may cause increased breathing as the body attempts to meet oxygen demands.

E. Emotional state

Strong emotions can affect breathing.

Examples include:

- Fear.
- Anxiety.
- Excitement.
- Anger.
- Stress.

These emotions may activate the nervous system, causing breathing to become faster or irregular.

F. Altitude

Altitude refers to the height of a location above sea level.

At high altitudes:

- Atmospheric pressure is lower.
- Oxygen partial pressure is lower.
- Less oxygen enters the blood with each breath.
- Breathing rate and depth may increase as the body adjusts.

Kenyan example: People travelling from lowland areas to high-altitude locations such as parts of the Kenyan highlands may initially experience changes in breathing as their bodies adjust to the environment.

G. Environmental conditions

Environmental conditions may influence breathing.

Examples:

- Dusty environments.
- Smoke.
- Air pollution.
- Chemical fumes.
- Poor ventilation.

These conditions may irritate the respiratory tract and cause coughing, wheezing or difficulty in breathing.

H. Body temperature

An increase in body temperature, such as during fever, may increase the rate of breathing.

This is partly because metabolic activity may increase.

I. Body fitness

People who exercise regularly may have more efficient respiratory and cardiovascular systems.

A physically fit person may have a lower resting breathing rate than a less physically fit person, although this varies between individuals.

6.3 Summary of factors affecting breathing rate

Factor	Effect on breathing rate
Age	Children generally breathe faster than adults.
Exercise	Increases breathing rate and depth.
Sex	May contribute to average differences in resting breathing rates.
Illness	Respiratory infections and fever may increase breathing rate.
Emotions	Fear and anxiety may increase breathing rate.
Altitude	High altitude may increase breathing rate.
Pollution	Irritates airways and may affect breathing.
Body temperature	Fever may increase breathing rate.
Physical fitness	Good fitness may lower resting breathing rate.

6.4 Practical activity: Investigating the effect of exercise on breathing rate

Objective: To investigate how physical activity affects breathing rate.

Materials:

- Stopwatch.
- Notebook.
- Pen.
- Safe open space.

Procedure:

1. Work in pairs.
2. Allow one learner to sit quietly for five minutes.
3. Count the number of breaths taken in one minute.
4. Record the resting breathing rate.
5. Ask the learner to jog on the spot for two minutes.
6. Immediately count the breathing rate again for one minute.
7. Allow the learner to rest.
8. Record the breathing rate after five minutes of recovery.
9. Compare the readings.

Results table

Condition	Breathing rate (breaths per minute)
At rest	
Immediately after exercise	
After five minutes of rest	

Discussion questions

1. What was the breathing rate at rest?
2. What happened to the breathing rate after exercise?
3. Why did the breathing rate increase?

4. Why did the breathing rate decrease during recovery?

Conclusion: Exercise increases the body's oxygen demand and carbon dioxide production, causing breathing rate and depth to increase.

Safety precautions:

- Learners should perform moderate exercise appropriate to their fitness.
- Learners with health conditions should follow appropriate medical guidance.
- Stop the activity if a learner experiences dizziness, chest pain or unusual difficulty in breathing.

7.0 DISEASES OF THE HUMAN RESPIRATORY SYSTEM

7.1 Meaning of respiratory diseases

Respiratory diseases are illnesses or medical conditions that affect the organs and structures responsible for breathing and gaseous exchange.

They may affect the nose, throat, trachea, bronchi, bronchioles, alveoli or lungs.

Some respiratory diseases are infectious and can spread from one person to another, while others are non-communicable and may result from allergies, environmental exposure, genetic factors or other causes.

The major respiratory diseases covered in this sub-strand are:

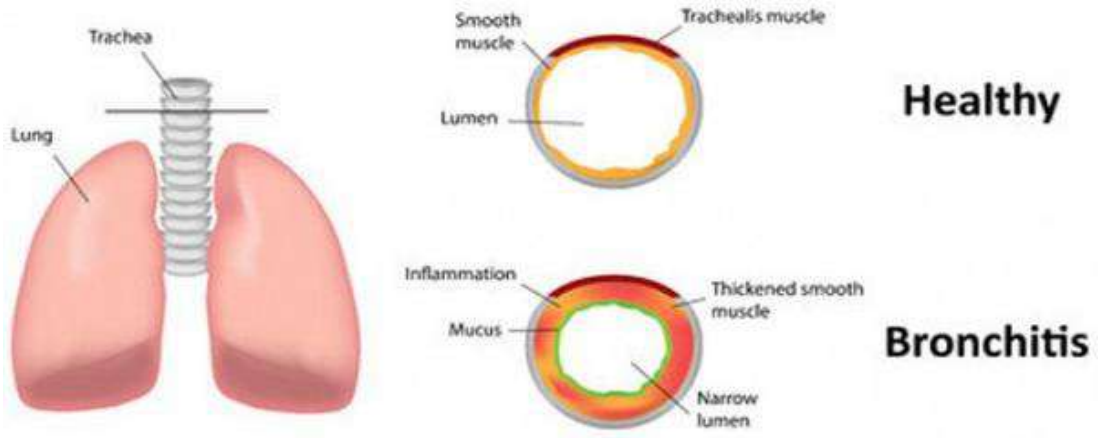
1. Bronchitis.
2. Pneumonia.
3. Asthma.
4. Tuberculosis (TB).

7.2 Bronchitis

Meaning of bronchitis

Bronchitis is an inflammation of the lining of the bronchial tubes, which carry air into and out of the lungs.

The inflammation causes the air passages to become swollen and may increase mucus production.



Types of bronchitis

A. Acute bronchitis

- Usually develops suddenly.
- Commonly follows a viral respiratory infection.
- Causes temporary inflammation of the bronchial tubes.

- Often improves within a few weeks.

B. Chronic bronchitis

- Involves a long-lasting productive cough.
- Is commonly associated with prolonged exposure to cigarette smoke and other airway irritants.
- Is a form of chronic obstructive pulmonary disease (COPD).

Causes of bronchitis

1. Viral infections.
2. Exposure to cigarette smoke.
3. Air pollution.
4. Dust and chemical fumes.
5. Exposure to other respiratory irritants.
6. Repeated respiratory infections.

Signs and symptoms of bronchitis

- Persistent coughing.
- Production of mucus or phlegm.
- Chest discomfort.
- Wheezing.
- Shortness of breath.
- Mild fever in some cases.
- Fatigue.

Effects of bronchitis

1. Reduces the diameter of the air passages.
2. Increases mucus production.
3. Interferes with normal airflow.
4. May cause difficulty in breathing.
5. May lead to persistent coughing.

Prevention and control of bronchitis

1. Avoid smoking and exposure to second-hand smoke.
2. Reduce exposure to dust and air pollution.
3. Wear appropriate protective equipment in dusty workplaces.
4. Maintain good personal hygiene.
5. Wash hands regularly.
6. Cover the mouth and nose when coughing or sneezing.
7. Seek medical attention when symptoms are severe or persistent.
8. Avoid unnecessary use of antibiotics because many cases of acute bronchitis are caused by viruses.

7.3 Pneumonia

Meaning of pneumonia

Pneumonia is an infection that causes inflammation of the air sacs (alveoli) in one or both lungs.

The alveoli may fill with fluid or pus, interfering with normal gaseous exchange.



Causes of pneumonia

Pneumonia may be caused by:

1. Bacteria.
2. Viruses.
3. Fungi.

Common bacterial causes include *Streptococcus pneumoniae*.

Signs and symptoms of pneumonia

- Coughing.
- Fever.
- Chills.
- Chest pain, especially when breathing or coughing.
- Rapid breathing.
- Difficulty in breathing.
- Production of mucus or phlegm.
- Fatigue.
- Reduced appetite.

In severe cases, oxygen levels in the blood may become dangerously low.

How pneumonia affects gaseous exchange

1. Infection causes inflammation of the alveoli.

2. Fluid and inflammatory cells may accumulate in the air sacs.
3. The normal movement of oxygen across the alveolar walls becomes less efficient.
4. Less oxygen enters the blood.
5. The affected person may experience difficulty in breathing.
6. Severe pneumonia may cause respiratory failure.

Prevention and control of pneumonia

1. Ensure children receive recommended immunisations.
2. Practise regular handwashing.
3. Avoid exposure to tobacco smoke.
4. Maintain proper ventilation in homes and classrooms.
5. Practise good respiratory hygiene.
6. Maintain a balanced diet.
7. Seek early medical attention when symptoms appear.
8. Complete prescribed treatment.
9. Reduce overcrowding where possible.

Kenyan context: Pneumonia is an important public health concern, particularly among young children, older people and individuals with weakened immune systems.

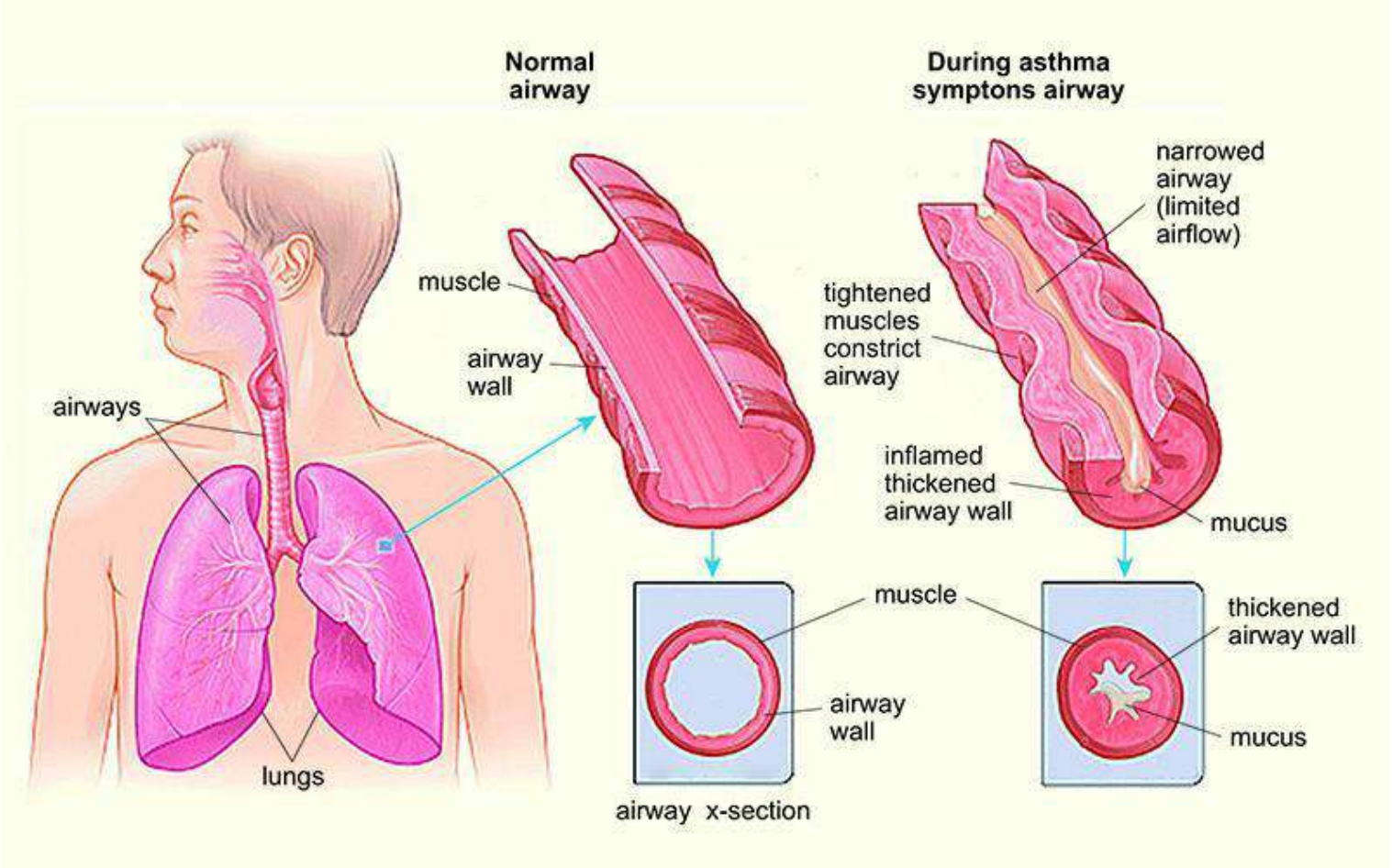
7.4 Asthma

Meaning of asthma

Asthma is a chronic inflammatory condition of the airways characterised by episodes of airway narrowing, swelling and increased mucus production.

It causes difficulty in moving air into and out of the lungs.

Asthma is generally non-communicable, meaning it does not spread from one person to another.



Causes and triggers of asthma

Asthma may be associated with genetic and environmental factors.

Common triggers include:

1. Dust.
2. Pollen.
3. Smoke.
4. Cold air.
5. Animal fur or dander.
6. Respiratory infections.
7. Air pollution.
8. Physical exercise in some individuals.
9. Strong chemical smells.
10. Certain occupational substances.

What happens during an asthma attack?

1. A trigger causes the airways to react.
2. The airway lining becomes inflamed.
3. Smooth muscles around the bronchioles contract.
4. Excess mucus may be produced.
5. The airway diameter becomes narrower.

6. Airflow is restricted.
7. The person experiences difficulty in breathing.

Signs and symptoms of asthma

- Wheezing (a whistling sound during breathing).
- Shortness of breath.
- Chest tightness.
- Coughing.
- Difficulty breathing, especially at night or early morning.

Symptoms may vary from mild to severe.

Prevention and control of asthma

1. Identify and avoid personal triggers.
2. Avoid cigarette smoke.
3. Reduce exposure to dust.
4. Keep living spaces clean.
5. Use prescribed inhalers correctly.
6. Follow the asthma management plan provided by a healthcare professional.
7. Attend regular medical reviews.
8. Seek urgent medical assistance during a severe attack.

Important: Asthma can be controlled with appropriate treatment. A person with asthma should not stop prescribed medication without medical advice.

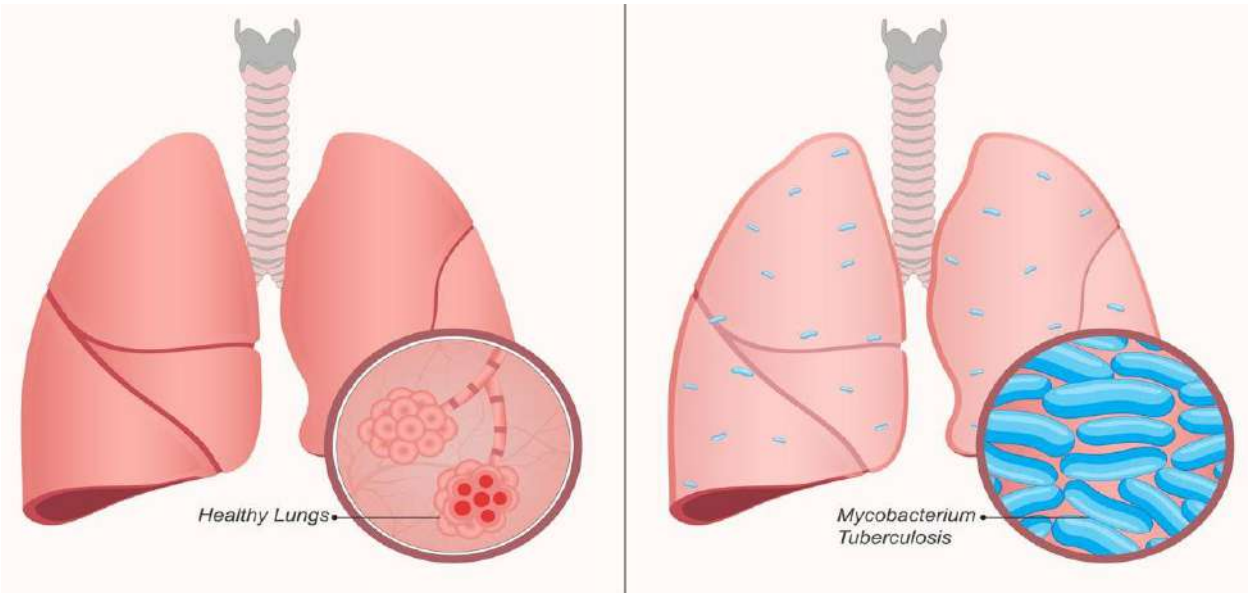
7.5 Tuberculosis (TB)

Meaning of tuberculosis

Tuberculosis is an infectious disease caused by a bacterium known as *Mycobacterium tuberculosis*.

It mainly affects the lungs, although it can also affect other parts of the body.

Pulmonary tuberculosis is tuberculosis that affects the lungs.



How tuberculosis spreads

Pulmonary TB spreads through the air when a person with infectious TB releases tiny infectious particles while:

- Coughing.
- Sneezing.
- Speaking.
- Singing.

Other people may become infected when they inhale these particles.

TB is not normally spread through sharing plates, touching, handshakes or ordinary sharing of food.

Risk factors associated with tuberculosis

1. Close and prolonged contact with a person who has infectious TB.
2. HIV infection.
3. Malnutrition.
4. Weakened immune systems.
5. Overcrowded living conditions.
6. Poorly ventilated rooms.
7. Certain chronic illnesses.
8. Limited access to timely diagnosis and treatment.

Signs and symptoms of tuberculosis

- Persistent cough, especially lasting two weeks or more.
- Coughing blood in some cases.
- Chest pain.
- Fever.
- Night sweats.
- Unexplained weight loss.
- Loss of appetite.
- General body weakness.
- Fatigue.

Effects of tuberculosis

1. Damages lung tissues.
2. Interferes with gaseous exchange.
3. May cause prolonged coughing.
4. May result in weight loss and weakness.
5. Can spread to other organs.
6. Untreated TB can become life-threatening.

Prevention and control of tuberculosis

1. Early diagnosis and treatment of infected persons.
2. Completion of prescribed TB treatment.
3. Ensuring proper ventilation in homes, schools and workplaces.
4. Covering the mouth and nose when coughing.
5. Avoiding prolonged exposure to infectious individuals without appropriate precautions.
6. Screening people who have been in close contact with TB patients.
7. Providing BCG vaccination according to national immunisation guidelines.
8. Maintaining good nutrition.
9. Strengthening HIV prevention, testing and treatment services.
10. Observing infection prevention measures in health facilities.

Treatment of tuberculosis

- TB is treated using a combination of specific antibiotics.
- Treatment usually lasts several months.
- The exact treatment depends on the type of TB and medical assessment.
- Patients should take medicines as prescribed.
- Failure to complete treatment may contribute to drug-resistant TB.

Important: A person suspected of having TB should seek testing and treatment at a health facility. TB is treatable and curable in most cases when appropriately managed.

7.6 Comparison of respiratory diseases

Disease	Main cause	Main affected structure	Major feature
Bronchitis	Often viral infection or airway irritants	Bronchi	Inflamed bronchial tubes and increased mucus
Pneumonia	Bacteria, viruses or fungi	Alveoli	Air sacs become inflamed and may fill with fluid
Asthma	Airway inflammation and triggers	Bronchi and bronchioles	Reversible narrowing of airways in many patients
Tuberculosis	*Mycobacterium tuberculosis*	Mainly lungs	Infectious disease that damages lung tissues

7.7 Communicable and non-communicable respiratory diseases

Communicable respiratory diseases are diseases that can spread from one person to another through infectious agents.

Examples:

- Pulmonary tuberculosis.
- Some forms of pneumonia.
- Viral respiratory infections.

Non-communicable respiratory conditions are not transmitted from one person to another.

Examples:

- Asthma.
- Chronic bronchitis associated with smoking or prolonged irritant exposure.

7.8 General prevention and control of respiratory diseases

Respiratory health can be maintained through the following practices:

1. Avoid smoking and tobacco products.
2. Avoid exposure to second-hand smoke.
3. Ensure proper ventilation in houses and classrooms.
4. Reduce exposure to dust and chemical fumes.
5. Wear suitable protective masks when exposed to harmful dust.
6. Wash hands regularly.
7. Cover the mouth and nose when coughing or sneezing.
8. Receive recommended vaccinations.
9. Maintain a balanced diet.
10. Exercise regularly.
11. Seek early medical attention when respiratory symptoms persist.
12. Complete prescribed treatment.
13. Avoid overcrowding where possible.
14. Keep the home and school environment clean.
15. Avoid indiscriminate use of antibiotics.

7.9 Importance of community awareness on respiratory diseases

Community awareness involves educating members of society about the causes, signs, prevention and control of respiratory diseases.

In Kenya, schools, health centres, community health promoters and local organisations can help create awareness.

Ways of creating awareness

- Preparing educational posters.
- Organising school health talks.
- Sharing electronic health messages.
- Conducting community health campaigns.
- Using radio and television programmes.
- Organising discussions with healthcare workers.
- Sharing accurate information through digital platforms.

Example of a school health message

PROTECT YOUR LUNGS!

- Avoid smoking.
- Keep your environment clean.
- Ensure proper ventilation.
- Cover your mouth when coughing.
- Get recommended vaccinations.
- Seek medical attention for persistent coughs.

- Complete prescribed treatment.

8.0 PRACTICAL ACTIVITIES AND LEARNING EXPERIENCES

The following activities help learners acquire practical skills and develop competencies through investigation and collaboration.

Activity 1: Identifying parts of the respiratory system

Objective: To identify the major structures of the human respiratory system.

Materials:

- Respiratory system chart.
- Textbook.
- Model of human lungs.
- Labels.
- Drawing materials.

Procedure:

1. Observe a chart showing the human respiratory system.
2. Identify the nostrils and nasal cavity.
3. Trace the pathway of air through the pharynx and larynx.
4. Identify the trachea.
5. Follow the branches into the bronchi and bronchioles.
6. Identify the lungs and alveoli.
7. Label the structures on a blank diagram.
8. Discuss the functions of each structure.

Expected outcome: Learners identify and explain the functions of the major respiratory structures.

Activity 2: Demonstrating the mechanism of breathing

Objective: To investigate how changes in thoracic cavity volume cause air to move into and out of the lungs.

Materials:

- Transparent plastic bottle.
- Two balloons.
- Y-shaped tube.
- Rubber sheet.
- Rubber bands.
- Adhesive tape.

Procedure:

1. Cut the bottom of a transparent plastic bottle.
2. Insert a Y-shaped tube through the bottle opening.
3. Attach a small balloon to each branch of the tube.
4. Secure the balloons to prevent air leakage.

5. Cover the cut bottom with a rubber sheet.
6. Pull the rubber sheet downwards.
7. Observe the balloons.
8. Push the rubber sheet upwards.
9. Observe the changes in the balloons.

Expected observations:

- Pulling the rubber sheet down causes the balloons to inflate.
- Pushing the rubber sheet upwards causes the balloons to deflate.

Conclusion: Changes in the volume of the thoracic cavity cause pressure changes that move air into and out of the lungs.

Activity 3: Investigating the effect of exercise on breathing rate

Objective: To establish the relationship between physical activity and breathing rate.

Procedure:

1. Measure the resting breathing rate of a learner.
2. Ask the learner to perform moderate exercise.
3. Measure the breathing rate immediately after exercise.
4. Allow the learner to rest.
5. Measure the breathing rate again.
6. Compare the readings.

Expected result: Breathing rate increases following exercise and gradually returns towards the resting level during recovery.

Activity 4: Observing the effect of carbon dioxide on limewater

Objective: To investigate the presence of carbon dioxide in exhaled air.

Materials:

- Fresh limewater.
- Two test tubes or suitable transparent containers.
- Drinking straws.
- Clean water.

Procedure:

1. Place equal amounts of fresh limewater in two transparent containers.
2. Leave one container as a control.
3. Using a clean drinking straw, gently bubble exhaled air through the limewater in the second container.
4. Observe and compare the two containers.

Expected observation: The limewater through which exhaled air is passed turns milky due to the formation of calcium carbonate.

Word equation:

Calcium hydroxide + Carbon dioxide → Calcium carbonate + Water.

Conclusion: Exhaled air contains carbon dioxide.

Safety precautions:

- Never inhale limewater.
- Use separate clean straws.
- Do not share drinking straws.
- Do not suck liquid into the mouth.
- Dispose of chemicals appropriately.

Activity 5: Creating awareness about respiratory diseases

Objective: To develop communication and community health awareness skills.

Procedure:

1. Divide learners into groups.
2. Assign each group one respiratory disease.
3. Research its causes, symptoms and prevention.
4. Prepare an educational poster.
5. Present the poster to classmates.
6. Display the posters on the classroom noticeboard.

Expected outcome: Learners develop awareness of respiratory diseases and their prevention.

REVISION EXERCISES

SECTION A: MULTIPLE-CHOICE QUESTIONS (30 MARKS)

Instructions: Answer all questions by selecting the correct alternative from options A, B, C and D. Each question carries one mark.

1. Gaseous exchange in human beings refers to the:

A. Movement of food through the digestive system.

B. Movement of oxygen and carbon dioxide between the body and the environment.

C. Movement of blood through the heart.

D. Breakdown of food in the stomach.

2. Which of the following is the main site of gaseous exchange in human beings?

A. Trachea.

B. Bronchi.

C. Alveoli.

D. Nasal cavity.

3. Which structure prevents food from entering the trachea during swallowing?

A. Larynx.

B. Epiglottis.

C. Bronchus.

D. Diaphragm.

4. The main function of the nasal cavity is to:

A. Produce oxygen.

B. Pump blood.

C. Filter, warm and moisten inhaled air.

D. Exchange gases with blood.

5. The trachea is prevented from collapsing by:

A. Muscular fibres.

B. C-shaped cartilage rings.

C. Blood vessels.

D. Alveolar sacs.

6. Which structures connect the trachea to the lungs?

A. Bronchi.

B. Alveoli.

C. Capillaries.

D. Bronchioles.

7. The walls of alveoli are suitable for gaseous exchange because they are:

A. Thick and muscular.

B. Made of cartilage.

C. One cell thick.

D. Covered with bones.

8. Which blood vessel surrounds the alveoli?

A. Artery only.

B. Pulmonary capillary.

C. Aorta.

D. Vena cava.

9. Oxygen moves from the alveoli into the blood through:

A. Active transport.

B. Osmosis.

C. Diffusion.

D. Transpiration.

10. Which gas diffuses from the blood into the alveoli?

A. Nitrogen.

B. Oxygen.

C. Hydrogen.

D. Carbon dioxide.

11. Most oxygen in human blood is transported by:

A. Plasma proteins.

B. Haemoglobin.

C. Platelets.

D. White blood cells.

12. Which of the following correctly describes inhalation?

A. The diaphragm relaxes and becomes dome-shaped.

B. The ribs move downwards and inwards.

C. The thoracic cavity decreases in volume.

D. The diaphragm contracts and flattens.

13. During normal exhalation, the diaphragm:

A. Contracts and flattens.

B. Relaxes and becomes dome-shaped.

C. Moves downwards.

D. Remains permanently contracted.

14. During inhalation, the volume of the thoracic cavity:

A. Decreases.

B. Remains constant.

C. Increases.

D. Becomes zero.

15. Air enters the lungs during inhalation because:

A. Lung pressure becomes lower than atmospheric pressure.

B. Lung pressure becomes higher than atmospheric pressure.

C. Blood pressure increases.

D. The lungs produce oxygen.

16. Which muscles contract during normal inhalation?

A. Internal intercostal muscles only.

B. External intercostal muscles and diaphragm.

C. Abdominal muscles only.

D. Neck muscles only.

17. The main respiratory centre responsible for generating the basic breathing rhythm is found in the:

A. Cerebellum.

B. Medulla oblongata.

C. Cerebrum.

D. Spinal cord.

18. Which chemical change normally provides the strongest stimulus for increasing breathing?

A. Decrease in carbon dioxide.

B. Increase in carbon dioxide.

C. Increase in nitrogen.

D. Decrease in glucose.

19. Which of the following is a function of chemoreceptors?

A. Producing red blood cells.

B. Detecting changes in blood gases and pH.

C. Digesting proteins.

D. Producing digestive enzymes.

20. What happens to breathing rate during strenuous physical exercise?

A. It decreases permanently.

B. It remains unchanged.

C. It increases.

D. It stops.

21. Which of the following generally has the highest resting breathing rate?

A. Healthy adult.

B. Healthy infant.

C. Healthy elderly adult.

D. Healthy adolescent.

22. At high altitudes, breathing rate may increase because:

A. Atmospheric pressure is higher.

B. Oxygen partial pressure is lower.

C. Carbon dioxide disappears.

D. The lungs stop functioning.

23. Which respiratory disease involves inflammation of the bronchial tubes?

A. Pneumonia.

B. Tuberculosis.

C. Bronchitis.

D. Asthma.

24. Pneumonia mainly affects the:

A. Alveoli.

B. Nasal hairs.

C. Diaphragm.

D. Vocal cords.

25. Which of the following is a common symptom of asthma?

A. Excessive urination.

B. Wheezing.

C. Joint dislocation.

D. Blurred vision.

26. Tuberculosis is caused by:

A. A virus.

B. A fungus.

C. Mycobacterium tuberculosis.

D. A protozoan.

27. Pulmonary tuberculosis mainly spreads through:

A. Sharing plates.

B. Shaking hands.

C. Inhaling infectious airborne particles.

D. Sharing clothes.

28. Which of the following practices helps prevent respiratory infections?

A. Smoking cigarettes.

B. Staying in poorly ventilated rooms.

C. Ignoring persistent coughing.

D. Maintaining good respiratory hygiene.

29. Which of the following is a major harmful effect of smoking on the respiratory system?

A. Improves lung capacity.

B. Damages respiratory tissues and cilia.

C. Increases alveolar surface area.

D. Strengthens the respiratory muscles.

30. In a breathing model, the rubber sheet at the bottom of a bottle represents the:

A. Trachea.

B. Lungs.

C. Diaphragm.

D. Bronchi.

SECTION B: STRUCTURED QUESTIONS – 50 MARKS

Instructions: Answer all questions. Write your answers clearly and use scientific terms appropriately.

Question 1: Human Respiratory System (8 marks)

a) Define gaseous exchange. (2 marks)

b) Name four structures of the human respiratory system involved in conducting air to the alveoli. (4 marks)

c) State two functions of the nasal cavity. (2 marks)

Question 2: Structure and Adaptations of the Respiratory System (8 marks)

a) State three structural adaptations of alveoli to gaseous exchange. (3 marks)

b) Explain two functions of the trachea in the human respiratory system. (2 marks)

c) Explain how the structure of the bronchioles enables them to perform their functions. (3 marks)

Question 3: Gaseous Exchange (8 marks)

a) Define diffusion. (2 marks)

b) Explain how oxygen moves from the alveoli into the blood. (3 marks)

c) Explain how carbon dioxide is removed from the blood through the lungs. (3 marks)

Question 4: Mechanism of Breathing (8 marks)

a) Differentiate between inhalation and exhalation. (2 marks)

b) Describe the changes that take place during inhalation under the following headings: (4 marks)

i. Diaphragm. ii. Ribs. iii. Thoracic cavity volume. iv. Pressure inside the lungs.

c) State two muscles involved in normal inhalation. (2 marks)

Question 5: Regulation and Factors Affecting Breathing (9 marks)

a) Name two parts of the brainstem involved in regulating breathing. (2 marks)

b) Explain how an increase in carbon dioxide concentration in the blood affects the breathing rate. (3 marks)

c) State four factors that influence the breathing rate in human beings. (4 marks)

Question 6: Respiratory Diseases and Prevention (9 marks)

a) Define the following respiratory conditions: (3 marks)

i. Bronchitis. ii. Pneumonia. iii. Asthma.

b) State three symptoms of pulmonary tuberculosis. (3 marks)

c) Explain three measures that can be used to prevent and control respiratory diseases in human beings. (3 marks)

12.0 REVISION ANSWER KEY AND MARKING SCHEME

Section A: Multiple Choice Answers

Question	Answer	Question	Answer
1	B	16	B
2	C	17	B
3	B	18	B
4	C	19	B
5	B	20	C
6	A	21	B
7	C	22	B
8	B	23	C
9	C	24	A
10	D	25	B
11	B	26	C
12	D	27	C
13	B	28	D
14	C	29	B
15	A	30	C

Section B: Suggested Answers and Marking Scheme

Question 1: Human Respiratory System (8 marks)

a) Gaseous exchange is the movement of oxygen into the blood and carbon dioxide out of the blood across respiratory surfaces. (2)

b) Any four:

- Nostrils.
- Nasal cavity.
- Pharynx.
- Larynx.
- Trachea.
- Bronchi.
- Bronchioles. (4)

c) Any two:

- Filters inhaled air.
- Warms incoming air.
- Moistens incoming air.
- Traps dust and microorganisms. (2)

Question 2: Structure and Adaptations of the Respiratory System (8 marks)

a) Any three:

- Numerous alveoli provide a large surface area.
- Thin walls reduce diffusion distance.
- Moist lining allows gases to dissolve.
- Rich blood supply maintains a concentration gradient.
- Close association with capillaries facilitates rapid diffusion. (3)

b) Any two explained:

- Conducts air between the larynx and bronchi.
- Mucus traps dust and microorganisms.
- Cilia move trapped particles towards the throat.
- Cartilage rings prevent collapse of the airway. (2)

c) Any three:

- Smooth muscles regulate the diameter of bronchioles.
- Their extensive branching distributes air throughout the lungs.
- They conduct air towards the alveoli.
- Smaller branches connect to alveolar ducts and sacs. (3)

Question 3: Gaseous Exchange (8 marks)

a) Diffusion is the movement of particles from a region of higher concentration to a region of lower concentration. (2)

b)

- Oxygen concentration is higher in alveolar air than in the incoming deoxygenated blood. (1)
- Oxygen dissolves in the moist alveolar lining. (1)
- It diffuses across the alveolar and capillary walls into the blood, where it combines with haemoglobin. (1)

c)

- Carbon dioxide is transported by blood to the lungs. (1)
- Its concentration is higher in the incoming blood than in the alveolar air. (1)
- It diffuses into the alveoli and is removed during exhalation. (1)

Question 4: Mechanism of Breathing (8 marks)

a)

- Inhalation is the movement of air into the lungs. (1)
- Exhalation is the movement of air out of the lungs. (1)

b)

i. Diaphragm contracts and flattens. (1)

ii. Ribs move upwards and outwards. (1)

iii. Thoracic cavity volume increases. (1)

iv. Pressure inside the lungs decreases below atmospheric pressure. (1)

c)

- External intercostal muscles. (1)
- Diaphragm. (1)

Question 5: Regulation and Factors Affecting Breathing (9 marks)

a)

- Medulla oblongata. (1)
- Pons. (1)

b)

- Increased carbon dioxide causes an increase in hydrogen ion concentration and a decrease in pH. (1)
- Chemoreceptors detect the changes and stimulate respiratory centres in the brainstem. (1)
- Breathing becomes faster and deeper, removing more carbon dioxide. (1)

c) Any four:

- Age.
- Exercise.
- Sex.
- Health condition.
- Emotional state.
- Altitude.
- Body temperature.
- Physical fitness.
- Environmental pollution. (4)

Question 6: Respiratory Diseases and Prevention (9 marks)

a)

i. Bronchitis is inflammation of the bronchial tubes. (1)

ii. Pneumonia is an infection causing inflammation of the alveoli, which may fill with fluid or pus. (1)

iii. Asthma is a chronic inflammatory condition involving narrowing of the airways, making breathing difficult. (1)

b) Any three:

- Persistent cough.
- Coughing blood.
- Night sweats.
- Fever.
- Weight loss.
- Chest pain.
- Loss of appetite.
- Fatigue. (3)

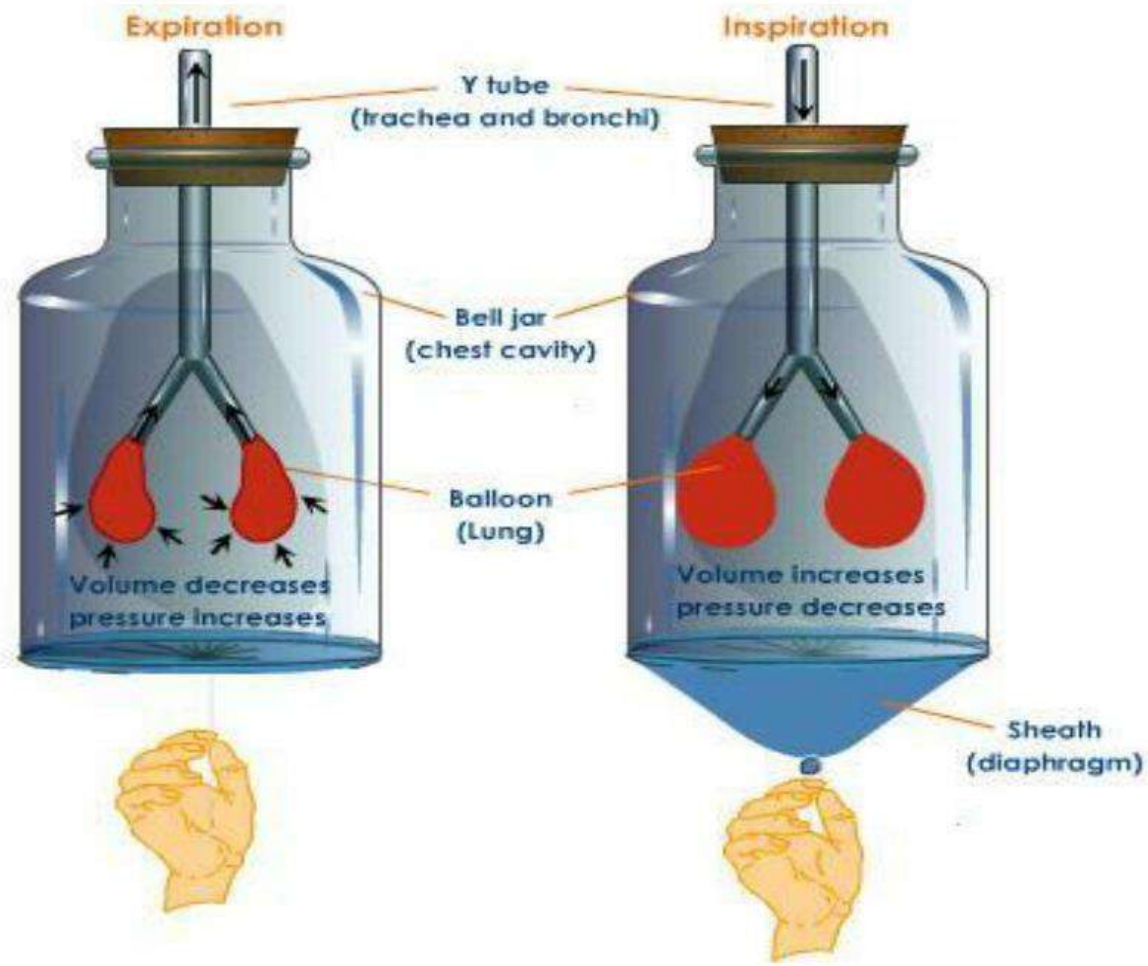
c) Any three explained:

- Avoid smoking to prevent damage to respiratory tissues.
- Maintain proper ventilation to reduce the concentration of infectious particles.
- Observe handwashing and respiratory hygiene to reduce the spread of infections.
- Receive recommended vaccinations to prevent certain respiratory diseases.
- Seek early medical attention for persistent respiratory symptoms.
- Complete prescribed treatment to prevent complications and drug resistance.
- Reduce exposure to dust and harmful fumes. (3)

13.0 END-OF-SUB-STRAND PROJECT

PRACTICAL CBE PROJECT

Constructing a Working Model of the Human Breathing Mechanism



Project objective

To construct a working model that demonstrates how the diaphragm and changes in thoracic cavity volume facilitate breathing in human beings.

Locally available materials

- Transparent plastic bottle.
- Two small balloons.
- One large balloon or rubber sheet.
- Two drinking straws and a Y-connector.
- Rubber bands.
- Adhesive tape.
- Scissors.
- Modelling clay.

Expected skills

- Research and investigation.
- Creativity and innovation.

- Manipulation of materials.
- Scientific observation.
- Communication and presentation.
- Collaboration and teamwork.

Expected outcome

A functional model demonstrating inhalation and exhalation, with correctly labelled structures and a clear explanation of pressure and volume changes.

Suggested project assessment rubric

Assessment area	**Marks**
Correct identification of materials	5
Accuracy of construction	10
Correct representation of respiratory structures	5
Demonstration of inhalation and exhalation	10
Scientific explanation	5
Creativity and presentation	5
Total	40

STRAND 1.0: LIFE SCIENCE

SUB-STRAND 1.3 HUMAN REPRODUCTION

1.0 INTRODUCTION TO HUMAN REPRODUCTION

1.1 Meaning of reproduction

Reproduction is the biological process through which living organisms produce new individuals of their own kind.

In human beings, reproduction is a sexual process involving the fusion of a male gamete (sperm cell) and a female gamete (ovum or egg cell) to form a zygote.

Human reproduction involves the male and female reproductive systems working together to facilitate fertilisation, development of the offspring and birth.

Importance of reproduction in human beings

Reproduction is important because it:

1. Ensures continuity of the human species.

2. Enables the transmission of genetic information from parents to offspring.
3. Introduces genetic variation among individuals.
4. Contributes to population growth.
5. Promotes family formation and continuity across generations.
6. Ensures the survival of human populations.

1.2 Important terms used in human reproduction

Term	Meaning
Reproduction	Production of new individuals of the same species.
Gamete	A specialised reproductive cell involved in fertilisation.
Sperm	Male reproductive cell.
Ovum	Female reproductive cell.
Fertilisation	Fusion of the nuclei of male and female gametes.
Zygote	First cell formed after fertilisation.
Conception	Commonly used to refer to the beginning of pregnancy following fertilisation and implantation.
Implantation	Attachment and embedding of the developing blastocyst into the uterine lining.
Gestation	Period during which an offspring develops in the uterus.
Embryo	Developing human organism during the early stages of development.
Foetus	Developing human organism from the end of the embryonic period until birth.
Parturition	Process of giving birth.
Ovulation	Release of a mature egg cell from an ovary.
Menstruation	Shedding of the uterine lining when pregnancy has not occurred.

2.0 THE HUMAN REPRODUCTIVE SYSTEM

2.1 Meaning of the human reproductive system

The human reproductive system is a collection of organs responsible for the production of gametes, secretion of reproductive hormones, fertilisation and the development of offspring.

There are two main reproductive systems:

1. Male reproductive system.
2. Female reproductive system.

Each system has specialised structures adapted to perform particular reproductive functions.

2.2 THE MALE REPRODUCTIVE SYSTEM

The male reproductive system consists of external and internal reproductive organs that produce, store and transport sperm cells.

2.3 Structures and functions of the male reproductive system

A. Testes

The testes are a pair of oval-shaped male reproductive organs located in the scrotum.

They are also known as testicles.

Functions of the testes

1. Produce sperm cells through a process called spermatogenesis.
2. Produce the male reproductive hormone testosterone.
3. Support the development of male secondary sexual characteristics.

4. Contribute to the maintenance of male reproductive functions.

Adaptations of the testes

- Contain numerous seminiferous tubules where sperm cells are produced.
- Have specialised cells called Leydig cells that produce testosterone.
- Are located outside the main body cavity in the scrotum, where a temperature slightly below normal body temperature supports sperm production.

B. Scrotum

The scrotum is a loose pouch of skin that holds the testes outside the main body cavity.

Functions

1. Protects the testes.
2. Maintains a suitable temperature for sperm production.
3. Allows the testes to move closer to or further from the body depending on environmental temperature.

Adaptations

- Contains muscles that help regulate the position of the testes.
- Has a skin surface that allows heat loss.
- Is located outside the main body cavity to maintain a suitable temperature.

C. Epididymis

The epididymis is a long, highly coiled tube attached to the back of each testis.

Functions

1. Stores sperm cells temporarily.
2. Provides an environment where sperm mature.
3. Transports sperm from the testes towards the vas deferens.

Adaptations

- Is highly coiled, providing a large surface area and storage space.
- Has a lining adapted to support sperm maturation.
- Connects to the vas deferens for sperm transportation.

D. Vas deferens (sperm duct)

The vas deferens is a muscular tube that carries sperm from the epididymis towards the ejaculatory duct.

Functions

1. Transports sperm during ejaculation.
2. Uses muscular contractions to propel sperm.
3. Connects the epididymis to the ejaculatory duct.

E. Seminal vesicles

The seminal vesicles are a pair of glands located behind the urinary bladder.

They produce a fluid that forms a significant portion of semen.

Functions

1. Secrete fluid rich in fructose, which provides energy for sperm.
2. Produce substances that support sperm movement and survival.
3. Contribute fluid to semen.

F. Prostate gland

The prostate gland is a gland located below the urinary bladder and surrounding the upper part of the urethra.

Functions

1. Produces fluid that contributes to semen.
2. Provides substances that support sperm function.
3. Helps maintain the appropriate chemical environment for sperm.

G. Bulbourethral glands

These are two small glands located below the prostate gland.

They are also called Cowper's glands.

Functions

1. Produce a lubricating fluid.
2. Help neutralise traces of acidic urine in the urethra.
3. Assist in preparing the urethra for the passage of semen.

H. Urethra

The urethra is a tube that runs through the penis and carries urine out of the body.

In males, it also conducts semen during ejaculation, although urine and semen do not normally pass through it at the same time.

Functions

- Carries urine out of the body.
- Carries semen during ejaculation.

I. Penis

The penis is the external male reproductive organ.

Functions

1. Deposits semen into the female reproductive tract during sexual intercourse.
2. Provides a passage for urine to leave the body.
3. Contains erectile tissues that become filled with blood during an erection.

Adaptations

- Contains erectile tissues that enable it to become erect.
- Has a urethra that conducts semen during ejaculation.
- Has a sensitive tip that contains numerous nerve endings.

J. Ejaculatory ducts

These are short ducts formed where the vas deferens joins the ducts from the seminal vesicles.

Function: They transport semen into the urethra during ejaculation.

2.4 Summary of the male reproductive organs

Structure	Main function
Testes	Produce sperm and testosterone.
Scrotum	Holds testes and regulates their temperature.
Epididymis	Stores and allows maturation of sperm.
Vas deferens	Transports sperm.
Seminal vesicles	Produce fructose-rich seminal fluid.
Prostate gland	Produces fluid that contributes to semen.
Bulbourethral glands	Produce lubricating fluid.
Urethra	Carries urine and semen out of the body.
Penis	Deposits semen into the female reproductive tract.
Ejaculatory ducts	Carry semen into the urethra.

3.0 THE FEMALE REPRODUCTIVE SYSTEM

3.1 Meaning of the female reproductive system

The female reproductive system is a group of organs responsible for producing ova, receiving sperm, providing a site for fertilisation, supporting pregnancy and facilitating childbirth.

The female reproductive system consists of internal and external reproductive structures.

3.2 Structures and functions of the female reproductive system

A. Ovaries

The ovaries are a pair of small, oval-shaped reproductive organs located on either side of the uterus.

Functions of the ovaries

1. Produce female gametes (ova or egg cells).
2. Produce oestrogen.
3. Produce progesterone, particularly through the corpus luteum after ovulation.
4. Regulate the menstrual cycle.
5. Support the development of female secondary sexual characteristics.

Adaptations

- Contain numerous ovarian follicles where egg cells develop.
- Have specialised cells that produce reproductive hormones.
- Release mature egg cells during ovulation.

B. Fallopian tubes (oviducts)

The fallopian tubes are two narrow muscular tubes connecting the regions near the ovaries to the uterus.

They are also called uterine tubes.

Functions

1. Transport the ovum from the region of the ovary towards the uterus.
2. Provide the usual site of fertilisation.
3. Transport the developing early embryo towards the uterus.

Adaptations

- Have cilia that help move the egg cell and early embryo.
- Contain smooth muscles that produce contractions.
- Have a suitable internal environment for fertilisation.
- Have finger-like projections called fimbriae near their openings that help guide the released egg into the tube.

C. Fimbriae

Fimbriae are finger-like projections located at the end of each fallopian tube near the ovary.

Functions

1. Help collect the ovum after ovulation.
2. Guide the ovum towards the opening of the fallopian tube.

D. Uterus (womb)

The uterus is a hollow, muscular, pear-shaped organ located in the pelvic cavity.

It is the organ where the embryo implants and the foetus develops during pregnancy.

Functions

1. Provides a site for implantation.
2. Supports the growth and development of the embryo and foetus.
3. Protects the developing baby.
4. Provides a suitable environment for pregnancy.
5. Contracts during childbirth to push the baby out.

Adaptations of the uterus

- Has thick muscular walls that stretch during pregnancy.
- Has a rich blood supply to support pregnancy.
- Has an inner lining called the endometrium, which becomes suitable for implantation.
- Contains smooth muscle that contracts during labour.
- Can expand considerably to accommodate the growing foetus.

E. Endometrium

The endometrium is the inner lining of the uterus.

Functions

1. Thickens during the menstrual cycle.
2. Provides a suitable site for implantation.
3. Contributes to the formation of the maternal part of the placenta.
4. Provides a supportive environment for early pregnancy.

If pregnancy does not occur, much of the functional layer of the endometrium is shed during menstruation.

F. Cervix

The cervix is the narrow lower part of the uterus that opens into the vagina.

Functions

1. Connects the uterus to the vagina.
2. Produces cervical mucus.
3. Helps protect the uterus against infection.
4. Remains relatively firm and closed during pregnancy.
5. Dilates during childbirth to allow the baby to pass.

G. Vagina

The vagina is a muscular, elastic canal extending from the cervix to the external genital opening.

Functions

1. Receives the penis and semen during sexual intercourse.
2. Provides a passage for menstrual flow.
3. Forms the birth canal during childbirth.

Adaptations

- Has elastic muscular walls that can stretch.
- Has a moist lining that protects the tissues.
- Contains a natural microbial environment that helps maintain an acidic condition.

H. Vulva

The vulva refers to the external female genital structures.

It includes the labia majora, labia minora, clitoris and the openings of the urethra and vagina.

Functions

- Protects the openings of the reproductive and urinary systems.
- Provides sensory functions.
- Helps protect the internal reproductive structures.

3.3 Summary of female reproductive structures

Structure	Main function
Ovaries	Produce ova and female reproductive hormones.
Fallopian tubes	Transport ova and provide the usual site of fertilisation.
Fimbriae	Help collect the released ovum.
Uterus	Supports implantation and foetal development.
Endometrium	Provides a site for implantation.
Cervix	Connects uterus to vagina and dilates during birth.
Vagina	Receives semen, allows menstrual flow and forms birth canal.

Vulva	External protection of the reproductive openings.

4.0 ADAPTATIONS OF HUMAN GAMETES TO THEIR FUNCTIONS

4.1 Meaning of gametes

Gametes are specialised reproductive cells that take part in sexual reproduction.

Human beings produce two types of gametes:

1. Male gamete – sperm cell.
2. Female gamete – ovum (egg cell).

Each human gamete contains 23 chromosomes, which is half the normal number of chromosomes found in most human body cells (46).

During fertilisation, the nuclei of the two gametes fuse to restore the diploid chromosome number of 46.

4.2 Structure of the male gamete (sperm cell)

A sperm cell is a microscopic male reproductive cell produced in the seminiferous tubules of the testes.

It is adapted for swimming towards and fertilising the ovum.

Parts of a sperm cell and their functions

A. Head

The head is the front part of the sperm cell.

It contains:

- A nucleus containing 23 chromosomes.
- An acrosome containing enzymes that help the sperm penetrate the protective layers surrounding the ovum.

B. Neck

The neck connects the head to the middle piece.

It contains structures that organise the arrangement of microtubules in the sperm tail.

C. Middle piece

The middle piece contains numerous mitochondria.

Function:

- Supplies energy in the form of ATP required for sperm movement.

D. Tail (flagellum)

The tail is a long whip-like structure.

Function:

- Moves from side to side to propel the sperm towards the ovum.

Adaptations of sperm cells to their functions

Adaptation	Importance
Streamlined shape	Reduces resistance during swimming.
Long tail	Enables movement towards the ovum.
Numerous mitochondria	Supply energy for movement.

Acrosome	Contains enzymes that assist penetration of the ovum's outer coverings.
Haploid nucleus	Contains 23 chromosomes that combine with those of the ovum.
Minimal cytoplasm	Reduces unnecessary weight and allows efficient movement.
Cell membrane receptors	Help the sperm interact with the egg's surrounding cells and coverings.

4.3 Structure of the female gamete (ovum)

An ovum is the female reproductive cell produced in the ovaries.

It is larger than a sperm cell and contains stored nutrients and cytoplasm that support early development.



Main parts of the ovum

A. Nucleus

- Contains 23 chromosomes.
- Carries hereditary information from the mother.

B. Cytoplasm

- Contains organelles and stored substances.
- Supports the early stages of development.

C. Cell membrane

- Surrounds the ovum.
- Regulates the movement of substances into and out of the cell.

D. Zona pellucida

The zona pellucida is a protective glycoprotein layer surrounding the ovum.

Functions:

- Protects the ovum.
- Participates in sperm recognition and binding.
- Helps prevent the entry of additional sperm after fertilisation.

E. Corona radiata

The corona radiata is a layer of follicular cells surrounding the ovum.

Functions:

- Provides protection.
- Helps support the egg cell.
- Forms part of the protective environment surrounding the ovum.

Adaptations of the ovum

1. Contains a haploid nucleus with 23 chromosomes.
2. Has a relatively large amount of cytoplasm.
3. Contains substances that support early embryonic development.
4. Has protective outer coverings.
5. Has specialised surface structures involved in sperm recognition.
6. Contains a cell membrane that helps prevent the entry of additional sperm after fertilisation.

4.4 Differences between sperm and ovum

Sperm cell	**Ovum**
Male gamete.	Female gamete.
Produced in testes.	Produced in ovaries.
Small in size.	Much larger in size.
Motile due to a flagellum.	Does not move independently using a tail.
Has very little cytoplasm.	Has abundant cytoplasm.
Contains a head, middle piece and tail.	Has a rounded cell structure.
Produced continuously after puberty in males.	Released during ovulation from the available ovarian follicle.
Contains 23 chromosomes.	Contains 23 chromosomes.

5.0 HORMONAL REGULATION OF HUMAN REPRODUCTION

5.1 Meaning of hormones

Hormones are chemical substances produced by endocrine glands and released into the bloodstream to regulate activities in different parts of the body.

In human reproduction, hormones control:

- Development of reproductive organs.
- Production of gametes.
- Menstrual cycle.
- Ovulation.
- Development of secondary sexual characteristics.
- Maintenance of pregnancy.
- Childbirth.
- Milk production after birth.

5.2 Hormones involved in male reproduction

A. Follicle-stimulating hormone (FSH)

FSH is produced by the anterior pituitary gland.

Functions in males

1. Stimulates Sertoli cells in the seminiferous tubules.
2. Supports sperm production.
3. Helps maintain normal spermatogenesis.

B. Luteinising hormone (LH)

LH is produced by the anterior pituitary gland.

In males, it is also called interstitial cell-stimulating hormone in some biological descriptions.

Functions

1. Stimulates Leydig cells in the testes.
2. Promotes testosterone production.
3. Supports male reproductive development.

C. Testosterone

Testosterone is the main male reproductive sex hormone, produced mainly by Leydig cells in the testes.

Functions

1. Promotes development of male reproductive organs.
2. Supports sperm production.
3. Causes deepening of the voice during puberty.
4. Promotes growth of facial and body hair.
5. Supports increased muscle and bone development.
6. Influences sexual development and reproductive behaviour.

5.3 Hormones involved in female reproduction

A. Follicle-stimulating hormone (FSH)

Produced by the anterior pituitary gland.

Functions

1. Stimulates the growth of ovarian follicles.
2. Supports maturation of the ovum.
3. Stimulates the production of oestrogen by developing follicles.

B. Luteinising hormone (LH)

Produced by the anterior pituitary gland.

Functions

1. Triggers ovulation.
2. Promotes formation of the corpus luteum.
3. Stimulates progesterone secretion by the corpus luteum.

C. Oestrogen

Oestrogen is produced mainly by developing ovarian follicles.

Functions

1. Promotes development of female reproductive organs.
2. Causes development of female secondary sexual characteristics.
3. Stimulates thickening of the endometrium.
4. Helps regulate the menstrual cycle.
5. Contributes to the maintenance of bone health.

D. Progesterone

Progesterone is produced mainly by the corpus luteum after ovulation and later by the placenta during pregnancy.

Functions

1. Maintains the endometrium for implantation.
2. Supports the maintenance of pregnancy.
3. Reduces uterine contractions during pregnancy.
4. Helps prepare the mammary glands for milk production.

E. Human chorionic gonadotropin (hCG)

hCG is a hormone produced by cells of the developing placenta.

Functions

1. Maintains the corpus luteum during early pregnancy.
2. Supports continued progesterone production during early pregnancy.
3. Forms the basis of many pregnancy tests.

F. Prolactin

Prolactin is produced by the anterior pituitary gland.

Function:

- Stimulates milk production in the mammary glands after childbirth.

G. Oxytocin

Oxytocin is released from the posterior pituitary gland.

Functions

1. Stimulates contractions of the uterus during labour.
2. Causes milk ejection during breastfeeding.

5.4 Summary of reproductive hormones

Hormone	Main source	Major function
FSH	Anterior pituitary	Stimulates sperm production in males and follicle development in females.
LH	Anterior pituitary	Stimulates testosterone production and triggers ovulation.
Testosterone	Testes	Regulates male reproductive development and functions.
Oestrogen	Mainly ovarian follicles	Develops female characteristics and stimulates endometrial growth.
Progesterone	Corpus luteum and placenta	Maintains the uterine lining during pregnancy.
hCG	Developing placenta	Maintains the corpus luteum during early pregnancy.

Prolactin	Anterior pituitary	Stimulates milk production.
Oxytocin	Released by posterior pituitary	Stimulates uterine contractions and milk ejection.

5.5 Hormonal regulation of the menstrual cycle

Meaning of the menstrual cycle

The menstrual cycle is a series of regular changes that occur in the ovaries and uterus of a female during the reproductive years.

A typical menstrual cycle is approximately 28 days, although normal cycles vary considerably between individuals.

The cycle prepares the reproductive system for possible pregnancy.

Main phases of the menstrual cycle

A. Menstrual phase

Usually occurs at the beginning of the cycle.

Events:

1. The previous cycle's pregnancy has not occurred.
2. Progesterone and oestrogen levels fall.
3. The functional layer of the endometrium breaks down.
4. Blood and tissue are discharged through the vagina.
5. FSH begins stimulating the development of ovarian follicles.

B. Follicular phase

Events:

1. FSH stimulates ovarian follicle development.
2. One follicle usually becomes dominant.
3. The developing follicle produces oestrogen.
4. Oestrogen stimulates repair and thickening of the endometrium.
5. Increasing oestrogen eventually contributes to an LH surge.

C. Ovulation

Ovulation is the release of a mature egg cell from an ovary.

Events:

1. A rapid increase in LH occurs.
2. The mature ovarian follicle ruptures.
3. The ovum is released.
4. The ovum is collected by the fimbriae.
5. It enters the fallopian tube.

Ovulation occurs at different times in different menstrual cycles. It does not always occur on day 14.

D. Luteal phase

Events:

1. The ruptured follicle develops into the corpus luteum.

2. The corpus luteum secretes progesterone and some oestrogen.
3. Progesterone maintains the thickened endometrium.
4. If fertilisation and implantation do not occur, the corpus luteum degenerates.
5. Progesterone and oestrogen levels decrease.
6. Menstruation begins and a new cycle starts.

If pregnancy occurs, hCG helps maintain the corpus luteum during early pregnancy until the placenta takes over most progesterone production.

6.0 DEVELOPMENT IN HUMAN BEINGS FROM FERTILISATION TO BIRTH

6.1 Meaning of fertilisation

Fertilisation is the process through which the haploid nucleus of a sperm cell fuses with the haploid nucleus of an ovum to form a diploid zygote.

In human beings, fertilisation normally takes place in the ampulla, which is the wider part of the fallopian tube.

6.2 Events during fertilisation

1. During sexual intercourse, semen may be deposited in the vagina.
2. Sperm cells move through the cervix and uterus towards the fallopian tube.
3. An ovum released during ovulation enters the fallopian tube.
4. A sperm cell reaches the ovum.
5. The sperm undergoes processes that enable it to penetrate the egg's surrounding cells and protective layers.
6. The sperm membrane fuses with the egg membrane.
7. The egg activates mechanisms that prevent additional sperm from entering.
8. The male and female genetic material combine.
9. A diploid zygote is formed.

Chromosome number after fertilisation

The human body normally has 46 chromosomes.

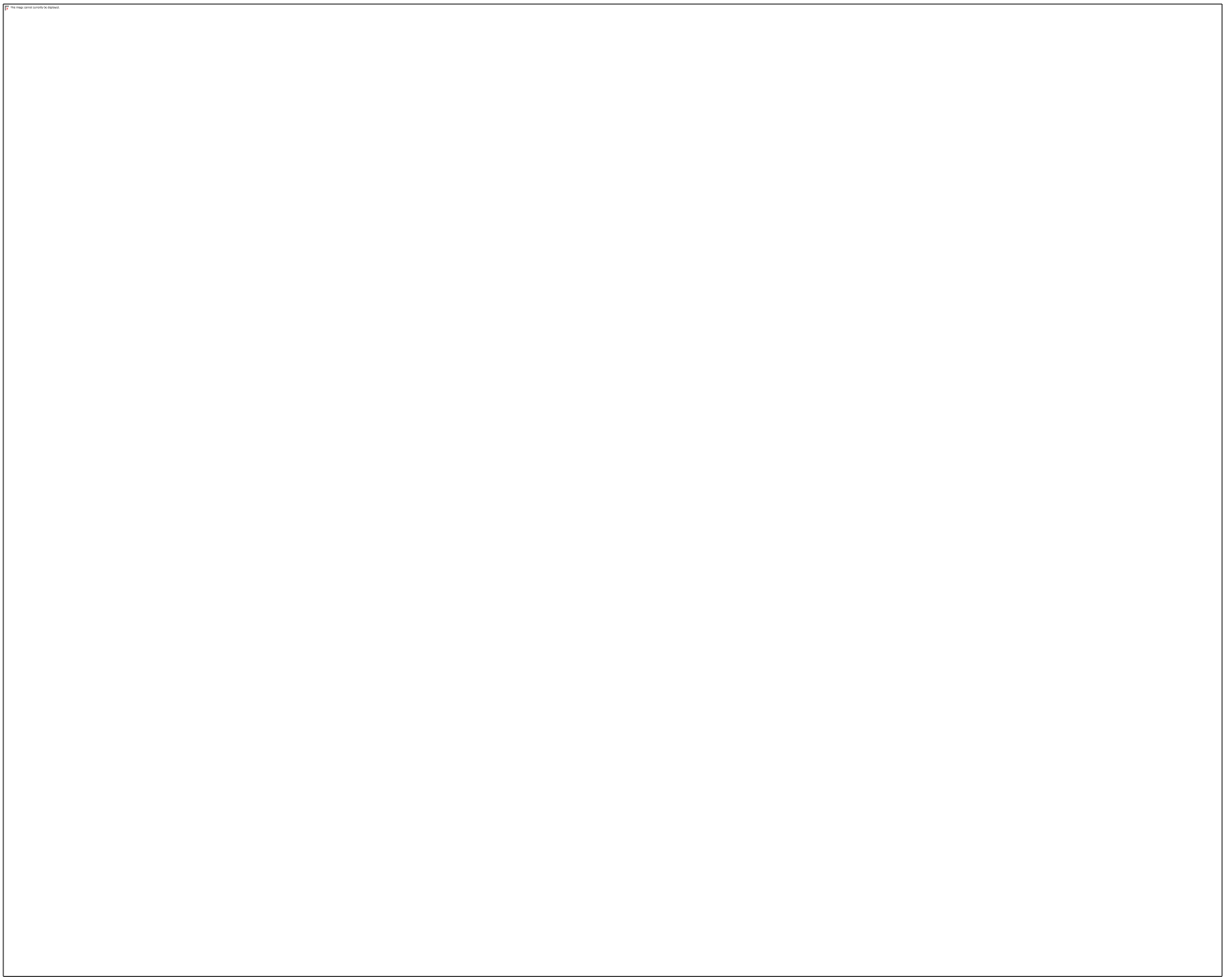
- Sperm cell: 23 chromosomes.
- Ovum: 23 chromosomes.
- Zygote: 46 chromosomes.

23+23=4623+23=46

This restores the diploid chromosome number.

6.3 Stages of development from zygote to foetus

The development of a human being begins with fertilisation and proceeds through several stages.



A. Zygote

A zygote is the single diploid cell formed immediately after fertilisation.

Characteristics

1. Contains 46 chromosomes.
2. Contains genetic information from both parents.
3. Begins dividing through mitosis.
4. Travels towards the uterus through the fallopian tube.
5. Develops into a multicellular structure.

B. Cleavage

Cleavage refers to rapid successive mitotic divisions of the zygote.

During cleavage:

- The zygote divides into two cells.
- The two cells divide into four cells.
- Further divisions produce eight cells and more.

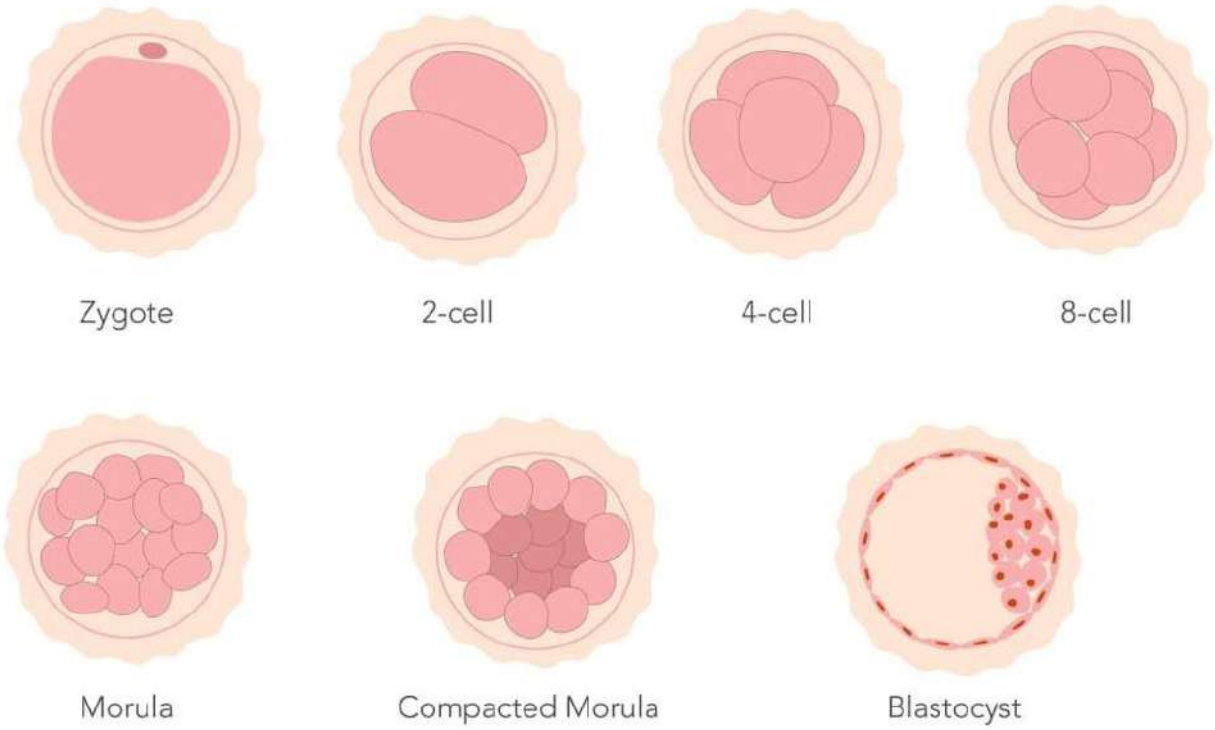
- The resulting cells are called blastomeres.
- The overall embryo does not initially increase much in size because the divisions occur within the original protective covering.

C. Morula

The morula is a solid ball of cells formed after repeated cleavage divisions.

Characteristics

1. Resembles a small mulberry.
2. Consists of numerous cells.
3. Develops as the zygote continues dividing.
4. Moves towards the uterus.
5. Develops into a blastocyst.



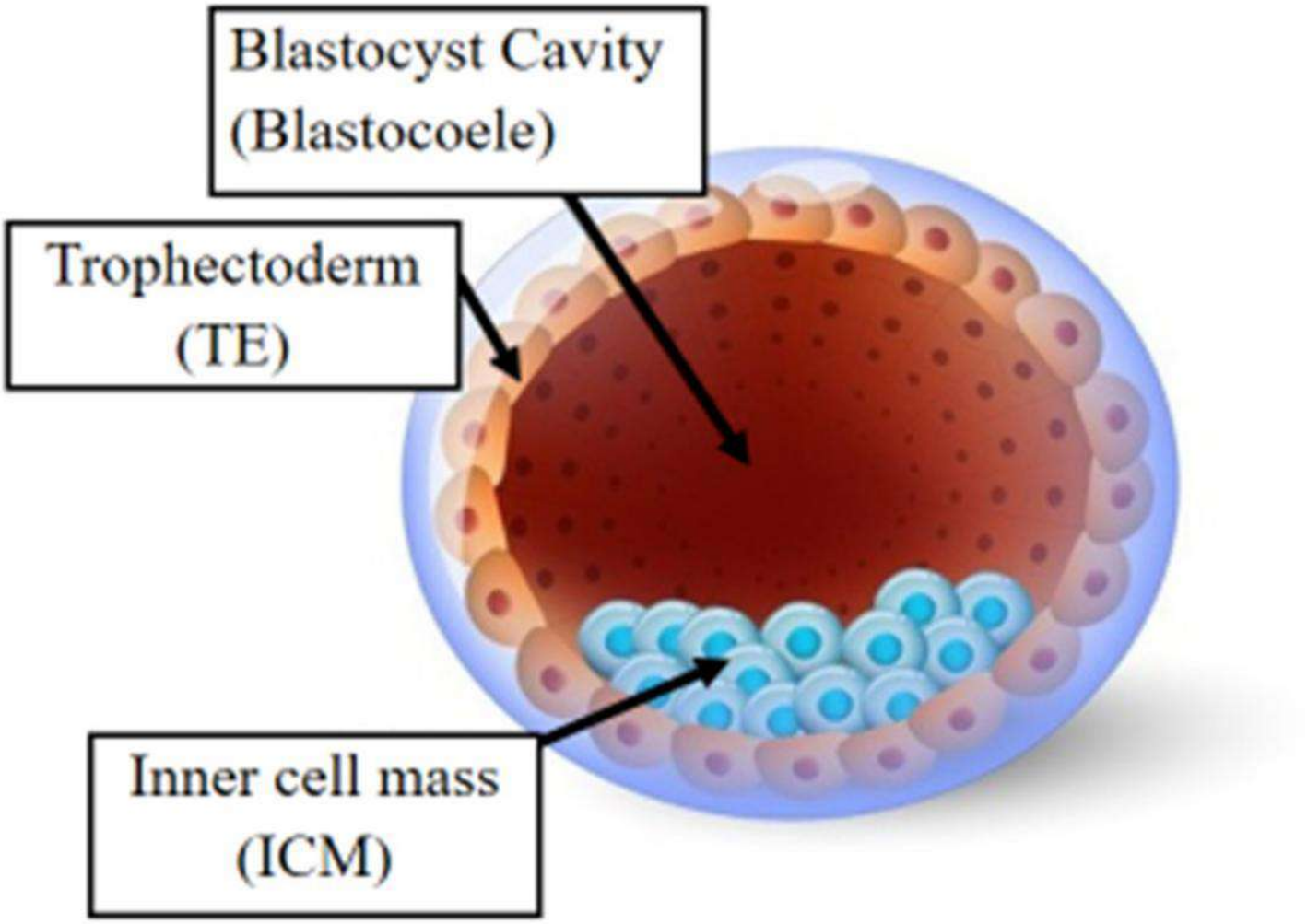
D. Blastocyst (blastula stage)

The blastocyst is a hollow, fluid-filled structure formed during early human development.

In human embryology, the more accurate term is *blastocyst*, although blastula may appear in general descriptions of animal development.

Main parts of the blastocyst

1. Trophoblast.
2. Inner cell mass.
3. Blastocyst cavity (blastocoel).



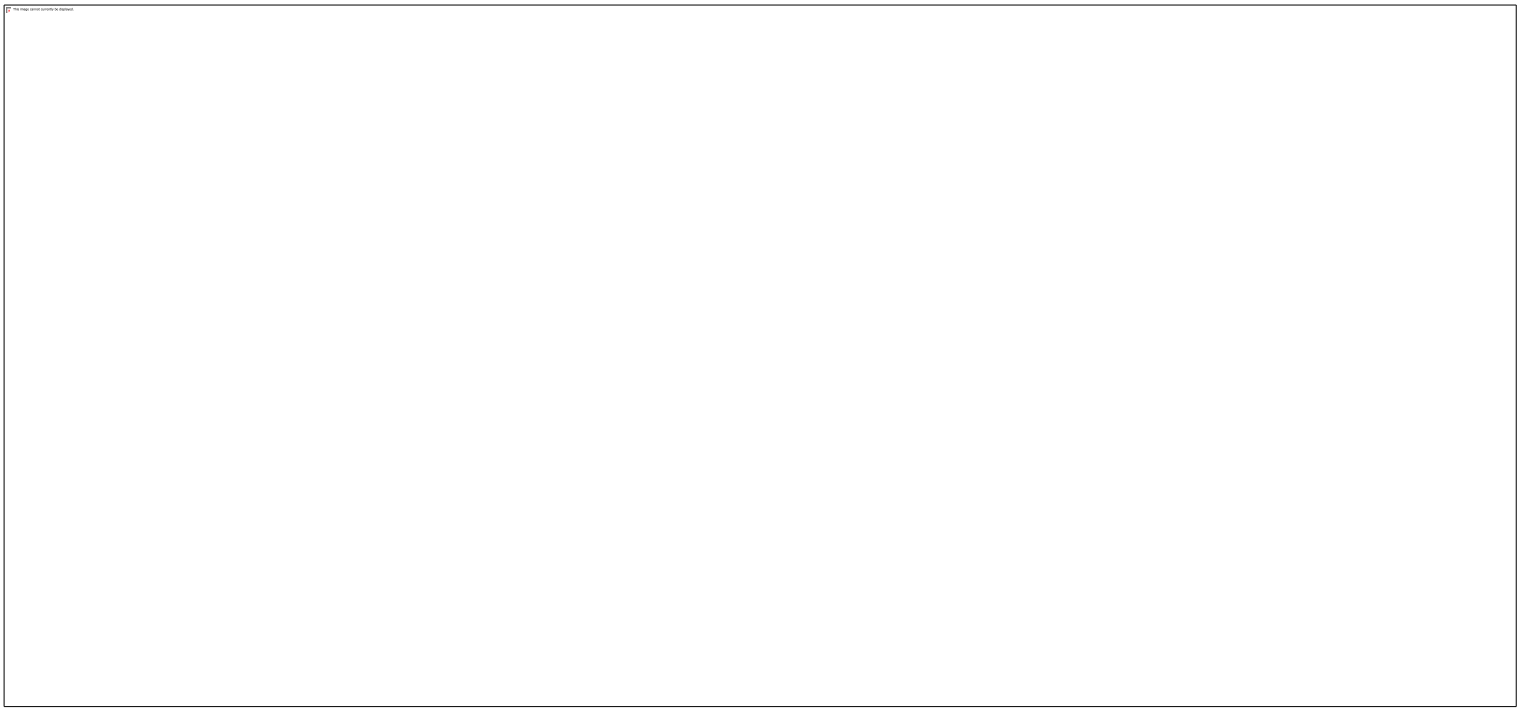
Functions of its parts

Part	Function
Trophoblast	Contributes to implantation and formation of the foetal part of the placenta.
Inner cell mass	Develops into the embryo.
Blastocyst cavity	Contains fluid and provides space within the blastocyst.

E. Implantation

Implantation is the process through which the blastocyst attaches to and becomes embedded in the endometrium of the uterus.

It normally begins approximately 6–7 days after fertilisation.



Events during implantation

1. The blastocyst reaches the uterus.
2. It attaches to the endometrium.
3. Trophoblast cells interact with and invade the uterine lining.
4. The blastocyst becomes embedded in the endometrium.
5. Placental development begins.
6. Hormonal support of pregnancy is established.

Importance of implantation

- Establishes the developing embryo within the uterus.
- Allows the developing placenta to form.
- Supports exchange of nutrients and waste products.
- Helps establish the hormonal environment needed for pregnancy.

F. Gastrulation

Gastrulation is an early embryonic process during which cells are organised into three primary germ layers.

The three germ layers are:

1. Ectoderm.
2. Mesoderm.
3. Endoderm.

Developmental importance of the germ layers

Germ layer	Major structures formed
Ectoderm	Nervous system and epidermis of the skin.
Mesoderm	Muscles, bones, blood, heart and kidneys.
Endoderm	Lining of the digestive and respiratory tracts and some associated organs.

These layers provide the foundation for the development of the different organs and body systems.

G. Embryo

An embryo is the developing human organism from early development until the end of the eighth week after fertilisation.

Characteristics of the embryonic stage

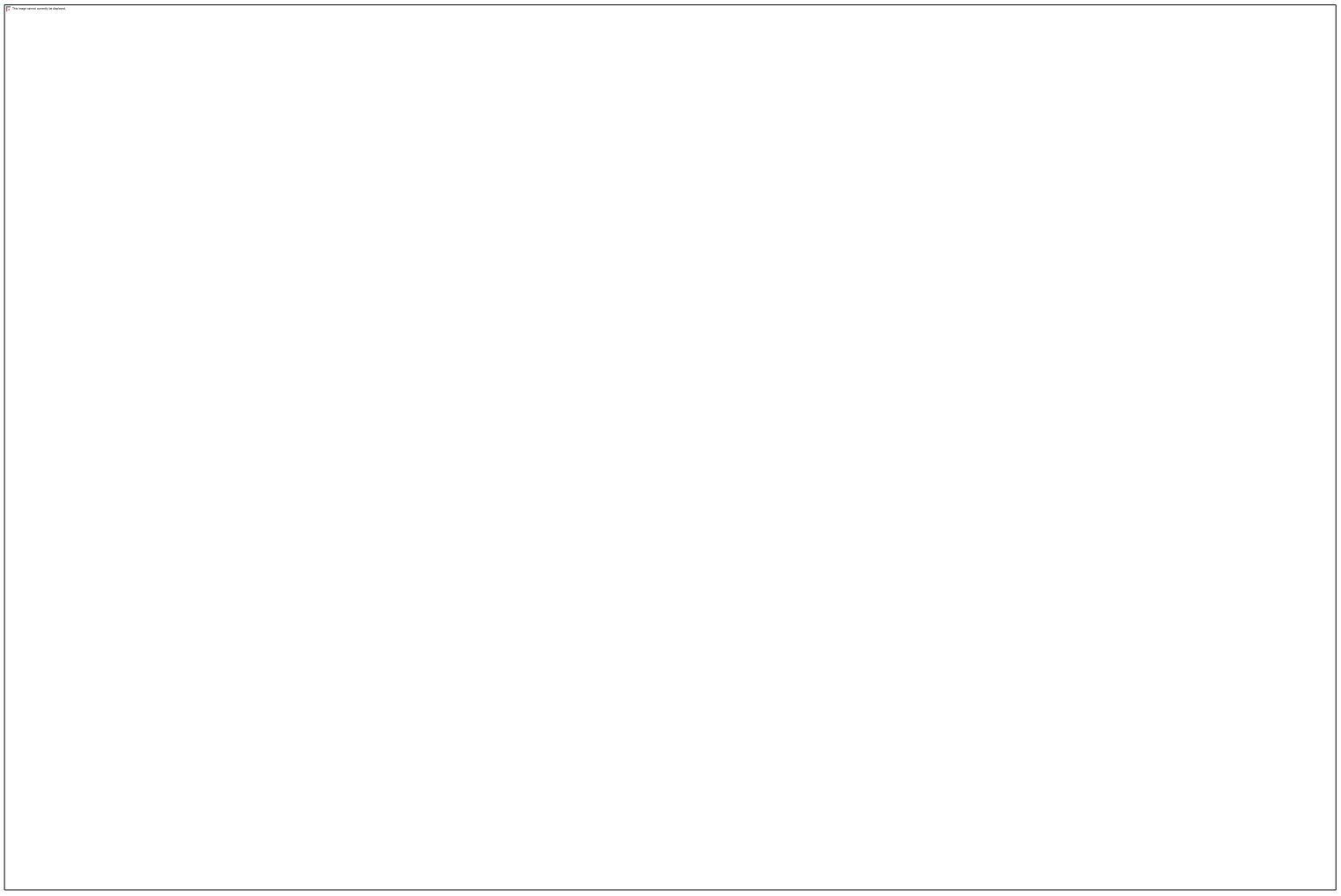
1. Major body structures begin to form.
2. The neural tube develops, forming the foundation of the brain and spinal cord.
3. The heart begins to develop and beat.
4. Limb buds appear.
5. Eyes and ears begin forming.
6. Major organs begin developing through organogenesis.

Importance of the embryonic stage

This is a very important stage because the foundations of most major body organs and systems are established.

H. Foetus

A foetus is the developing human organism from the beginning of the ninth week after fertilisation until birth.



Characteristics of the foetal stage

1. Body structures become more recognisable.
2. Organs grow and mature.
3. Bones develop and become stronger.
4. Limbs become more developed.

5. The brain continues developing.
6. Foetal movements become noticeable during pregnancy.
7. The lungs continue maturing in preparation for breathing after birth.
8. The foetus increases in size and body mass.

6.4 Summary of prenatal development

Stage	Description
Fertilisation	Fusion of sperm and ovum nuclei.
Zygote	Single diploid cell formed after fertilisation.
Cleavage	Repeated mitotic divisions of the zygote.
Morula	Solid ball of developing cells.
Blastocyst	Hollow structure with trophoblast and inner cell mass.
Implantation	Attachment and embedding of the blastocyst in the endometrium.
Gastrulation	Formation of three primary germ layers.
Embryo	Early development and formation of major body structures.
Foetus	Growth and maturation of body structures until birth.

Important scientific distinction: Fertilisation occurs in the fallopian tube, while implantation normally occurs in the uterus.

7.0 EXTRA-EMBRYONIC MEMBRANES AND THEIR FUNCTIONS

During pregnancy, specialised membranes develop around the embryo and foetus. These membranes protect the developing baby and support its growth.

The main structures include:

1. Amnion.
2. Chorion.
3. Allantois.
4. Yolk sac.

7.1 Amnion

The amnion is a thin membrane that surrounds the developing embryo and foetus, forming the amniotic sac.

It encloses the amniotic fluid.



Functions of the amnion

1. Encloses and protects the developing foetus.
2. Contains amniotic fluid.
3. Provides a protective environment for foetal development.
4. Allows the foetus to move freely.
5. Helps prevent direct compression of the foetus.
6. Maintains a relatively stable environment around the foetus.

7.2 Amniotic fluid

Amniotic fluid is the liquid found inside the amniotic sac surrounding the developing foetus.

Functions of amniotic fluid

A. Protection

- Acts as a shock absorber.
- Protects the foetus from mechanical injuries.
- Reduces the effects of sudden movements and external pressure.

B. Buoyancy

- Allows the foetus to float in the fluid.
- Reduces the effects of gravity on the developing body.

C. Movement

- Allows the foetus to move freely.
- Supports the development of muscles and joints.
- Prevents excessive adhesion between the foetus and surrounding membranes.

D. Temperature regulation

- Helps maintain a relatively stable temperature around the foetus.

E. Prevention of compression

- Reduces pressure on the umbilical cord.
- Helps prevent the developing foetus from being excessively compressed.

F. Development of the respiratory system

- Foetal breathing movements and movement of fluid in and out of the developing lungs contribute to normal lung development.

7.3 Chorion

The chorion is the outermost foetal membrane surrounding the developing embryo and other foetal membranes.

Functions

1. Contributes to the formation of the foetal part of the placenta.
2. Produces chorionic villi that help establish contact with maternal tissues.
3. Supports the exchange of substances between maternal and foetal circulations through the placenta.

7.4 Yolk sac

The yolk sac is an extra-embryonic structure that plays important roles in early embryonic development.

Functions

1. Supports early blood cell formation.
2. Contributes to early development of the digestive system.
3. Is associated with the origin and migration of primordial germ cells.
4. Provides early nutritional support before the placenta is fully established.

7.5 Allantois

The allantois is a small extra-embryonic structure associated with the development of the umbilical blood vessels.

Functions

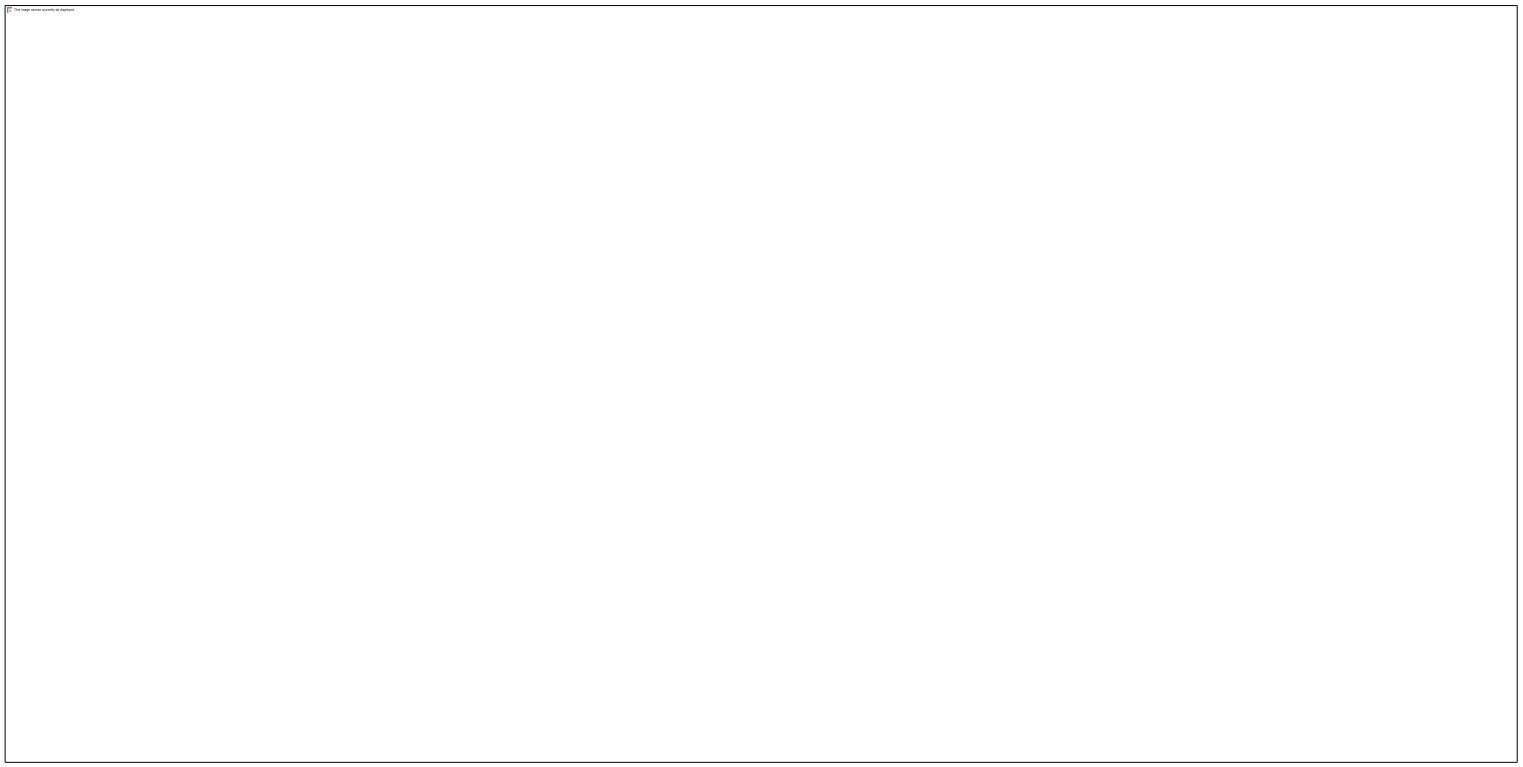
1. Contributes to the development of the umbilical blood vessels.
2. Is involved in the development of structures associated with the urinary bladder.
3. Supports the development of the placenta and umbilical cord in mammals.

8.0 THE PLACENTA AND UMBILICAL CORD

8.1 Meaning of the placenta

The placenta is a temporary specialised organ that develops during pregnancy and connects the developing foetus to the uterine wall.

It allows the exchange of substances between maternal and foetal blood without normally allowing the two blood supplies to mix directly.



8.2 Structure of the placenta

The placenta consists of:

1. A foetal component derived mainly from the chorion.
2. A maternal component derived from the endometrium.

It contains numerous chorionic villi surrounded by maternal blood spaces.

The chorionic villi contain foetal capillaries that facilitate exchange of substances.

8.3 Functions of the placenta

A. Supply of oxygen

- Oxygen passes from maternal blood across the placental barrier into foetal blood.
- The oxygen is transported to the developing foetus.

B. Supply of nutrients

- Glucose, amino acids, fatty acids, vitamins and mineral ions pass from maternal blood to foetal blood.
- These nutrients support growth and development.

C. Removal of waste products

- Carbon dioxide moves from foetal blood into maternal blood.
- Other metabolic waste products are also transferred to maternal blood for removal by the mother's organs.

D. Hormone production

The placenta produces hormones such as:

- Human chorionic gonadotropin (hCG).
- Progesterone.
- Oestrogens.
- Human placental lactogen.

These hormones help maintain pregnancy and prepare the mother's body for the demands of pregnancy.

E. Protection

- The placenta provides a selective barrier.
- It helps prevent the transfer of some harmful substances and microorganisms.
- However, it does not block all harmful substances, medicines or infections.

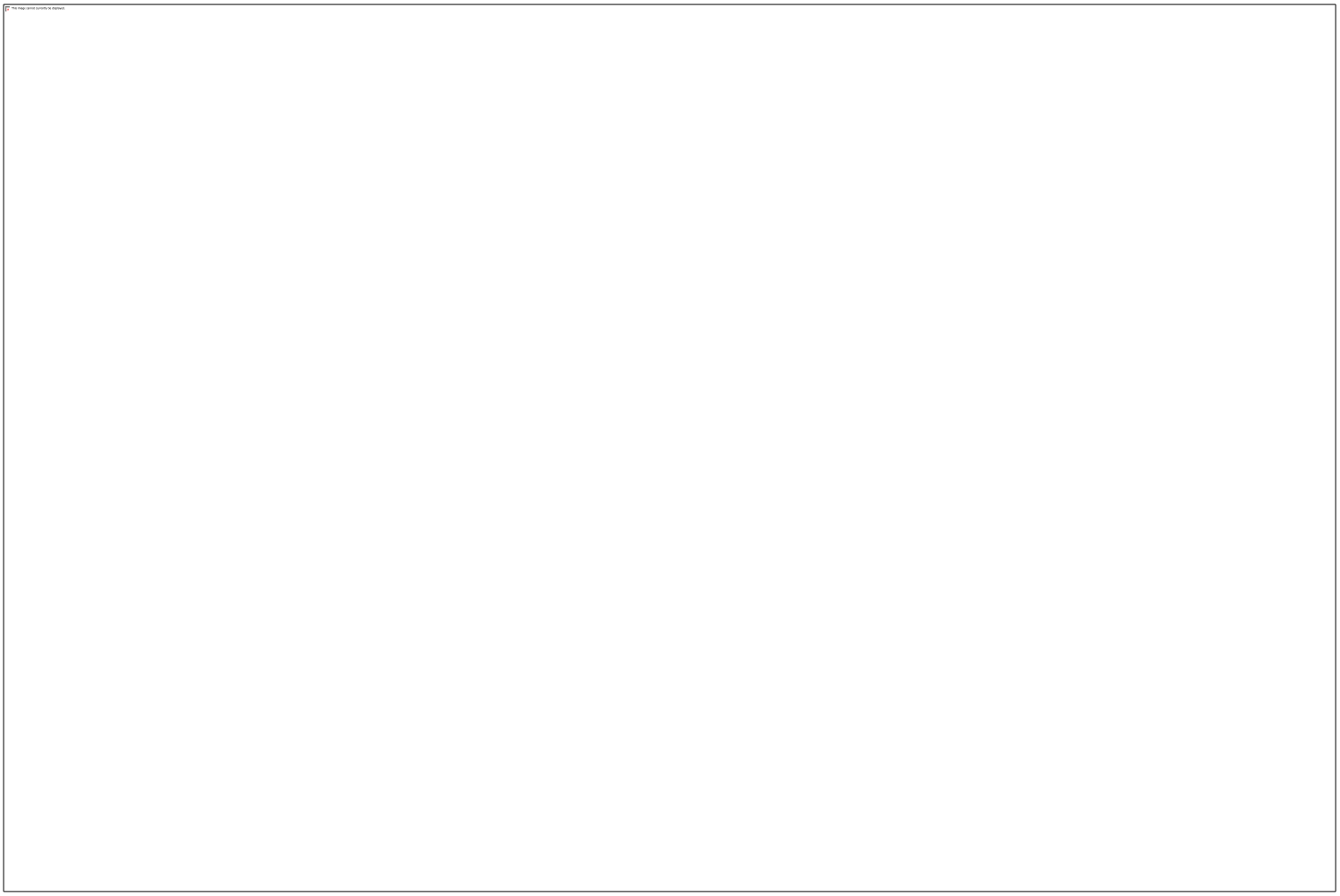
Important: Alcohol, nicotine and some medicines can cross the placenta and affect foetal development.

8.4 Umbilical cord

The umbilical cord is a flexible structure connecting the foetus to the placenta.

It normally contains three blood vessels:

- Two umbilical arteries.
- One umbilical vein.



Functions of the umbilical cord

1. Carries deoxygenated blood from the foetus to the placenta through the two umbilical arteries.
2. Carries oxygenated blood from the placenta to the foetus through the umbilical vein.
3. Provides a connection between the foetus and placenta.
4. Allows transport of nutrients and removal of waste products.

Important distinction:

- Umbilical arteries carry blood away from the foetus towards the placenta.
- Umbilical vein carries blood from the placenta towards the foetus.

The names arteries and veins are based on the direction of blood flow relative to the heart, not on the oxygen content of the blood.

8.5 Comparison between placenta and umbilical cord

Placenta	Umbilical cord
Temporary organ attached to the uterine wall.	Flexible cord connecting the foetus to the placenta.
Facilitates exchange of substances.	Transports blood between the foetus and placenta.
Produces pregnancy-related hormones.	Contains two arteries and one vein.
Has maternal and foetal components.	Contains blood vessels embedded in Wharton's jelly.

9.0 ADAPTATIONS OF THE UTERUS DURING PREGNANCY

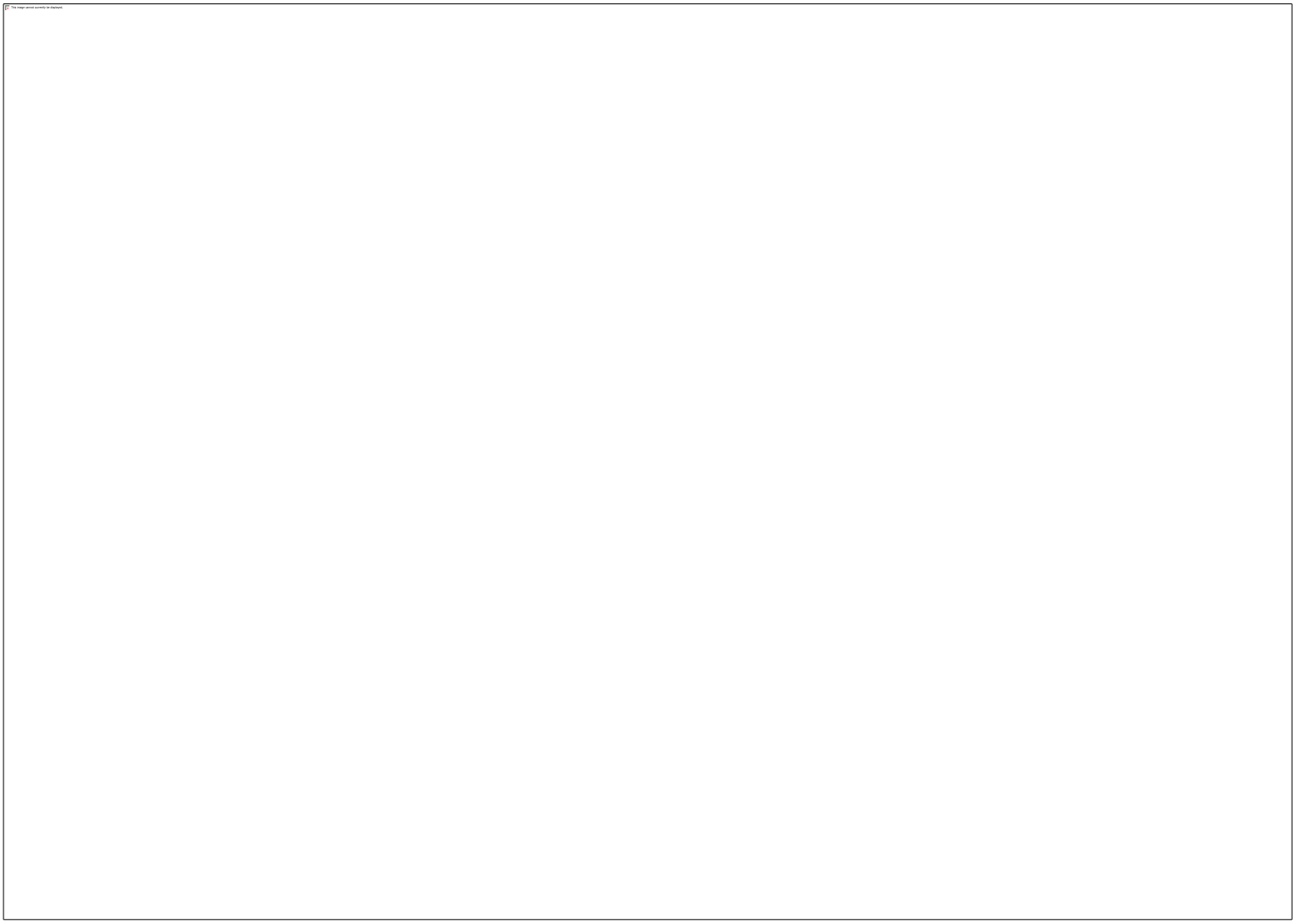
9.1 Meaning of pregnancy

Pregnancy is the period during which a developing embryo and later foetus grows inside the uterus.

Human pregnancy normally lasts approximately 40 weeks when counted from the first day of the last menstrual period, or approximately 38 weeks from fertilisation.

9.2 Structural adaptations of the uterus during pregnancy

The uterus undergoes several changes to accommodate the developing foetus.



A. Enlargement of the uterus

- The uterus increases greatly in size.
- Its muscular walls stretch to accommodate the growing foetus.
- It provides enough space for foetal development.

B. Thick muscular walls

- The uterus has a thick muscular layer called the myometrium.
- The muscles stretch during pregnancy.
- They contract strongly during labour to push the baby out.

C. Increased blood supply

- The uterus develops an extensive network of blood vessels.
- This supports the formation and functioning of the placenta.
- It ensures adequate maternal blood reaches the placental exchange region.

D. Development of the endometrium

- The endometrium becomes thick and highly vascular.
- It provides a suitable environment for implantation.
- It supports the development of the placenta.

E. Formation of the placenta

- The placenta develops at the implantation site.
- It supports exchange of gases, nutrients and waste products.
- It produces hormones necessary for pregnancy.

F. Formation of the amniotic sac

- The amnion surrounds the foetus.
- It encloses amniotic fluid.
- It provides protection and allows movement.

G. Changes in the cervix

- The cervix remains firm and closed during most of pregnancy.
- A mucus plug forms in the cervical canal.
- The mucus plug helps protect the uterus against infection.
- During labour, the cervix softens, thins and dilates.

H. Increased elasticity

- The uterine tissues stretch to accommodate foetal growth.
- The uterus can expand significantly as pregnancy progresses.

9.3 Summary of uterine adaptations

Adaptation	**Importance**
Enlargement	Accommodates the growing foetus.
Thick muscular walls	Support pregnancy and childbirth.
Increased blood supply	Supports placental exchange.
Thickened endometrium	Supports implantation.
Placenta formation	Facilitates exchange of substances.
Amniotic sac formation	Protects the foetus.
Cervical mucus plug	Helps prevent infection.
Cervical dilation during labour	Allows passage of the baby.

10.0 DEVELOPMENT OF THE FOETUS DURING PREGNANCY

Human prenatal development is commonly divided into three trimesters.

Each trimester covers approximately three months.



10.1 First trimester (weeks 1–12)

The first trimester is the earliest stage of pregnancy.

Major developments

1. Fertilisation and implantation occur.
2. The placenta begins developing.
3. The neural tube develops.
4. The heart develops and begins beating.
5. The brain and spinal cord develop.
6. Limb buds appear and develop.
7. Major organs begin forming.
8. The face and sensory structures begin developing.
9. By the end of this trimester, the developing organism has recognisable human features.

Importance: This is a critical period for organ formation. Exposure to harmful substances, certain infections and some medicines may interfere with development.

10.2 Second trimester (weeks 13–27)

During the second trimester:

1. The foetus grows rapidly.
2. Bones continue developing.
3. Muscles become stronger.
4. Foetal movements become more noticeable.
5. Facial features become more distinct.
6. External reproductive structures become more developed.
7. The nervous system continues maturing.
8. Hearing structures develop.

9. The foetus develops more coordinated movements.

10.3 Third trimester (weeks 28–birth)

During the third trimester:

1. The foetus increases in body mass.
2. The brain develops rapidly.
3. The lungs continue maturing.
4. Fat accumulates beneath the skin.
5. The foetus gains weight.
6. Body organs continue maturing.
7. The foetus often moves into a head-down position in preparation for birth.
8. The foetus prepares physiologically for life outside the uterus.

10.4 Summary of the three trimesters

First trimester	Second trimester	Third trimester
Major organs begin forming.	Rapid growth occurs.	Rapid weight gain occurs.
Heart begins beating.	Movements become noticeable.	Brain and lungs continue maturing.
Neural tube develops.	Bones and muscles develop.	Foetus prepares for birth.
Placenta develops.	Sensory systems mature.	Foetal position may change to head-down.

11.0 THE PROCESS OF CHILDBIRTH (PARTURITION)

11.1 Meaning of parturition

Parturition is the physiological process through which a fully developed baby is delivered from the uterus through the birth canal.

Childbirth involves coordinated hormonal and muscular activities.

Oxytocin plays an important role in stimulating uterine contractions.

11.2 Stages of childbirth

Stage 1: Cervical dilation

This is usually the longest stage of labour.

Events:

1. Uterine contractions begin.
2. The contractions become stronger and more regular.
3. The cervix softens and becomes thinner.
4. The cervix gradually dilates.
5. The amniotic sac may rupture, releasing amniotic fluid.
6. The cervix opens sufficiently to allow the baby to pass.

Stage 2: Delivery of the baby

Events:

1. The cervix becomes fully dilated.
2. Strong uterine contractions continue.

3. The baby moves down the birth canal.
4. The mother may experience an urge to push.
5. The baby passes through the vagina.
6. The baby is delivered.

Stage 3: Delivery of the placenta

This stage is also known as the afterbirth.

Events:

1. The uterus continues contracting after the baby is born.
2. The placenta separates from the uterine wall.
3. The placenta and associated membranes are expelled.
4. The uterus contracts to reduce bleeding.

11.3 Role of hormones during childbirth

Oxytocin

- Stimulates uterine contractions.
- Helps strengthen contractions through positive feedback.
- Supports the progression of labour.

Prostaglandins

- Help soften and prepare the cervix.
- Support uterine contractions.

Relaxin

- Contributes to changes in the cervix and pelvic ligaments during pregnancy and childbirth.

11.4 Importance of antenatal care

Antenatal care refers to healthcare services provided to a pregnant woman during pregnancy.

It is important because it:

1. Monitors the health of the mother.
2. Monitors foetal growth and development.
3. Helps identify pregnancy complications early.
4. Provides nutritional advice.
5. Supports prevention and management of certain infections.
6. Provides appropriate vaccination and supplementation.
7. Promotes safe delivery planning.
8. Provides guidance on breastfeeding and newborn care.

Kenyan context: Pregnant women are encouraged to attend antenatal clinics at recognised health facilities, including dispensaries, health centres and hospitals.

12.0 MULTIPLE BIRTHS IN HUMAN BEINGS

12.1 Meaning of multiple births

Multiple births occur when a woman gives birth to two or more babies from the same pregnancy.

Examples include:

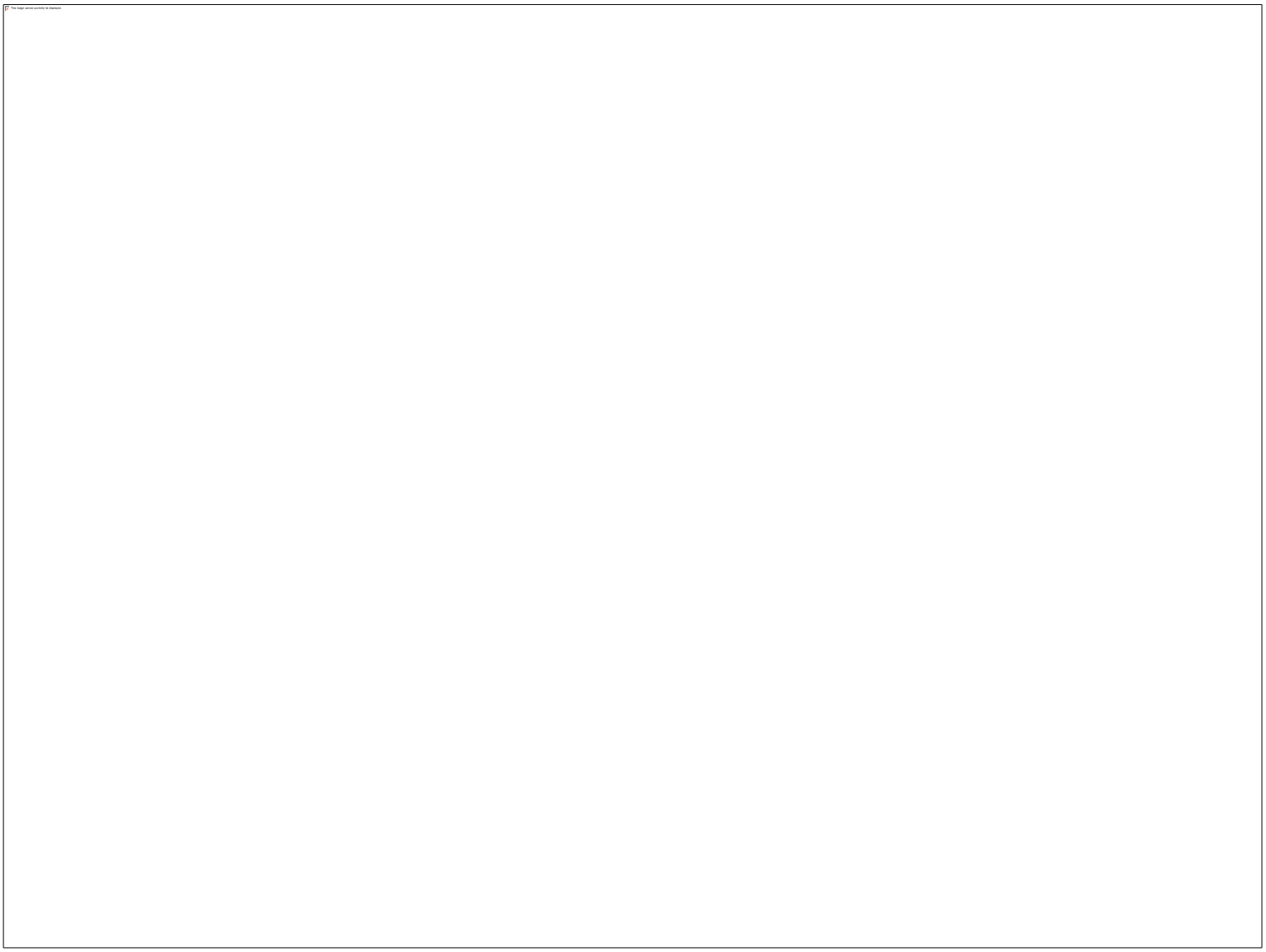
- Twins.
- Triplets.
- Quadruplets.
- Quintuplets.

The most common form of multiple birth is twins.

12.2 Types of twins

There are two major types of twins:

1. Identical twins.
2. Fraternal twins.



A. Identical twins (monozygotic twins)

Identical twins develop from one fertilised ovum.

How they form

1. One ovum is released from an ovary.
2. One sperm fertilises the ovum.
3. A single zygote is formed.
4. The developing embryo splits into two separate embryonic cell groups.
5. Two genetically very similar individuals develop.

Characteristics

- Usually have the same sex.
- Have nearly identical genetic information.
- Often have similar physical features.
- May share a placenta, depending on when the embryo splits.
- May have separate or shared amniotic sacs depending on the timing of separation.

B. Fraternal twins (dizygotic twins)

Fraternal twins develop when two separate ova are fertilised by two different sperm cells.

How they form

1. Two ova are released during the same menstrual cycle.
2. Each ovum is fertilised by a different sperm cell.
3. Two separate zygotes are formed.
4. Each zygote develops independently.
5. Two babies develop in the uterus.

Characteristics

- May be of the same sex or different sexes.
- Are genetically similar to ordinary siblings, sharing approximately half of their segregating genetic variation on average.
- Usually have separate placentas, although the placentas may become closely attached.

12.3 Differences between identical and fraternal twins

Identical twins	**Fraternal twins**
Develop from one zygote.	Develop from two zygotes.
Form when one embryo splits.	Form when two ova are fertilised.
Have nearly identical genetic information.	Have genetic differences similar to ordinary siblings.
Usually have the same sex.	May be of the same or different sexes.
May share one placenta.	Usually have separate placentas.

12.4 Causes and factors associated with multiple births

1. Hereditary factors, especially a family history of fraternal twinning.
2. Maternal age, particularly increasing maternal age in the reproductive years.
3. Fertility medicines that stimulate the development of more than one ovarian follicle.
4. Assisted reproductive technologies such as in-vitro fertilisation (IVF).
5. Transfer of more than one embryo during fertility treatment.

Note: Identical twinning is generally considered a random event and is less strongly associated with family history than fraternal twinning.

12.5 Challenges associated with multiple pregnancies

Multiple pregnancies may increase the risk of:

- Premature birth.
- Low birth weight.
- Maternal anaemia.
- Pregnancy-related high blood pressure.
- Gestational diabetes.
- Difficulties during childbirth.
- Increased need for specialised antenatal care.

Importance of medical care: Multiple pregnancies require appropriate antenatal monitoring to support the health of both the mother and babies.

13.0 DISEASES AND DISORDERS OF THE HUMAN REPRODUCTIVE SYSTEM

13.1 Meaning of reproductive diseases and disorders

Reproductive diseases and disorders are medical conditions that affect the organs, tissues and functions of the male or female reproductive systems.

They may affect:

- Fertility.
- Sexual health.
- Pregnancy.
- Menstrual function.
- Hormonal balance.
- Reproductive organs.

Some are infectious, while others are caused by hormonal changes, genetic factors, abnormal cell growth or structural problems.

The major conditions covered in this sub-strand include:

1. Sexually transmitted infections (STIs).
2. Ectopic pregnancy.
3. Prostate cancer.
4. Penile cancer.
5. Testicular cancer.

6. Gynaecological cancers.

13.2 Sexually transmitted infections (STIs)

Meaning of STIs

Sexually transmitted infections are infections that are mainly spread through sexual contact, including vaginal, anal or oral sexual activity.

Some STIs can also be transmitted from mother to child during pregnancy, childbirth or breastfeeding, depending on the infection.

Examples of sexually transmitted infections

Infection	Causative organism
Gonorrhoea	*Neisseria gonorrhoeae* (bacterium)
Syphilis	*Treponema pallidum* (bacterium)
Chlamydia	*Chlamydia trachomatis* (bacterium)
Genital herpes	Herpes simplex virus (HSV)
Genital warts	Certain types of human papillomavirus (HPV)
HIV infection	Human immunodeficiency virus
Trichomoniasis	*Trichomonas vaginalis* (protozoan)
Hepatitis B	Hepatitis B virus

A. Gonorrhoea

Gonorrhoea is a sexually transmitted bacterial infection caused by *Neisseria gonorrhoeae*.

Signs and symptoms

- Pain or burning during urination.
- Abnormal genital discharge.
- Pelvic pain in some women.
- Pain or swelling in the testes in some men.
- Some infected individuals have no symptoms.

Complications

- Pelvic inflammatory disease.
- Infertility.
- Ectopic pregnancy due to damage to the fallopian tubes.
- Infection in other parts of the body.

Prevention and control

1. Abstinence from sexual activity prevents sexual transmission.
2. Correct and consistent condom use reduces the risk of infection.
3. Testing at recognised health facilities.
4. Appropriate antibiotic treatment.
5. Ensuring sexual partners are assessed and treated where necessary.
6. Avoiding self-medication.

B. Syphilis

Syphilis is a bacterial infection caused by *Treponema pallidum*.

Stages and symptoms

1. Primary stage – commonly produces a painless sore called a chancre.
2. Secondary stage – may cause skin rashes, including on the palms and soles.
3. Latent stage – the infection remains in the body without obvious symptoms.
4. Late stage – may damage the heart, brain and other organs if untreated.

Complications

- Damage to the nervous system.
- Cardiovascular complications.
- Congenital syphilis when transmitted from mother to baby.
- Severe health complications if untreated.

Prevention and control

- Correct and consistent condom use.
- Regular testing where indicated.
- Early diagnosis.
- Treatment with appropriate antibiotics.
- Testing and treatment of sexual partners.
- Antenatal screening to prevent transmission to babies.

C. Chlamydia

Chlamydia is a bacterial STI caused by *Chlamydia trachomatis*.

Symptoms

- Pain during urination.
- Abnormal genital discharge.
- Lower abdominal pain.
- Bleeding between menstrual periods in some women.
- Pain in the testes in some men.
- Frequently no symptoms.

Complications

- Pelvic inflammatory disease.

- Infertility.
- Ectopic pregnancy.
- Epididymitis in males.

Prevention and control

- Correct and consistent condom use.
- Testing and early diagnosis.
- Treatment using prescribed antibiotics.
- Partner testing and treatment.
- Avoiding sexual contact until treatment guidance has been followed.

D. Genital herpes

Genital herpes is a viral infection caused by herpes simplex virus, mainly HSV-2 and sometimes HSV-1.

Signs and symptoms

- Painful blisters or sores around the genital area.
- Itching.
- Burning sensations.
- Pain during urination in some cases.
- Recurrent outbreaks.

Prevention and control

- Avoiding sexual contact during active outbreaks.
- Correct condom use, although condoms do not eliminate all risk.
- Medical assessment and antiviral treatment.
- Honest communication between partners.
- Understanding that infection can spread even when sores are not visible.

E. Human papillomavirus (HPV)

HPV is a group of viruses that infect the skin and mucous membranes.

Some types cause genital warts, while certain high-risk types may cause cancers.

Possible effects

- Genital warts.
- Cervical cancer.
- Penile cancer.
- Anal cancer.
- Some cancers of the throat and other reproductive-related tissues.

Prevention and control

1. HPV vaccination.
2. Appropriate cervical cancer screening.

3. Correct condom use to reduce, but not eliminate, transmission risk.
4. Seeking medical assessment for unusual genital growths or lesions.

13.3 General prevention and control of STIs

1. Abstinence from sexual activity prevents sexual transmission.
2. Correct and consistent use of condoms reduces the risk of many STIs.
3. Avoid sharing needles and other equipment contaminated with blood.
4. Seek testing when exposed or when symptoms occur.
5. Obtain early medical treatment.
6. Ensure partners are tested and treated where appropriate.
7. Receive recommended vaccinations, including HPV and hepatitis B vaccines.
8. Avoid discrimination and stigma towards infected persons.
9. Attend antenatal screening to reduce mother-to-child transmission.
10. Obtain accurate reproductive health information from qualified healthcare providers.

Important scientific point: Many STIs may have no obvious symptoms. Absence of symptoms does not necessarily mean a person is free from infection.

13.4 Ectopic pregnancy

Meaning of ectopic pregnancy

An ectopic pregnancy occurs when a fertilised egg implants outside the normal cavity of the uterus.

Most ectopic pregnancies occur in the fallopian tube.

Causes and risk factors

1. Damage to the fallopian tubes.
2. Previous pelvic inflammatory disease.
3. Previous ectopic pregnancy.
4. Previous surgery involving the fallopian tubes.
5. Certain fertility treatments.
6. Smoking.
7. Some infections that cause scarring of the reproductive tract.

Signs and symptoms

- Missed menstrual period.
- Lower abdominal pain, often on one side.
- Vaginal bleeding.
- Shoulder-tip pain in some cases.
- Dizziness.
- Fainting in severe cases.

Complications

1. Rupture of the fallopian tube.

2. Severe internal bleeding.
3. Damage to reproductive structures.
4. Shock.
5. Maternal death if emergency treatment is not obtained.

Prevention and control

- Early diagnosis of reproductive tract infections.
- Appropriate treatment of pelvic inflammatory disease.
- Avoiding smoking.
- Seeking early antenatal assessment.
- Obtaining immediate medical attention when symptoms suggest ectopic pregnancy.

Important: An ectopic pregnancy cannot develop into a normal birth and requires urgent professional medical assessment. Sudden severe abdominal pain, fainting or shoulder-tip pain in a possible pregnancy requires emergency medical attention.

13.5 Prostate cancer

Meaning of prostate cancer

Prostate cancer is a disease characterised by uncontrolled growth of abnormal cells in the prostate gland.

The prostate gland is part of the male reproductive system and is located below the urinary bladder.

Risk factors

1. Increasing age.
2. Family history of prostate cancer.
3. Inherited genetic factors.
4. Certain population-related risk differences.

Signs and symptoms

Early prostate cancer may have no symptoms.

Possible symptoms include:

- Difficulty starting urination.
- Weak urine stream.
- Frequent urination, especially at night.
- Blood in urine or semen.
- Difficulty emptying the bladder.
- Pain in the back or bones in advanced disease.

Prevention and control

1. Seek medical advice about prostate health.
2. Discuss appropriate screening or testing with qualified healthcare professionals.
3. Maintain a healthy lifestyle.
4. Seek medical assessment for persistent urinary symptoms.

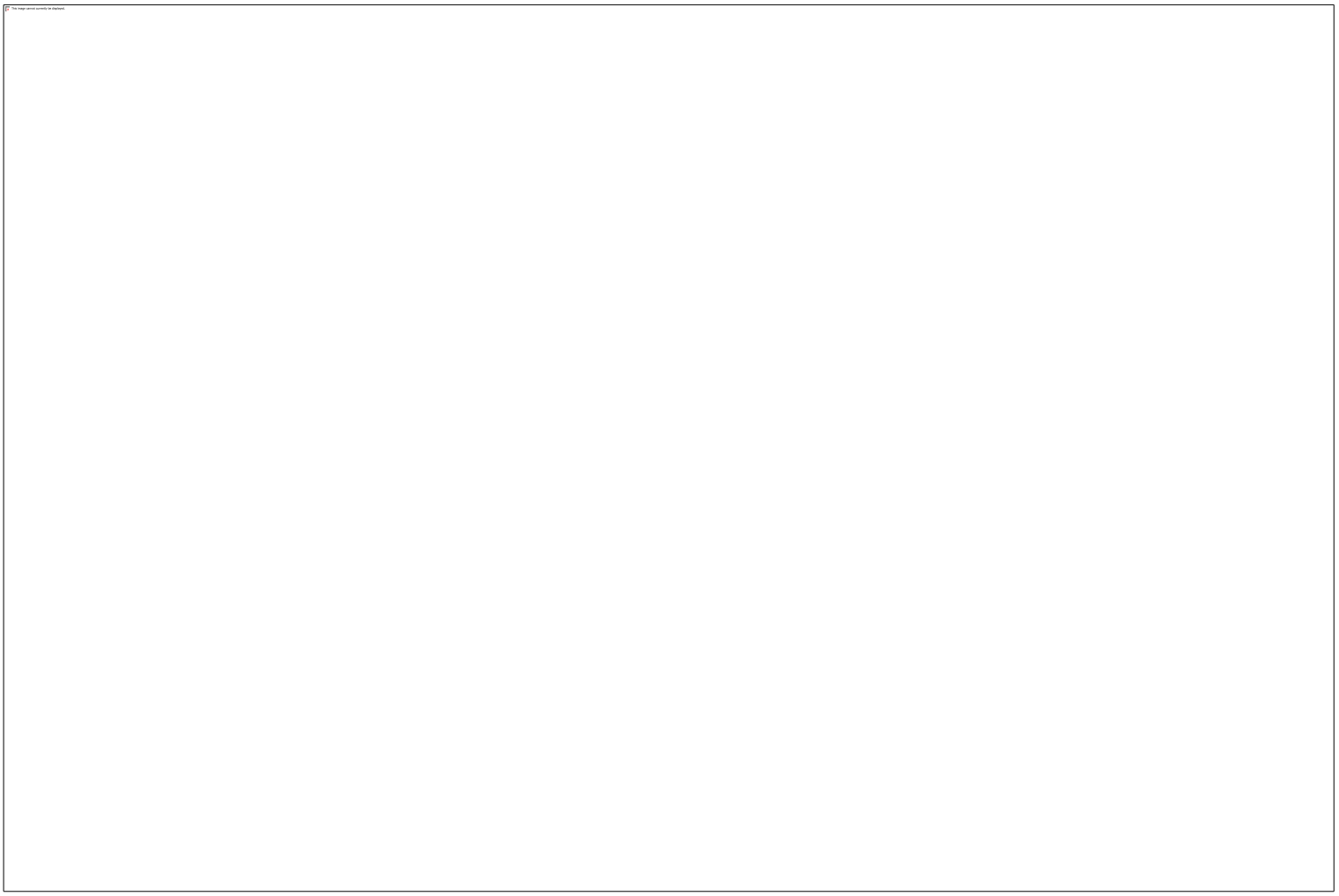
5. Follow recommended treatment after diagnosis.

Note: Urinary symptoms do not automatically indicate prostate cancer; other conditions, such as benign prostate enlargement, can produce similar symptoms.

13.6 Penile cancer

Meaning of penile cancer

Penile cancer is the abnormal and uncontrolled growth of cells in the tissues of the penis.



Risk factors

1. Persistent infection with certain high-risk HPV types.
2. Smoking.
3. Poor genital hygiene.
4. Certain chronic inflammatory conditions.
5. Weakened immunity.
6. Increasing age.

Signs and symptoms

- A persistent sore on the penis.
- Unusual growths or lumps.
- Skin colour changes.
- Abnormal discharge.

- Bleeding from a lesion.
- Persistent swelling.

Prevention and control

1. HPV vaccination according to recommended guidelines.
2. Good genital hygiene.
3. Avoiding smoking.
4. Seeking early medical assessment for unusual penile changes.
5. Appropriate treatment of persistent genital infections.

13.7 Testicular cancer

Meaning of testicular cancer

Testicular cancer is the uncontrolled growth of abnormal cells in one or both testes.

Risk factors

- History of undescended testes.
- Previous testicular cancer.
- Family history.
- Certain developmental and genetic factors.

Signs and symptoms

1. Painless lump in a testis.
2. Enlargement of one testis.
3. Heaviness in the scrotum.
4. Pain or discomfort in the testis.
5. Dull ache in the lower abdomen or groin.

Prevention and control

- Seek medical assessment for any unusual lump or swelling.
- Attend follow-up care for a history of undescended testes.
- Obtain early diagnosis.
- Follow appropriate treatment.

Important: Testicular cancer is often treatable, particularly when detected early. Not every testicular lump is cancer, but all persistent or unusual lumps should be medically assessed.

13.8 Gynaecological cancers

Meaning of gynaecological cancers

Gynaecological cancers are cancers that develop in the organs of the female reproductive system.

The main types include:

1. Cervical cancer.
2. Ovarian cancer.
3. Uterine cancer (endometrial cancer).

4. Vaginal cancer.
5. Vulval cancer.

A. Cervical cancer

Cervical cancer develops in the cervix, which is the lower part of the uterus.

Main cause

- Persistent infection with high-risk types of human papillomavirus (HPV).

Risk factors

- Persistent high-risk HPV infection.
- Weakened immunity.
- Smoking.
- Lack of appropriate cervical screening.

Signs and symptoms

- Abnormal vaginal bleeding.
- Bleeding after sexual intercourse.
- Unusual vaginal discharge.
- Pelvic pain.
- Pain during sexual intercourse.

Prevention and control

1. HPV vaccination.
2. Cervical cancer screening.
3. Early diagnosis of precancerous changes.
4. Appropriate treatment of precancerous lesions.
5. Early medical assessment of unusual symptoms.

Kenyan context: Kenya has a National Cervical Cancer Elimination Action Plan for 2026–2030, which prioritises HPV vaccination, screening, early detection and treatment.



Regional Office for Africa+1

B. Ovarian cancer

Ovarian cancer is the abnormal growth of cells in one or both ovaries.

Risk factors

- Increasing age.
- Family history.
- Certain inherited genetic changes.
- Some reproductive and hormonal factors.

Signs and symptoms

- Persistent abdominal bloating.
- Pelvic or abdominal pain.
- Feeling full quickly when eating.
- Changes in urinary habits.
- Unexplained abdominal swelling.

Prevention and control

- Awareness of persistent symptoms.
- Appropriate medical assessment.
- Genetic counselling for individuals with relevant family histories.
- Early diagnosis and treatment.

C. Uterine (endometrial) cancer

Uterine cancer refers to cancer arising in the uterus. The most common type develops in the endometrium.

Risk factors

- Increasing age.
- Obesity.
- Prolonged exposure to oestrogen without adequate progesterone.
- Certain inherited genetic conditions.

Signs and symptoms

- Abnormal vaginal bleeding.
- Bleeding after menopause.
- Unusual vaginal discharge.
- Pelvic pain in some cases.

Prevention and control

- Maintaining a healthy body mass.
- Seeking medical assessment for unusual vaginal bleeding.
- Appropriate management of hormonal and metabolic health.
- Early diagnosis and treatment.

D. Vaginal cancer

Vaginal cancer is a rare cancer that develops in the tissues of the vagina.

Possible signs

- Abnormal vaginal bleeding.
- Unusual discharge.
- Pelvic pain.
- A lump in the vagina.

Prevention and control

- HPV vaccination.

- Appropriate cervical screening as recommended.
- Early medical assessment of unusual symptoms.

E. Vulval cancer

Vulval cancer is a cancer that develops in the external female genital structures.

Signs and symptoms

- Persistent itching.
- Skin colour changes.
- Lumps or sores.
- Bleeding.
- Persistent pain or discomfort.

Prevention and control

- HPV vaccination.
- Avoiding smoking.
- Seeking early medical assessment.
- Appropriate management of persistent vulval skin conditions.

13.9 Summary of reproductive cancers

Cancer	Main affected organ	Possible warning sign
Prostate cancer	Prostate gland	Persistent urinary difficulties.
Penile cancer	Penis	Persistent sore or abnormal growth.
Testicular cancer	Testes	Unusual lump or swelling.
Cervical cancer	Cervix	Abnormal vaginal bleeding.
Ovarian cancer	Ovaries	Persistent bloating and pelvic discomfort.
Uterine cancer	Uterus	Abnormal vaginal bleeding.
Vaginal cancer	Vagina	Abnormal bleeding or lump.
Vulval cancer	Vulva	Persistent itching or unusual skin changes.

Important: Warning signs are not proof of cancer. A healthcare professional must carry out appropriate examinations and tests to establish a diagnosis.

14.0 PREVENTION AND CONTROL OF HUMAN REPRODUCTIVE SYSTEM DISEASES

Maintaining a healthy reproductive system requires proper hygiene, responsible health practices, early diagnosis and access to appropriate healthcare services.

14.1 General preventive measures

1. **Maintain personal hygiene:** Clean the external reproductive organs appropriately to reduce irritation and certain infections.
2. **Practise responsible reproductive health behaviour:** Make informed decisions that protect reproductive health.
3. **Vaccination:** Receive recommended vaccines such as HPV and hepatitis B vaccines.
4. **Early diagnosis:** Seek medical attention when unusual symptoms occur.
5. **Regular medical check-ups:** Attend appropriate reproductive health assessments.
6. **Avoid smoking:** Smoking increases the risk of certain reproductive cancers.
7. **Healthy nutrition:** Eat a balanced diet containing vitamins, minerals and proteins.
8. **Physical activity:** Exercise regularly to support general health.
9. **Avoid self-medication:** Obtain professional advice before using reproductive medicines.
10. **Health education:** Access accurate reproductive health information from recognised sources.
11. **Antenatal care:** Attend pregnancy clinics to monitor maternal and foetal health.
12. **Cancer screening:** Participate in recommended screening programmes.

14.2 Importance of early detection

Early detection involves identifying a disease or abnormality before it progresses to an advanced stage.

It is important because it:

- Improves chances of successful treatment.
- Reduces complications.
- Helps prevent the spread of certain infections.
- Protects fertility where possible.
- Reduces treatment costs in some cases.
- Improves quality of life.
- Helps prevent avoidable deaths.

14.3 Reproductive health services in Kenya

Reproductive health services are available through various levels of the Kenyan healthcare system.

Examples include:

- Dispensaries.
- Health centres.
- Sub-county hospitals.
- County referral hospitals.
- National referral hospitals.
- Specialised reproductive health clinics.

Services may include:

1. Antenatal and postnatal care.
2. STI testing and treatment.

3. Family planning counselling.
4. HPV vaccination.
5. Cervical cancer screening.
6. Fertility assessment.
7. Maternal and newborn healthcare.
8. Reproductive health education.

15.0 MODERN TECHNOLOGY AND HUMAN REPRODUCTION

15.1 Meaning of reproductive technology

Reproductive technology refers to scientific and medical methods used to investigate, assist, manage or improve human reproductive processes.

Modern reproductive technology has improved the diagnosis and treatment of reproductive conditions and has provided assistance to some individuals and couples experiencing difficulties with conception.

15.2 Major reproductive technologies

A. In-vitro fertilisation (IVF)

In-vitro fertilisation is an assisted reproductive technology in which an egg is fertilised by sperm outside the body in a laboratory.

Main stages of IVF

1. Ovarian stimulation: Medicines are used under medical supervision to stimulate the development of ovarian follicles.
2. Egg retrieval: Mature eggs are collected from the ovaries.
3. Sperm collection: A semen sample is obtained.
4. Fertilisation: Eggs and sperm are brought together in a laboratory, or a sperm is injected into an egg using ICSI.
5. Embryo culture: Fertilised eggs develop in controlled laboratory conditions.
6. Embryo transfer: A selected embryo is transferred into the uterus.
7. Pregnancy testing: Medical tests are performed to determine whether implantation and pregnancy have occurred.

Importance of IVF

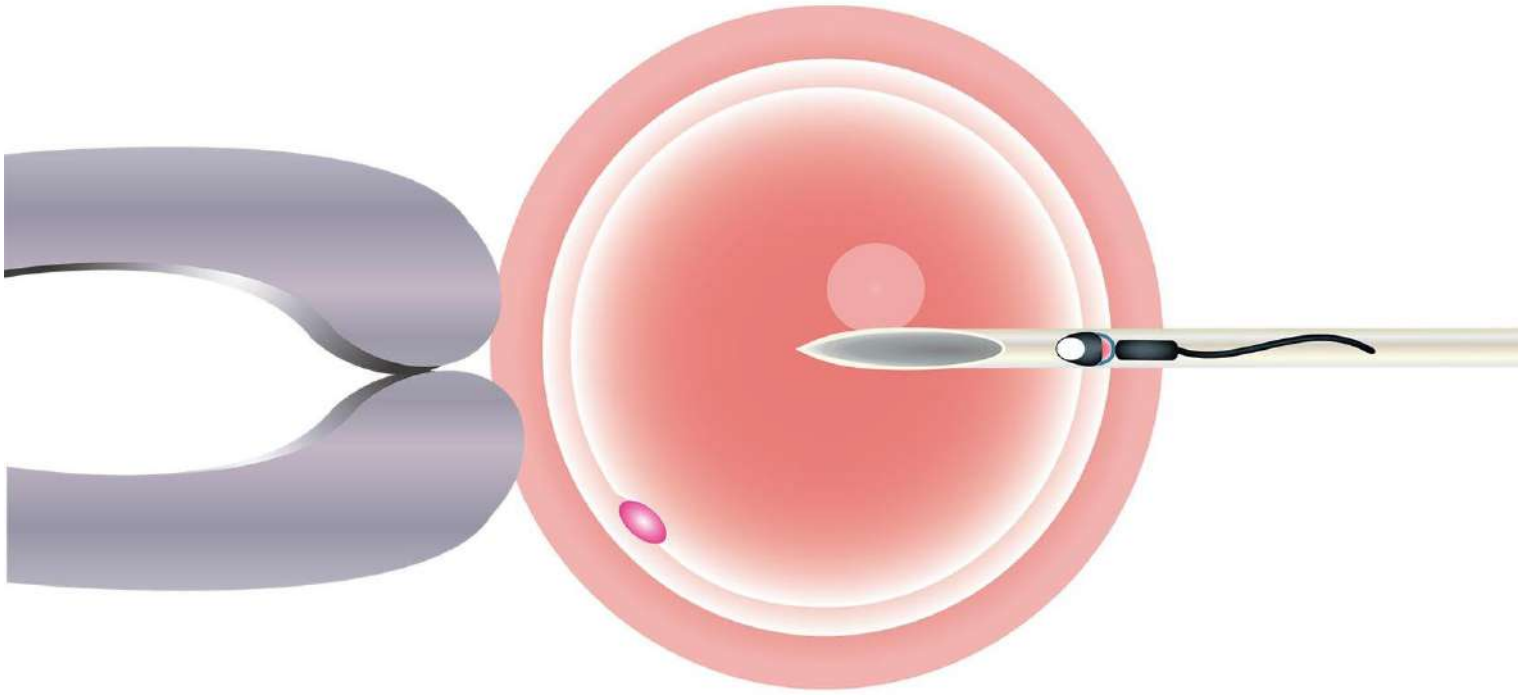
- Helps some individuals and couples experiencing infertility.
- May assist people with damaged fallopian tubes.
- May be used in cases of certain sperm-related fertility problems.
- Can support the use of donated eggs or sperm where legally and ethically permitted.
- May allow genetic testing of embryos for selected inherited conditions.

Limitations and challenges

- It can be expensive.
- It may not always result in pregnancy.
- It may involve emotional and physical stress.
- It may increase the likelihood of multiple pregnancy if more than one embryo is transferred.
- It requires specialised facilities and trained professionals.

B. Intracytoplasmic sperm injection (ICSI)

ICSI is an assisted reproductive procedure in which a single sperm cell is injected directly into the cytoplasm of an egg.



Importance

1. Helps in certain cases of male-factor infertility.
2. Can be used when sperm numbers or movement are severely reduced.
3. May be used when previous IVF fertilisation has been unsuccessful.
4. Enables fertilisation using a single selected sperm cell.

C. Artificial insemination

Artificial insemination involves placing prepared sperm into the female reproductive tract using medical procedures rather than through sexual intercourse.

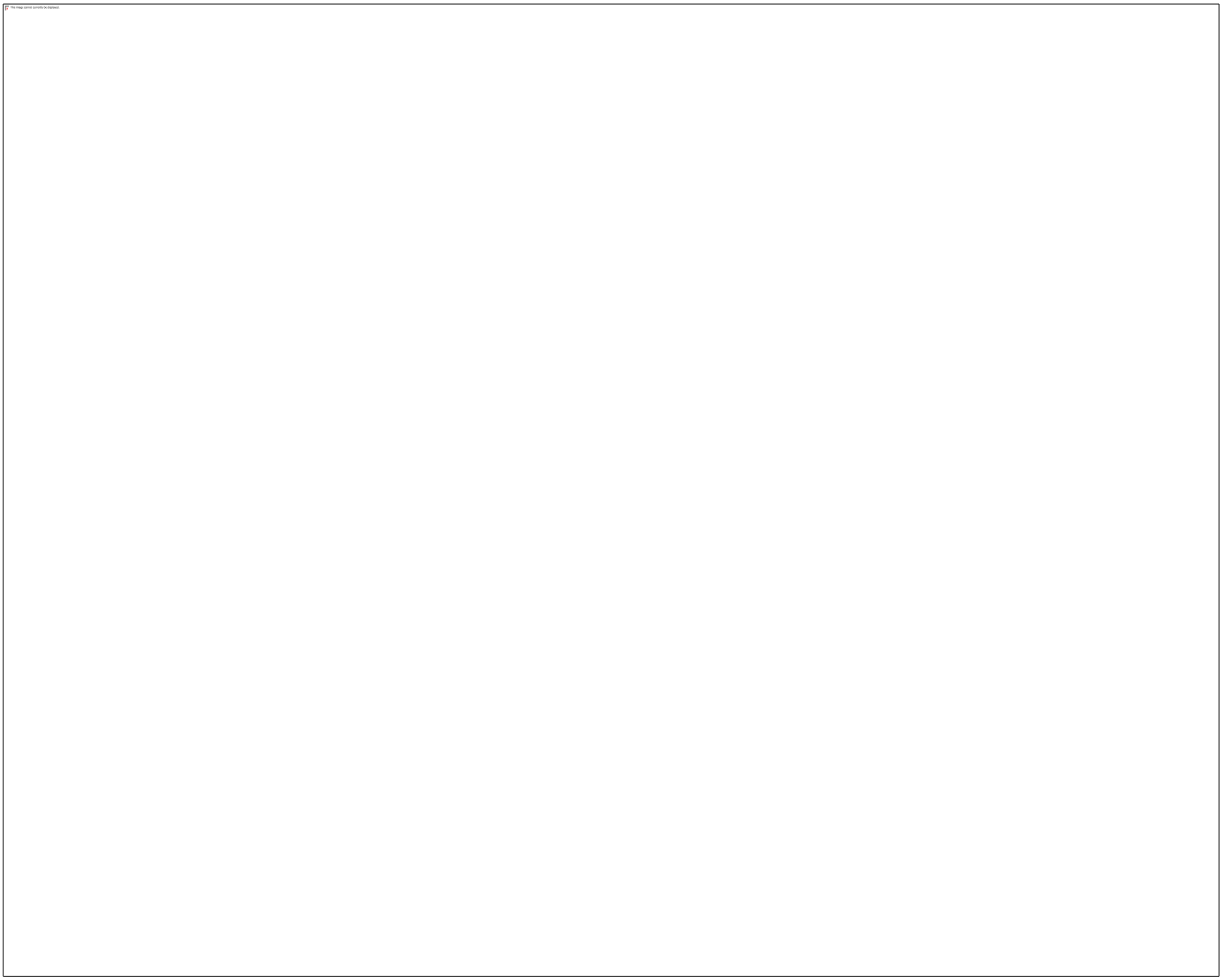
One example is intrauterine insemination (IUI), where sperm is placed directly into the uterus.

Importance

- May assist in certain cases of infertility.
- May be used when sperm delivery or movement is a challenge.
- Can be used with donor sperm in appropriate clinical circumstances.

D. Ultrasound scanning

Ultrasound scanning uses high-frequency sound waves to produce images of internal body structures.



Applications in reproduction

1. Confirms the location of pregnancy.
2. Monitors foetal growth.
3. Assesses the number of developing foetuses.
4. Helps identify some structural abnormalities.
5. Monitors the placenta and amniotic fluid.
6. Helps assess foetal position.

E. Genetic testing

Genetic testing involves examining DNA, chromosomes or genes to identify certain inherited conditions or genetic changes.

Applications

- Identifying inherited genetic disorders.
- Investigating certain causes of infertility.
- Supporting reproductive counselling.
- Testing embryos for selected inherited conditions during assisted reproduction.

F. Pregnancy testing

Pregnancy tests detect human chorionic gonadotropin (hCG), a hormone produced during pregnancy.

Types

1. Urine pregnancy tests.
2. Blood pregnancy tests.

Importance

- Help detect pregnancy.
- Support early antenatal care.
- Assist healthcare workers in investigating pregnancy-related conditions.

15.3 Benefits of modern reproductive technology

1. Assists individuals and couples experiencing infertility.
2. Improves the diagnosis of reproductive disorders.
3. Helps monitor foetal development.
4. Supports early detection of some pregnancy complications.
5. Helps identify selected inherited disorders.
6. Supports safer pregnancy management.
7. Provides additional options for individuals with reproductive difficulties.

15.4 Ethical and social issues associated with reproductive technology

Modern reproductive technology raises several ethical and social questions.

A. Cost and accessibility

- Some reproductive procedures are expensive.
- Access may be limited to individuals living near specialised health facilities.
- This may create inequality in access to reproductive services.

B. Multiple pregnancies

- Some fertility treatments may increase the likelihood of twins or higher-order multiple births.
- Multiple pregnancies may carry additional health risks.

C. Storage of embryos

- IVF may result in embryos that are not immediately transferred.
- Questions may arise concerning their storage, future use and disposal.

D. Donor gametes

- Use of donated sperm or eggs may raise questions about genetic parenthood, identity and family relationships.

E. Genetic selection

- Genetic testing may help identify inherited diseases.
- However, concerns arise when genetic selection is used for non-medical preferences.

F. Informed consent

- Individuals must understand the procedures, possible risks, benefits and alternatives.
- Medical decisions should be made voluntarily.

G. Cultural and religious perspectives

- Communities may have different views concerning assisted reproduction.
- Respectful discussions and ethical guidance are important.

H. Privacy and confidentiality

- Reproductive and genetic information is personal.
- Healthcare workers should protect patient information.

15.5 Modern technology and reproductive healthcare in Kenya

Modern reproductive healthcare in Kenya includes:

- Ultrasound services in antenatal clinics.
- Laboratory testing for STIs.
- Cervical cancer screening.
- HPV vaccination.
- Fertility assessment.
- Assisted reproductive services in specialised facilities.
- Maternal health monitoring.
- Genetic counselling and selected genetic tests.

Key inquiry question: How does modern technology impact human reproduction?

Modern technology has improved the understanding, diagnosis and management of human reproductive processes. However, its use should be guided by safety, accessibility, informed consent, ethical considerations and respect for human dignity.

16.0 PRACTICAL ACTIVITIES AND INVESTIGATIONS

These activities provide opportunities for learners to develop scientific skills, teamwork, communication, creativity and critical thinking.

Activity 1: Identifying structures of the male reproductive system

Objective: To identify the major parts of the male reproductive system and explain their functions.

Materials

- Male reproductive system chart.
- Textbook.
- Labels.
- Drawing materials.

Procedure

1. Observe a diagram of the male reproductive system.
2. Identify the testes.
3. Locate the scrotum.
4. Identify the epididymis.

5. Trace the vas deferens.
6. Identify the seminal vesicles and prostate gland.
7. Locate the urethra and penis.
8. Label the structures on a blank diagram.
9. Discuss the functions of each structure.

Expected outcome: Learners identify and describe the reproductive structures accurately.

Activity 2: Identifying structures of the female reproductive system

Objective: To identify the major female reproductive organs and their functions.

Procedure

1. Observe a labelled diagram of the female reproductive system.
2. Identify the ovaries.
3. Locate the fallopian tubes.
4. Identify the uterus and endometrium.
5. Locate the cervix and vagina.
6. Draw and label the reproductive system.
7. Discuss how each structure contributes to reproduction.

Expected outcome: Learners explain the adaptations of the female reproductive system.

Activity 3: Investigating stages of prenatal development

Objective: To arrange the stages of human development in the correct sequence.

Materials

- Pictures of a zygote.
- Morula.
- Blastocyst.
- Implantation.
- Embryo.
- Foetus.

Procedure

1. Observe the supplied pictures.
2. Identify each developmental stage.
3. Arrange the pictures in the correct sequence.
4. Discuss the major changes occurring at each stage.
5. Present the findings to the class.

Expected sequence:

Fertilisation → Zygote → Cleavage → Morula → Blastocyst → Implantation → Embryo → Foetus → Birth.

Activity 4: Investigating the importance of amniotic fluid

Objective: To demonstrate how fluid can cushion and protect an object from mechanical impact.

Materials

- Two small eggs.
- Two transparent containers.
- Water.
- Cotton wool.
- A safe working surface.

Procedure

1. Place one egg in a container with water.
2. Place the second egg in a container without water, using suitable cushioning to make the comparison safe.
3. Gently apply a controlled, low-force movement to the containers.
4. Observe the cushioning effect of the water.
5. Discuss how amniotic fluid protects the developing foetus.

Conclusion: Fluid can cushion objects against mechanical impact. Amniotic fluid provides a protective environment around the developing foetus.

Note: This is a simplified demonstration, not an exact reproduction of conditions inside the uterus.

Activity 5: Creating awareness about reproductive health

Objective: To develop communication and citizenship competencies.

Procedure

1. Divide learners into groups.
2. Assign each group a topic such as STIs, HPV vaccination, reproductive cancers or antenatal care.
3. Research the topic using reliable sources.
4. Prepare an educational poster.
5. Present the poster to classmates.
6. Display the posters on the classroom noticeboard.

Expected outcome: Learners develop awareness of reproductive health and disease prevention.

REVISION EXERCISES

SECTION A: MULTIPLE-CHOICE QUESTIONS (30 MARKS)

Instructions: Answer all questions. Choose the correct answer from alternatives A, B, C and D. Each question carries one mark.

1. Which of the following is the main function of the human reproductive system?

A. Digestion of food.

B. Production of new individuals.

C. Transportation of oxygen.

D. Removal of nitrogenous waste.

2. Which male reproductive organ produces sperm cells?

A. Prostate gland.

B. Epididymis.

C. Testes.

D. Seminal vesicles.

3. The main function of the scrotum is to:

A. Produce sperm cells.

B. Maintain a suitable temperature for sperm production.

C. Produce testosterone.

D. Store semen.

4. Where do sperm cells mature?

A. Urethra.

B. Epididymis.

C. Prostate gland.

D. Seminal vesicle.

5. Which structure transports sperm from the epididymis towards the ejaculatory duct?

A. Ureter.

B. Vas deferens.

C. Urethra.

D. Seminiferous tubule.

6. Which male reproductive hormone is mainly responsible for the development of male secondary sexual characteristics?

A. Progesterone.

B. Oestrogen.

C. Testosterone.

D. Prolactin.

7. Which female reproductive organ produces ova?

A. Uterus.

B. Cervix.

C. Ovary.

D. Vagina.

8. The usual site of fertilisation in human beings is the:

A. Uterus.

B. Fallopian tube.

C. Cervix.

D. Vagina.

9. Which structure provides the site for implantation and foetal development?

A. Ovary.

B. Urethra.

C. Uterus.

D. Vulva.

10. Which hormone triggers ovulation in human females?

A. Prolactin.

B. Oxytocin.

C. Luteinising hormone.

D. Testosterone.

11. Which hormone helps maintain the endometrium during pregnancy?

A. Progesterone.

B. Testosterone.

C. Insulin.

D. Adrenaline.

12. Which part of the sperm cell contains numerous mitochondria?

A. Head.

B. Middle piece.

C. Acrosome.

D. Nucleus.

13. The acrosome of a sperm cell contains:

A. Stored food.

B. Enzymes that assist penetration of the ovum's protective layers.

C. Haemoglobin.

D. Blood plasma.

14. How many chromosomes are normally found in a human sperm cell?

A. 23.

B. 46.

C. 44.

D. 48.

15. The first cell formed following fertilisation is called the:

A. Embryo.

B. Foetus.

C. Zygote.

D. Blastocyst.

16. The solid ball of cells formed during early embryonic development is called the:

A. Blastocyst.

B. Morula.

C. Foetus.

D. Placenta.

17. Which structure of the blastocyst develops into the embryo?

A. Trophoblast.

B. Inner cell mass.

C. Endometrium.

D. Chorion.

18. Implantation normally occurs in the:

A. Fallopian tube.

B. Ovary.

C. Endometrium.

D. Cervix.

19. The three primary germ layers formed during gastrulation are:

A. Amnion, chorion and placenta.

B. Ectoderm, mesoderm and endoderm.

C. Morula, blastocyst and embryo.

D. Ovary, uterus and cervix.

20. The developing human organism is called an embryo up to the end of the:

A. Second week after fertilisation.

B. Fourth week after fertilisation.

C. Eighth week after fertilisation.

D. Twelfth week after fertilisation.

21. Which structure facilitates the exchange of nutrients and gases between maternal and foetal blood?

A. Cervix.

B. Placenta.

C. Ovary.

D. Vagina.

22. Which blood vessel carries oxygenated blood from the placenta to the foetus?

A. Umbilical artery.

B. Pulmonary artery.

C. Umbilical vein.

D. Aorta.

23. Which of the following is a function of amniotic fluid?

A. Producing sperm cells.

B. Protecting the foetus against mechanical injury.

C. Producing reproductive hormones only.

D. Digesting nutrients.

24. Which hormone stimulates uterine contractions during childbirth?

A. Insulin.

B. Oxytocin.

C. Testosterone.

D. Glucagon.

25. Identical twins develop from:

A. Two ova fertilised by two sperm cells.

B. One zygote that separates into two embryonic structures.

C. Two separate placentas only.

D. Two different menstrual cycles.

26. Fraternal twins develop when:

A. One sperm fertilises two ova.

B. One zygote divides into two.

C. Two separate ova are fertilised by two sperm cells.

D. One embryo develops two hearts.

27. Ectopic pregnancy occurs when:

A. The foetus develops normally in the uterus.

B. Implantation occurs outside the normal uterine cavity.

C. The placenta is expelled during childbirth.

D. Ovulation occurs twice.

28. Which microorganism causes gonorrhoea?

A. Mycobacterium tuberculosis.

B. Neisseria gonorrhoeae.

C. Plasmodium falciparum.

D. Treponema pallidum.

29. Which virus is strongly associated with cervical cancer?

A. Influenza virus.

B. Hepatitis A virus.

C. Human papillomavirus.

D. Measles virus.

30. In-vitro fertilisation involves:

A. Fertilisation of an egg inside the fallopian tube only.

B. Fertilisation of an egg outside the body in a laboratory.

C. Development of sperm in the prostate gland.

D. Implantation of an embryo in the ovary.

SECTION B: STRUCTURED QUESTIONS – 50 MARKS

Instructions: Answer all questions. Write your answers clearly and use appropriate scientific terminology.

Question 1: The Human Reproductive System (8 marks)

a) Define human reproduction. (1 mark)

b) Name four structures of the male reproductive system. (4 marks)

c) State three functions of the female reproductive system. (3 marks)

Question 2: Adaptations and Hormonal Regulation (8 marks)

a) State three adaptations of the sperm cell to its reproductive function. (3 marks)

b) State two functions of testosterone in males. (2 marks)

c) Name the two pituitary hormones that regulate ovarian activity. (2 marks)

d) State one function of progesterone during pregnancy. (1 mark)

Question 3: Fertilisation and Development (9 marks)

a) Define fertilisation. (2 marks)

b) Name the structure where fertilisation normally occurs in human beings. (1 mark)

c) Arrange the following developmental stages in their correct sequence: (3 marks)

- Morula.
- Foetus.
- Zygote.
- Blastocyst.
- Embryo.
- Cleavage.

d) Differentiate between an embryo and a foetus. (2 marks)

e) State the chromosome number in a normal human zygote. (1 mark)

Question 4: Pregnancy and the Placenta (8 marks)

a) State three functions of the placenta. (3 marks)

b) Name the blood vessels found in the umbilical cord. (2 marks)

c) State three functions of amniotic fluid. (3 marks)

Question 5: Multiple Births and Childbirth (8 marks)

a) Differentiate between identical twins and fraternal twins. (4 marks)

b) Name the three stages of childbirth. (3 marks)

c) State one function of oxytocin during childbirth. (1 mark)

Question 6: Reproductive Diseases and Modern Technology (9 marks)

a) Define sexually transmitted infections. (1 mark)

b) State two preventive measures against STIs. (2 marks)

c) Explain what is meant by ectopic pregnancy. (2 marks)

d) Name two reproductive cancers affecting males. (2 marks)

e) State two applications of modern reproductive technology. (2 marks)

20.0 REVISION ANSWER KEY AND MARKING SCHEME

SECTION A: MULTIPLE CHOICE ANSWERS

Question	Answer	Question	Answer
1	B	16	B
2	C	17	B
3	B	18	C
4	B	19	B
5	B	20	C
6	C	21	B
7	C	22	C
8	B	23	B
9	C	24	B
10	C	25	B
11	A	26	C
12	B	27	B
13	B	28	B
14	A	29	C
15	C	30	B

SECTION B: SUGGESTED ANSWERS AND MARKING SCHEME

Question 1: The Human Reproductive System (8 marks)

a) Human reproduction is the biological process through which human beings produce offspring. (1)

b) Any four:

- Testes.
- Scrotum.
- Epididymis.
- Vas deferens.
- Seminal vesicles.
- Prostate gland.
- Penis.
- Urethra. (4)

c) Any three:

- Produces ova.
- Produces female reproductive hormones.
- Provides a site for fertilisation.
- Supports implantation.
- Supports foetal development.
- Facilitates childbirth. (3)

Question 2: Adaptations and Hormonal Regulation (8 marks)

a) Any three:

- Long tail for movement.
- Numerous mitochondria for energy production.
- Acrosome contains enzymes for penetration of the ovum's protective layers.
- Haploid nucleus carries 23 chromosomes.
- Streamlined shape reduces resistance during movement. (3)

b) Any two:

- Promotes development of male reproductive organs.
- Supports sperm production.
- Promotes facial and body hair growth.
- Causes deepening of the voice.
- Supports muscle and bone development. (2)

c)

- Follicle-stimulating hormone (FSH). (1)
- Luteinising hormone (LH). (1)

d) Maintains the endometrium and supports pregnancy. (1)

Question 3: Fertilisation and Development (9 marks)

a) Fertilisation is the fusion of the haploid nuclei of a sperm cell and an ovum to form a diploid zygote. (2)

b) Fallopian tube (oviduct). (1)

c) Correct sequence:

1. Zygote.
2. Cleavage.
3. Morula.
4. Blastocyst.
5. Embryo.
6. Foetus. (3)

d)

- Embryo: Developing human organism from fertilisation up to the end of the eighth week after fertilisation. (1)

- Foetus: Developing human organism from the beginning of the ninth week after fertilisation until birth. (1)

e) 46 chromosomes. (1)

Question 4: Pregnancy and the Placenta (8 marks)

a) Any three:

- Facilitates exchange of oxygen and carbon dioxide.
- Transfers nutrients from mother to foetus.
- Removes foetal waste products.
- Produces hormones that support pregnancy.
- Provides a selective barrier between maternal and foetal blood. (3)

b)

- Two umbilical arteries. (1)
- One umbilical vein. (1)

c) Any three:

- Protects the foetus from mechanical injury.
- Allows foetal movement.
- Provides buoyancy.
- Helps maintain a stable temperature.
- Reduces compression of the umbilical cord. (3)

Question 5: Multiple Births and Childbirth (8 marks)

a)

Identical twins:

- Develop from one zygote. (1)
- Have nearly identical genetic information. (1)

Fraternal twins:

- Develop from two separate zygotes. (1)
- Have genetic differences similar to ordinary siblings. (1)

b)

- Cervical dilation stage. (1)
- Delivery of the baby stage. (1)
- Delivery of the placenta stage. (1)

c) Stimulates uterine contractions during childbirth. (1)

Question 6: Reproductive Diseases and Modern Technology (9 marks)

a) STIs are infections mainly transmitted through sexual contact. (1)

b) Any two:

- Correct and consistent condom use.
- Abstinence.

- Regular STI testing where appropriate.
- Early treatment of infections.
- Partner testing and treatment.
- HPV and hepatitis B vaccination. (2)

c) Ectopic pregnancy is a condition in which a fertilised egg implants outside the normal uterine cavity, commonly in the fallopian tube. (2)

d) Any two:

- Prostate cancer.
- Penile cancer.
- Testicular cancer. (2)

e) Any two:

- IVF assists fertilisation outside the body.
- Ultrasound monitors foetal development.
- ICSI assists fertilisation by injecting a sperm into an egg.
- Genetic testing identifies selected inherited conditions.
- Artificial insemination assists sperm delivery.
- Pregnancy tests detect hCG. (2)

SUB-STRAND PROJECT

CBE PRACTICAL PROJECT

Constructing a Three-Dimensional Model of Human Reproduction



Project objective

To construct a three-dimensional model demonstrating the human reproductive system and the development of a human being from fertilisation to birth.

Locally available materials

- Cardboard.
- Clay or plasticine.
- Coloured paper.
- Recycled plastic materials.
- Wool or strings.
- Glue.
- Scissors.
- Markers.

- Recycled containers.

Project requirements

1. Construct a labelled model of the female reproductive system.
2. Show the location of the ovaries and fallopian tubes.
3. Indicate the usual site of fertilisation.
4. Show the uterus and endometrium.
5. Include a model of the developing embryo or foetus.
6. Demonstrate the placenta and umbilical cord.
7. Explain the functions of the structures.
8. Present the model to classmates.

Expected competencies

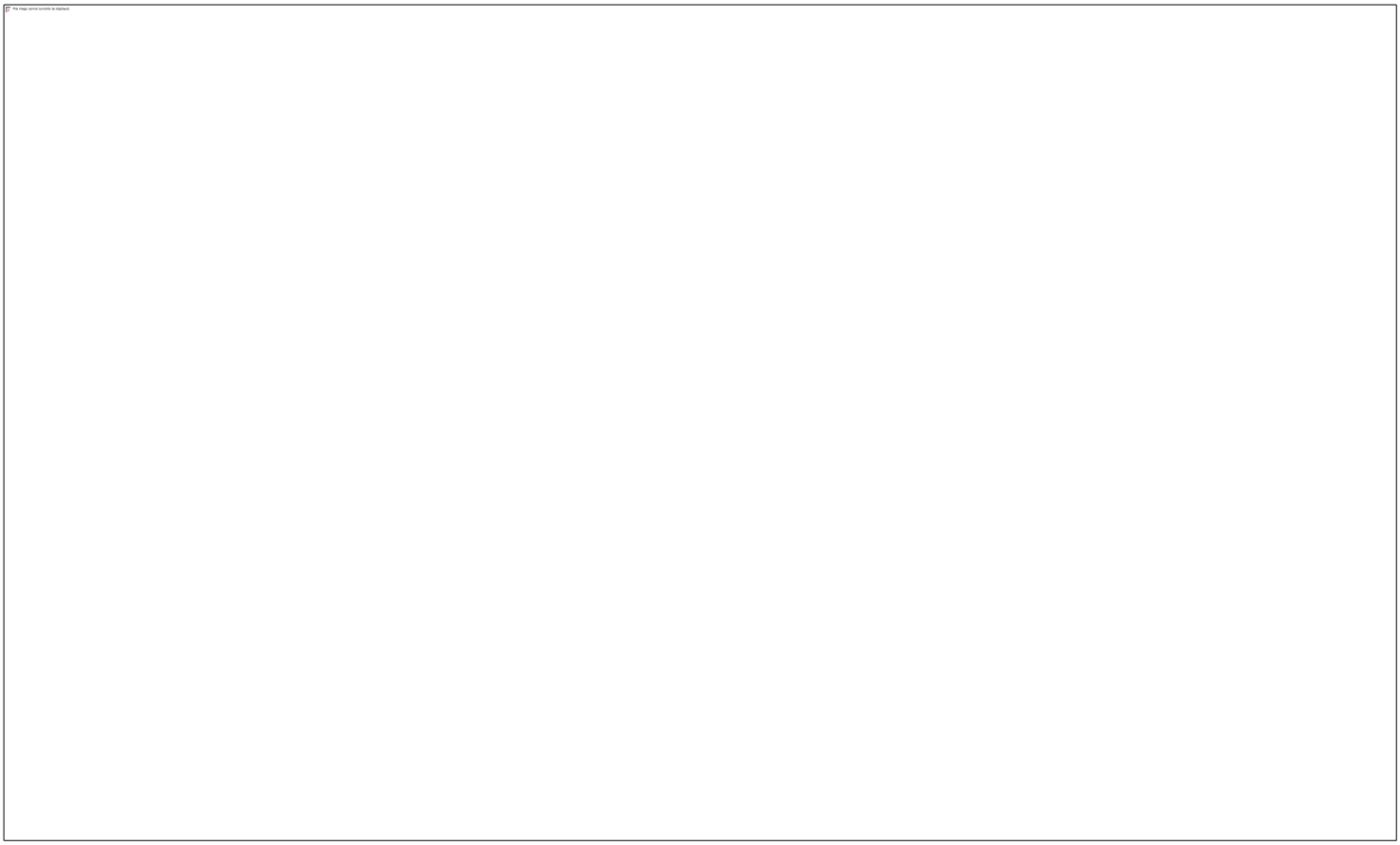
- Creativity and innovation.
- Communication and collaboration.
- Critical thinking.
- Scientific investigation.
- Digital literacy.
- Self-efficacy.

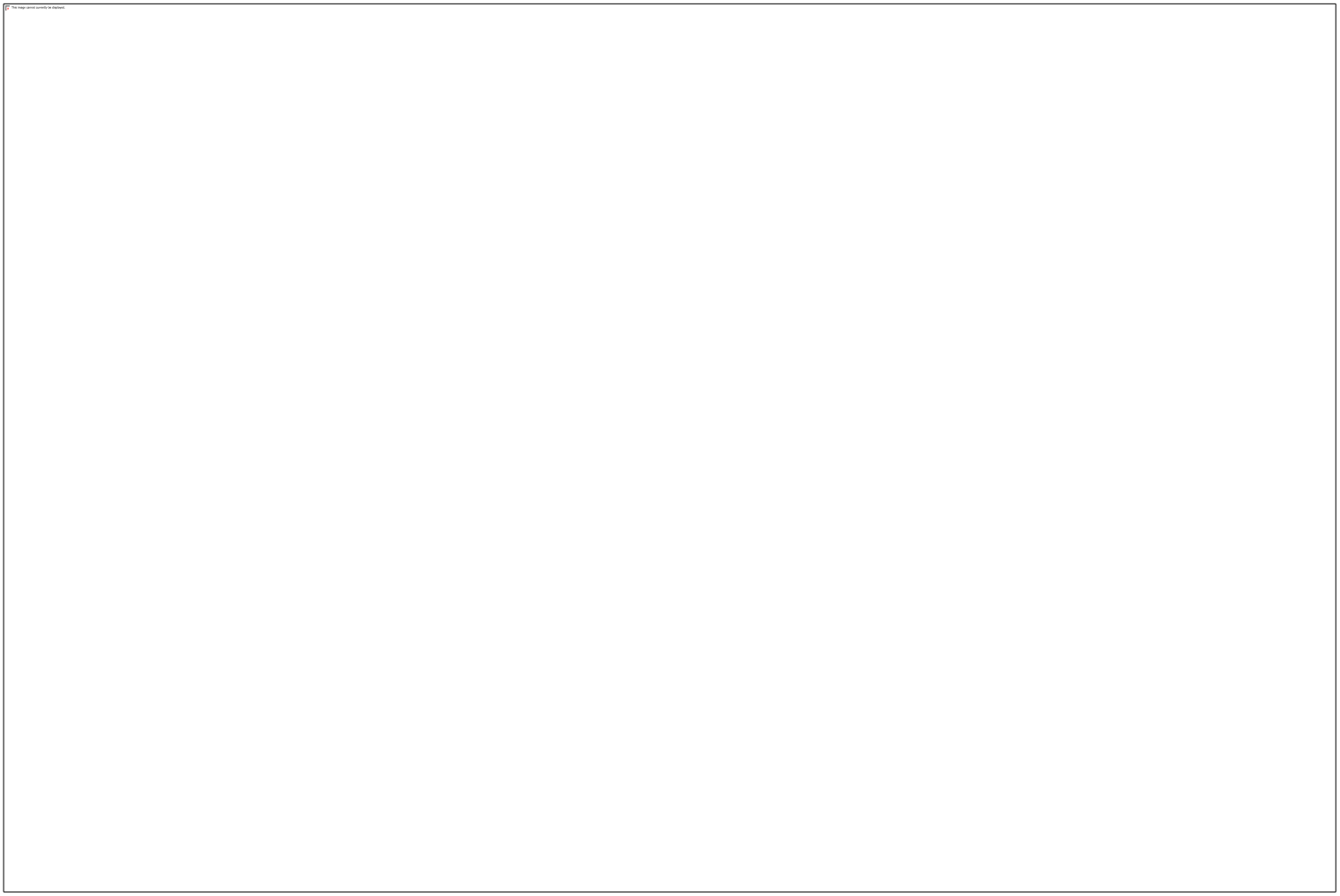
Suggested project assessment rubric

Assessment area	**Marks**
Accuracy of reproductive structures	10
Correct arrangement of structures	5
Demonstration of fertilisation and development	10
Labelling and scientific explanations	5
Creativity and use of local materials	5
Presentation and communication	5
Total	40

STRAND 1.0: LIFE SCIENCE

SUB-STRAND 1.4: RESPONSE AND COORDINATION IN PLANTS







1.0 Introduction to response and coordination in plants

Plants are living organisms that interact with their environment. They detect changes in their surroundings and respond in ways that help them survive, grow and reproduce.

Response is the reaction of an organism to a change in its internal or external environment.

A change that causes an organism to respond is called a **stimulus**. Examples include:

- Light from the sun.
- Gravity.
- Water in the soil.
- Touch or physical contact.
- Temperature changes.
- Chemicals in the environment.

Coordination is the process through which different parts of an organism work together to produce an appropriate response to a stimulus.

Unlike animals, plants do not have a nervous system. They coordinate many of their responses through chemical substances called **plant hormones**, particularly auxins.

Importance of responses in plants

Plant responses are important because they help plants to:

1. Obtain sunlight for photosynthesis.
2. Grow roots towards water and mineral salts.
3. Anchor themselves firmly in the soil.
4. Climb and obtain support from other structures.
5. Protect themselves from harmful environmental conditions.
6. Trap insects in insectivorous plants.
7. Regulate flowering according to seasonal changes.
8. Increase their chances of survival and reproduction.

2.0 NASTIC RESPONSES IN PLANTS

2.1 Meaning of nastic response

A **nastic response** is a movement of a plant or part of a plant in response to a stimulus, where the direction of movement does not depend on the direction from which the stimulus comes.

For example, the leaves of a sensitive plant may fold when touched, regardless of the direction from which the touch occurs.

Nastic movements are usually caused by changes in water pressure (turgor pressure) in specialised plant cells, although some may involve growth.

Characteristics of nastic responses

1. They are usually independent of the direction of the stimulus.
2. They may occur rapidly or slowly.
3. Some are reversible while others are irreversible.
4. They may be caused by changes in turgor pressure.
5. They help plants respond to environmental changes.
6. They do not necessarily involve growth towards or away from a stimulus.

2.2 Types of nastic responses

A. Photonasty

Photonasty is the movement of plant parts in response to changes in light intensity.

Examples:

- Some flowers open during the day and close at night.
- Some flowers close when light intensity decreases.
- Certain flowers open when exposed to bright light.

Survival value of photonasty

1. It helps flowers open when pollinators are active.
2. It protects reproductive parts during unfavourable conditions.
3. It may reduce water loss during periods of intense heat.
4. It helps plants coordinate flower opening with environmental conditions.

B. Thermonasty

Thermonasty is the movement of plant parts in response to changes in temperature.

Examples:

- Some flowers open when temperatures rise.
- Certain flowers close when temperatures fall.
- Tulip and crocus flowers may open in warmer conditions and close in cooler conditions.

Survival value of thermonasty

1. It protects delicate reproductive structures from cold conditions.
2. It allows flowers to open when temperatures are suitable for pollination.
3. It helps reduce exposure of reproductive organs to unfavourable environmental conditions.

C. Chemonasty

Chemonasty is a non-directional movement of a plant part in response to a chemical stimulus.

Examples:

- Tentacles of sundew plants may bend in response to chemical substances released by captured insects.
- Some insectivorous plants show movements associated with chemical substances from their prey.



Survival value of chemonasty

1. It enables insectivorous plants to capture or respond to prey.
2. It helps such plants obtain nutrients, especially nitrogen, from insects.
3. It increases survival in nutrient-poor soils.

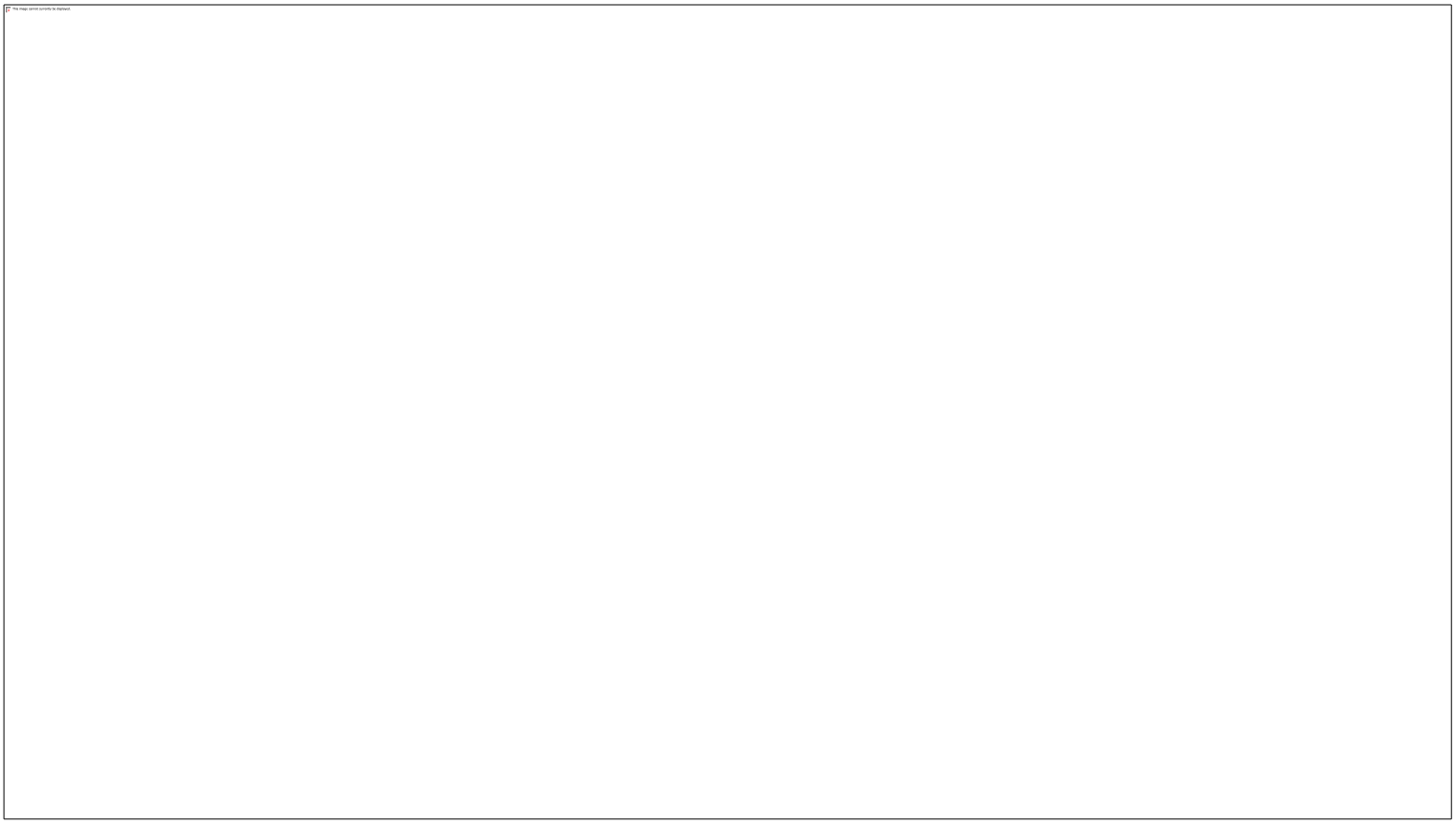
D. Haptonasty

Haptonasty is a non-directional movement of plant parts in response to physical contact or touch.

Examples:

- Some plant structures move or bend when touched.

- The tentacles of certain insectivorous plants respond to contact with prey.



Survival value of haptonasty

1. It helps insectivorous plants capture insects.
2. It assists plants in responding to physical contact.
3. It may help protect delicate plant structures.

Important distinction: Haptonasty is associated with touch-induced nastic movement. The term *thigmonasty* is also commonly used for touch-induced nastic movements, while *thigmotropism* refers to directional growth in response to touch.

Summary of nastic responses

Type	Stimulus	Example
Photonasty	Light	Flowers opening in daylight
Thermonasty	Temperature	Crocus flowers opening in warmth
Chemonasty	Chemicals	Sundew tentacles responding to insect chemicals
Haptonasty	Touch/contact	Touch-related movement in plant structures

3.0 TROPIC RESPONSES IN PLANTS

3.1 Meaning of tropism

A **tropic response** is a directional growth movement of a plant or plant part in response to an external stimulus.

The direction of growth depends on the direction from which the stimulus comes.

Tropic responses may be:

- **Positive tropism:** Growth towards the stimulus.
- **Negative tropism:** Growth away from the stimulus.

Examples:

- Shoots usually grow towards light: positive phototropism.
- Roots usually grow towards gravity: positive geotropism.
- Shoots usually grow away from gravity: negative geotropism.

Characteristics of tropic responses

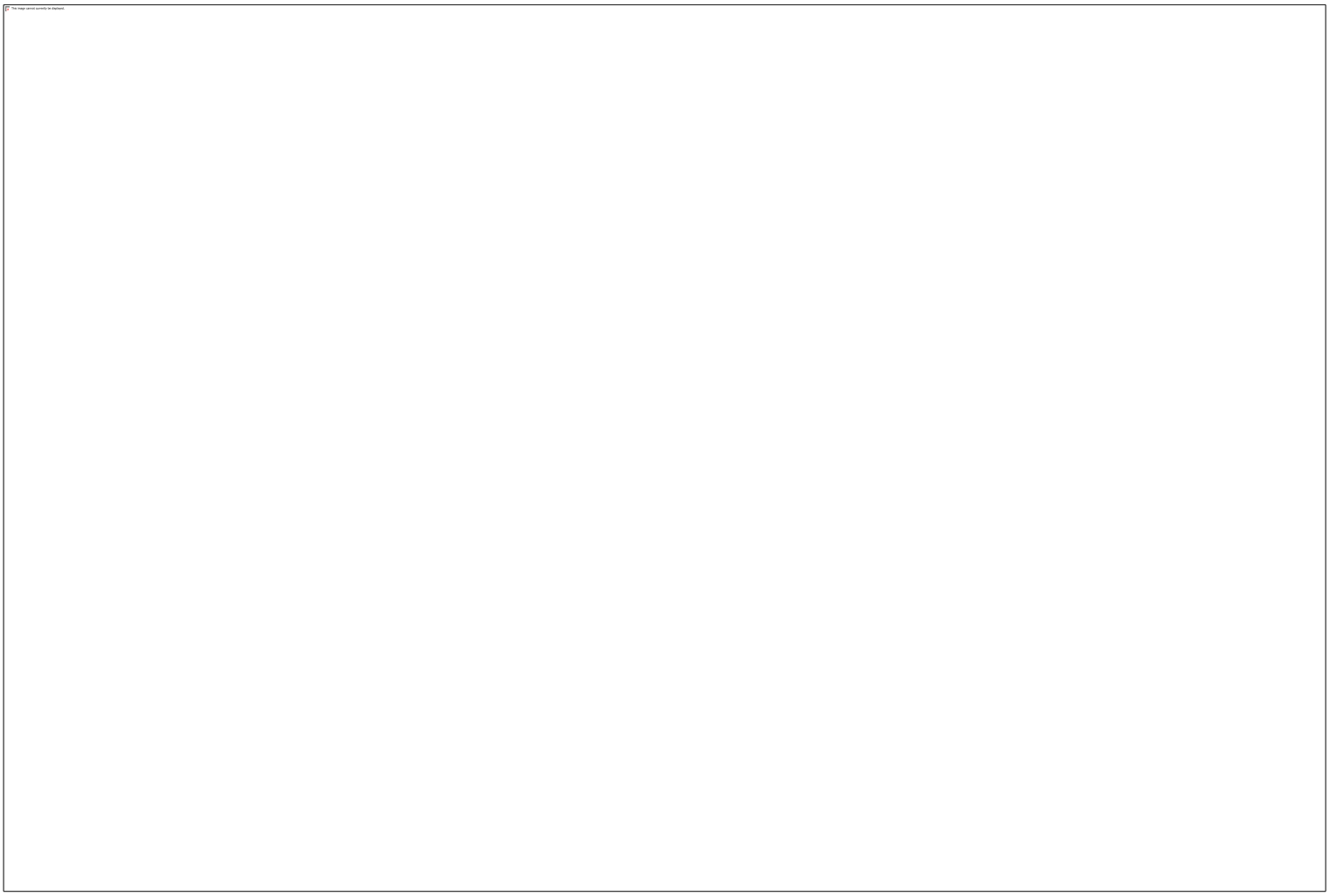
1. They involve growth of plant tissues.
2. They are directional responses.
3. They may be positive or negative.
4. They are usually slower than rapid nastic movements.
5. They are often controlled by plant hormones such as auxins.
6. They help plants obtain resources and survive in their environment.

3.2 Types of tropic responses

A. Phototropism

Phototropism is the directional growth of a plant part in response to light.

- Shoots generally show positive phototropism because they grow towards light.
- Roots generally show negative phototropism because they tend to grow away from light.



Explanation of phototropism in shoots

1. Light falls on one side of a young shoot.
2. Auxin moves towards the shaded side of the shoot.

3. A higher concentration of auxin accumulates on the shaded side.
4. Cells on the shaded side elongate more rapidly.
5. The shoot bends towards the light.

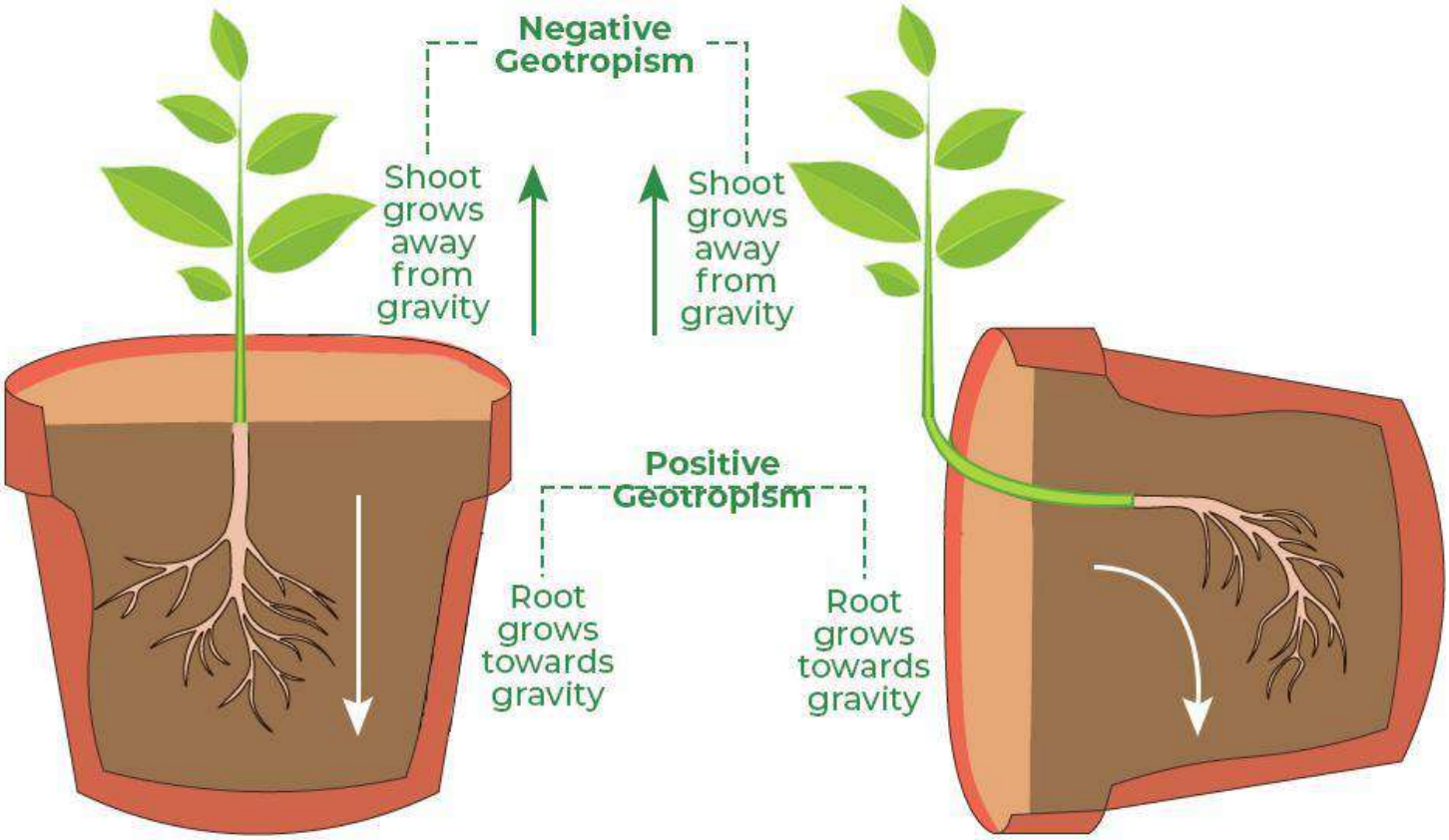
Survival value of phototropism

1. It enables leaves to receive adequate sunlight.
2. It increases the rate of photosynthesis.
3. It promotes food production.
4. It improves plant growth and development.

B. Geotropism (Gravitropism)

Geotropism is the directional growth of a plant part in response to gravity. It is also called gravitropism.

- Roots usually show positive geotropism because they grow towards gravity.
- Shoots usually show negative geotropism because they grow away from gravity.



Explanation of geotropism

When a seed germinates, gravity influences the direction in which the root and shoot grow.

- The root grows downwards towards gravity.
- The shoot grows upwards away from gravity.

Survival value of geotropism

1. It enables roots to penetrate the soil.

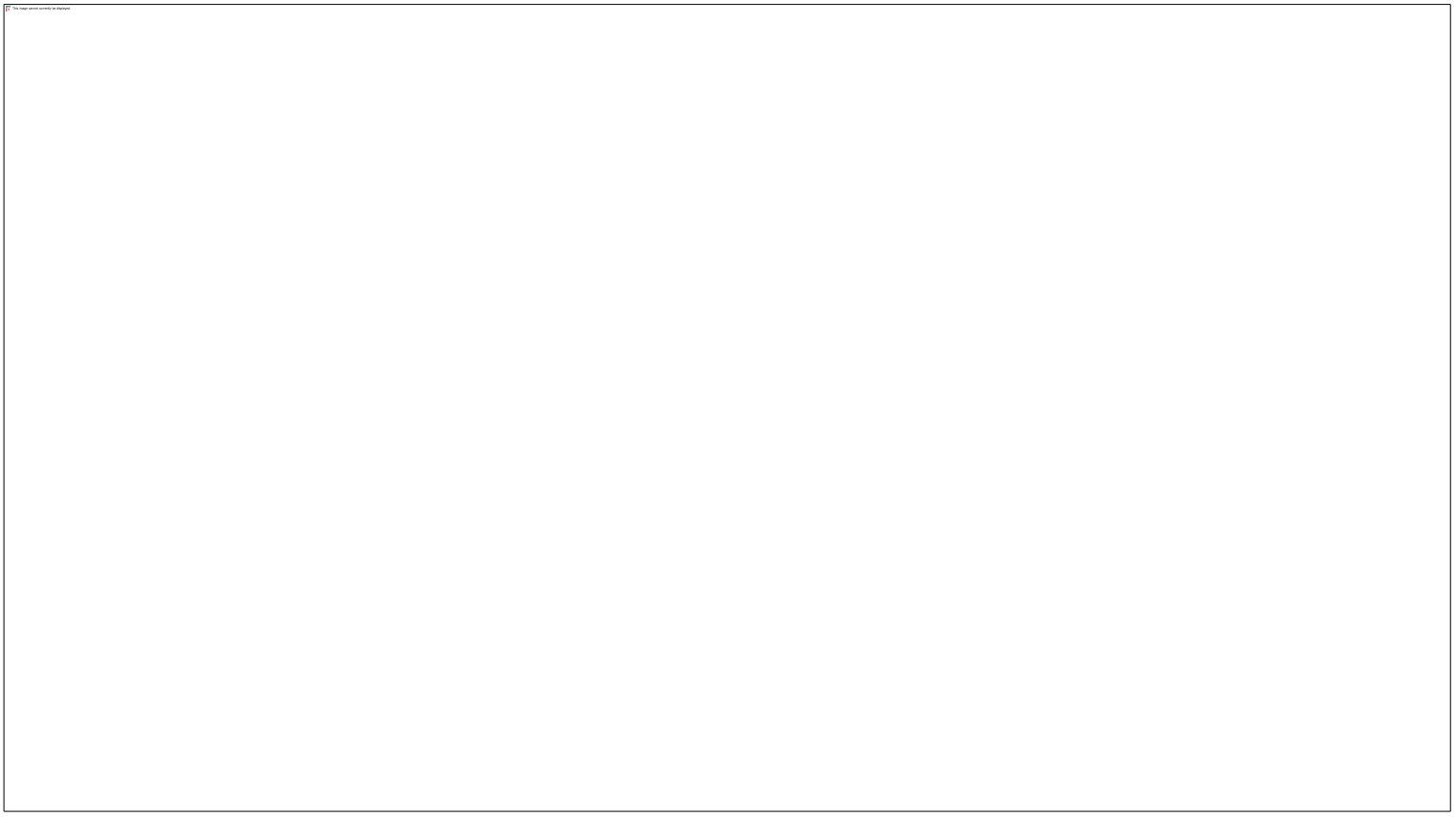
2. It helps roots absorb water and mineral salts.
3. It provides firm anchorage.
4. It enables shoots to grow upwards towards light.
5. It positions leaves for effective photosynthesis.

C. Thigmotropism

Thigmotropism is the directional growth of a plant part in response to touch or physical contact.

Examples:

- Tendrils of climbing plants coil around supporting structures.
- Passion fruit vines use tendrils to attach themselves to supports.
- Cucumber plants use tendrils to climb.



Explanation of thigmotropism

1. A tendril comes into contact with a supporting object.
2. The contact stimulates changes in growth on different sides of the tendril.
3. The side away from contact grows more rapidly.
4. The tendril bends and coils around the support.
5. The plant becomes firmly attached to the supporting structure.

Survival value of thigmotropism

1. It enables climbing plants to obtain support.
2. It helps plants reach areas with more sunlight.
3. It prevents weak stems from collapsing.
4. It enables plants to compete for light.

5. It allows plants to grow upwards without developing thick supporting stems.

3.3 Comparison between nastic and tropic responses

Nastic responses	Tropic responses
Movement does not depend on the direction of the stimulus.	Growth direction depends on the direction of the stimulus.
May involve changes in turgor pressure.	Involve differential growth of plant tissues.
May be rapid or slow.	Usually relatively slow.
May be reversible.	Growth-based responses are generally not easily reversible.
Example: flowers opening in response to light.	Example: shoots growing towards light.

4.0 AUXINS AND THEIR ROLE IN PLANT RESPONSES

4.1 Meaning of auxins

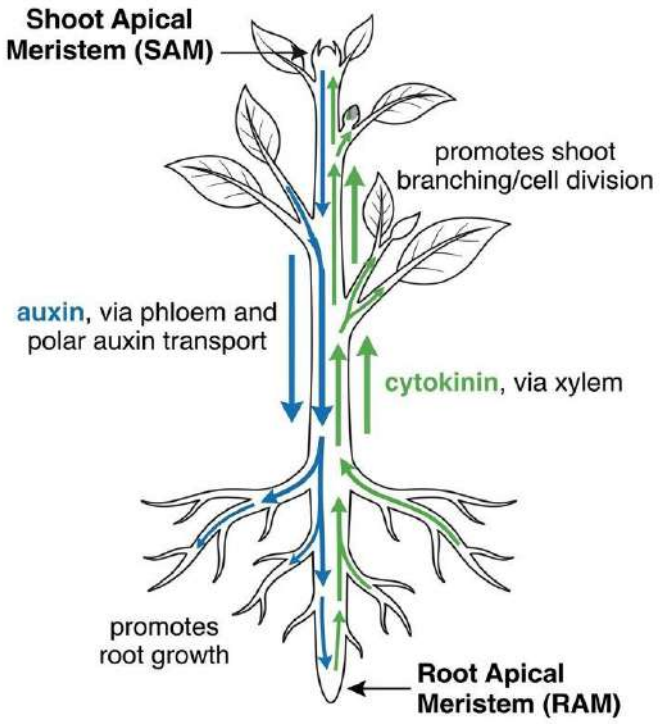
Auxins are plant growth hormones that regulate several activities in plants, including cell elongation, root development and tropic responses.

The most common naturally occurring auxin is **indole-3-acetic acid (IAA)**.

4.2 Sites of auxin production

Auxins are mainly produced in:

1. Shoot tips (apical meristems).
2. Young developing leaves.
3. Developing seeds.
4. Young fruits.
5. Other actively growing plant tissues.



4.3 Roles of auxins in plants

Auxins perform several important functions:

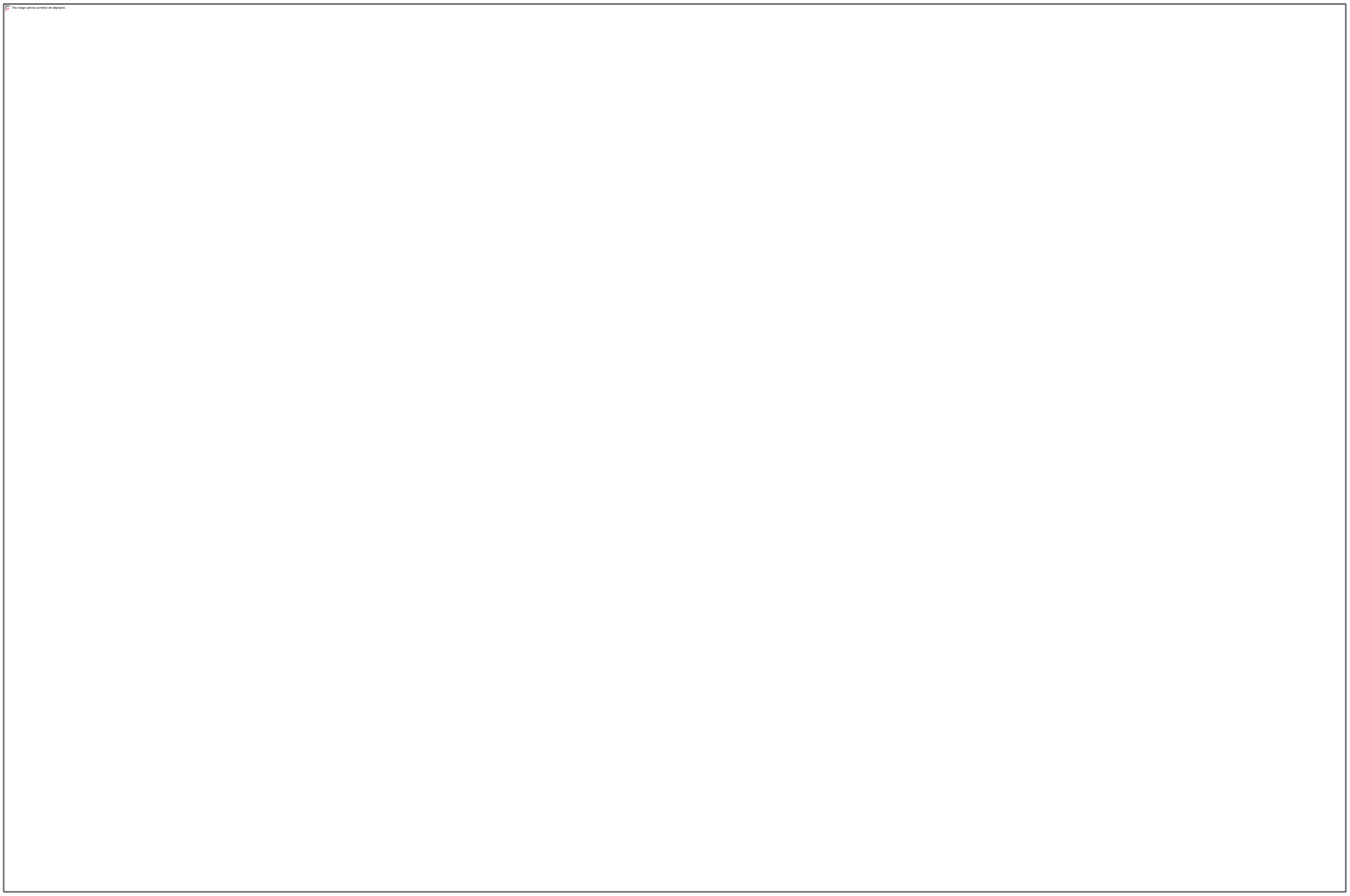
1. **Cell elongation:** They stimulate the elongation of cells, especially in young shoots.

2. **Phototropism:** They cause unequal growth on the two sides of a shoot exposed to light from one direction.
3. **Geotropism:** They help roots and shoots respond to gravity.
4. **Root formation:** They stimulate the development of adventitious roots in suitable concentrations.
5. **Apical dominance:** They help maintain the growth of the main shoot while suppressing the growth of some lateral buds.
6. **Fruit development:** They promote fruit development in some plants.
7. **Prevention of premature leaf fall:** They can delay the separation of leaves from stems.
8. **Plant development:** They influence the growth and development of different plant organs.

4.4 Effects of auxins on phototropism

When light shines on a young shoot from one side:

1. Auxin is produced mainly in the shoot tip.
2. Light causes auxin to become unevenly distributed, with more accumulating on the shaded side.
3. Cells on the shaded side elongate faster than cells on the illuminated side.
4. The shoot bends towards the light.



Why does the shoot bend towards light?

The shaded side elongates more rapidly than the illuminated side, causing the shoot to curve towards the light source.

4.5 Effects of auxins on geotropism

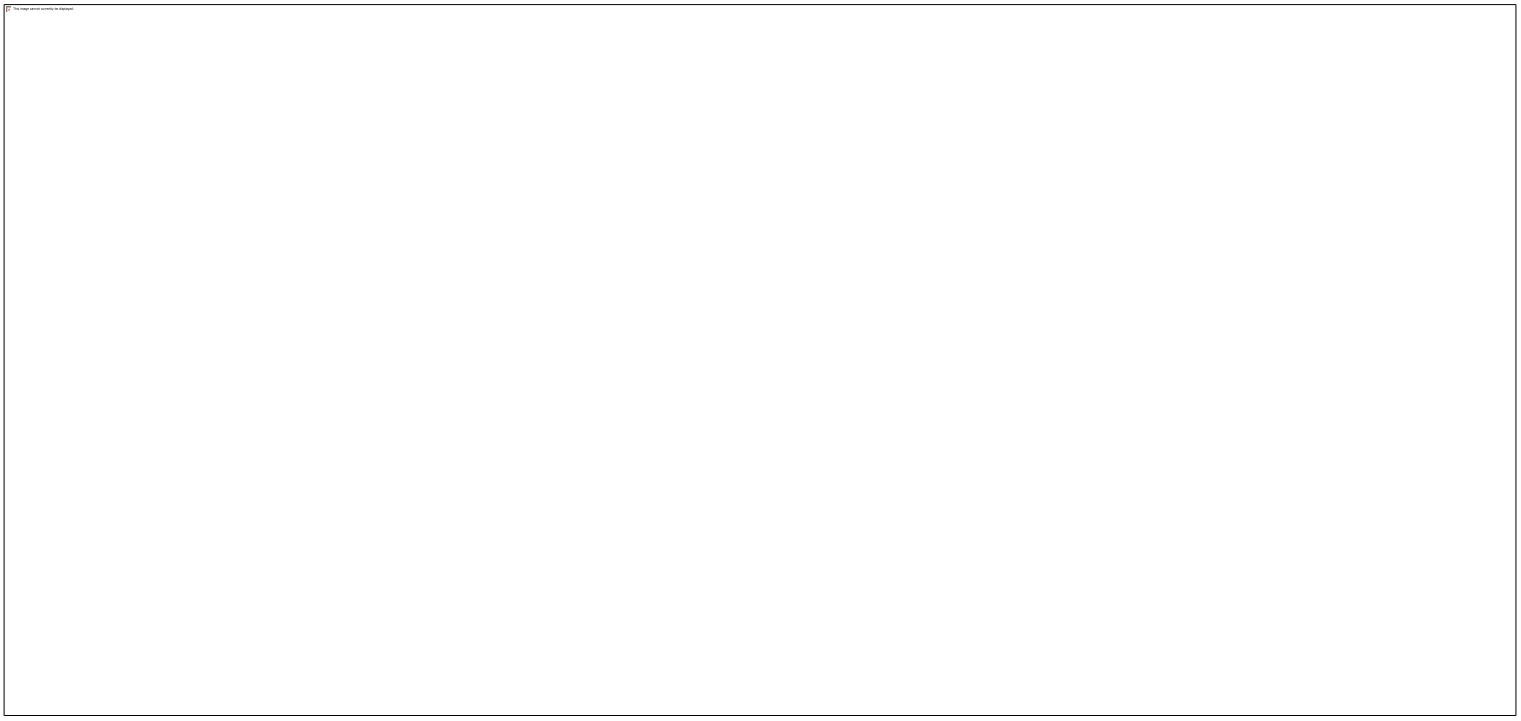
When a young plant is placed horizontally, gravity causes auxin to accumulate more on the lower side.

In shoots:

1. More auxin accumulates on the lower side.
2. Auxin stimulates greater cell elongation on the lower side.
3. The lower side grows faster.
4. The shoot bends upwards, away from gravity.

In roots:

1. More auxin accumulates on the lower side.
2. In roots, a high concentration of auxin inhibits cell elongation.
3. Cells on the upper side elongate faster.
4. The root bends downwards, towards gravity.



Important: Auxins do not have exactly the same effect in shoots and roots. A concentration that promotes elongation in shoots may inhibit elongation in roots.

4.6 Effects of auxins on thigmotropism

1. When a tendril touches a support, the contact stimulates changes in growth.
2. Growth becomes unequal on opposite sides of the tendril.
3. The side away from contact elongates more rapidly.
4. The tendril bends and coils around the support.

5.0 PHOTOPERIODISM

5.1 Meaning of photoperiodism

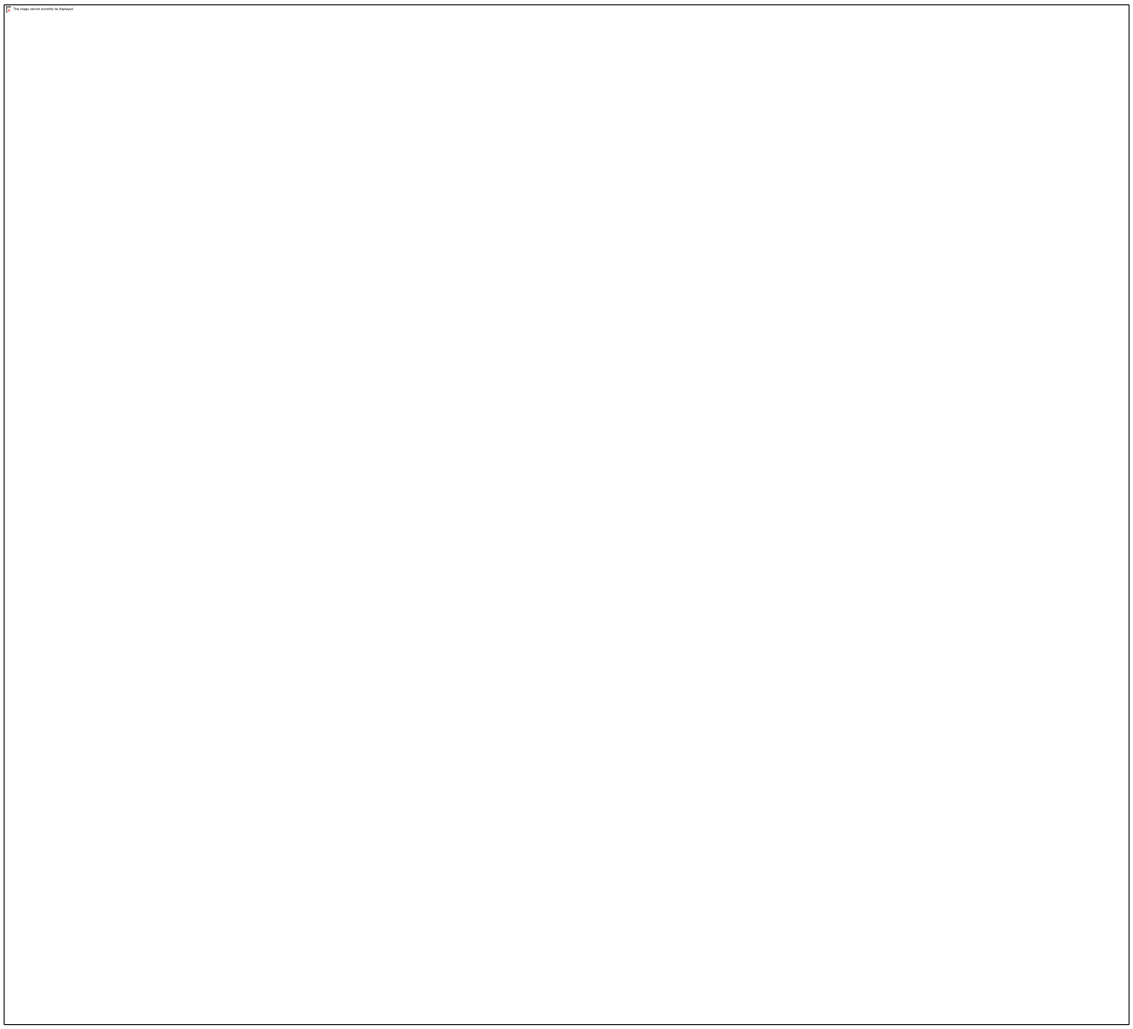
Photoperiodism is the response of plants to the relative lengths of day and night, especially in relation to flowering.

It enables plants to respond to seasonal changes in the environment.

The length of daylight experienced by a plant is called the **photoperiod**.

Photoperiodism influences:

- Flowering.
- Seed germination in some species.
- Dormancy.
- Tuber formation.
- Seasonal growth and development.



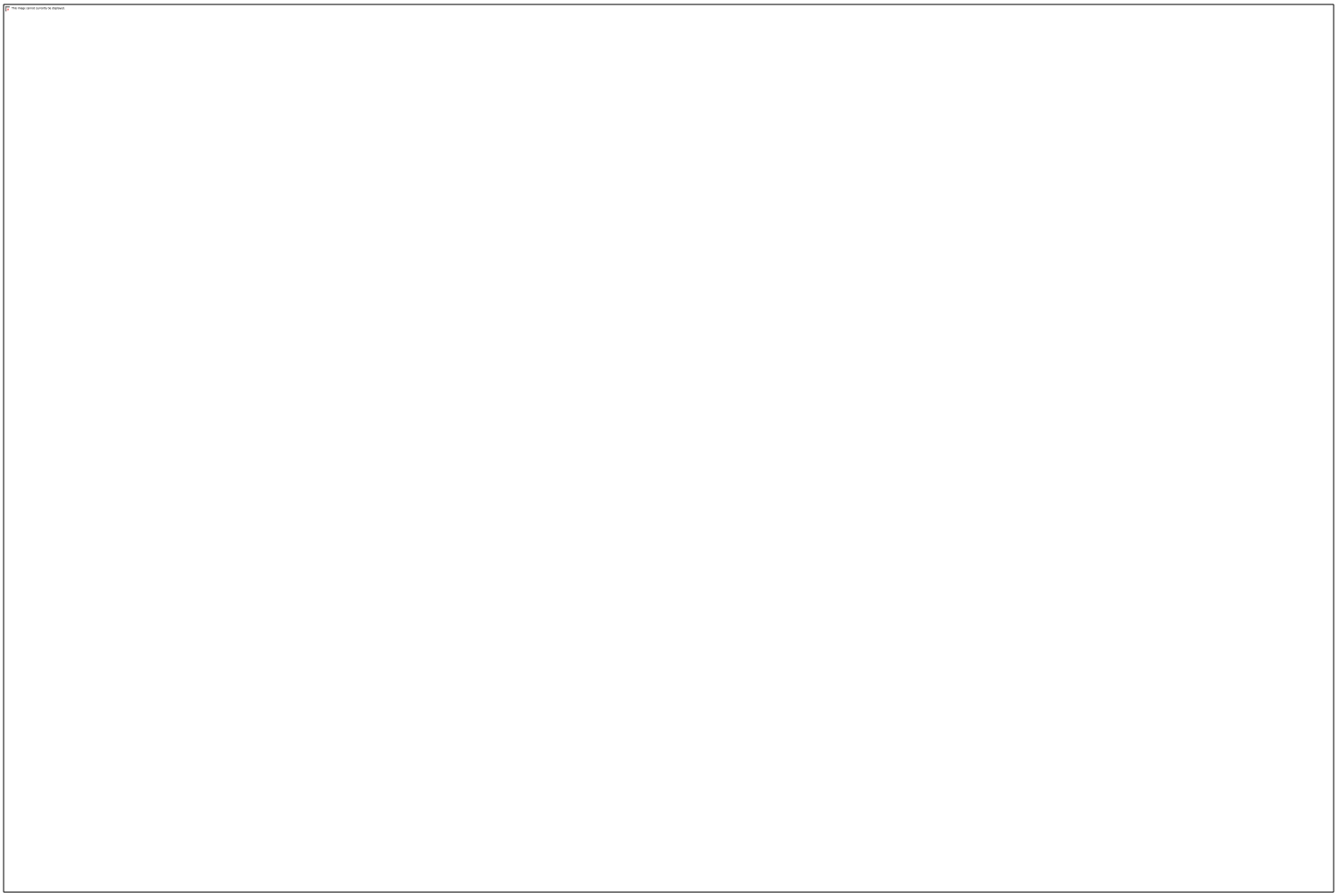
5.2 Types of plants based on photoperiodism

A. Short-day plants

Short-day plants flower when the day length is shorter than a particular critical period. They generally require a sufficiently long, uninterrupted night.

Examples:

- Chrysanthemums.
- Poinsettias.
- Some varieties of rice.
- Some varieties of soybean.



Agricultural importance

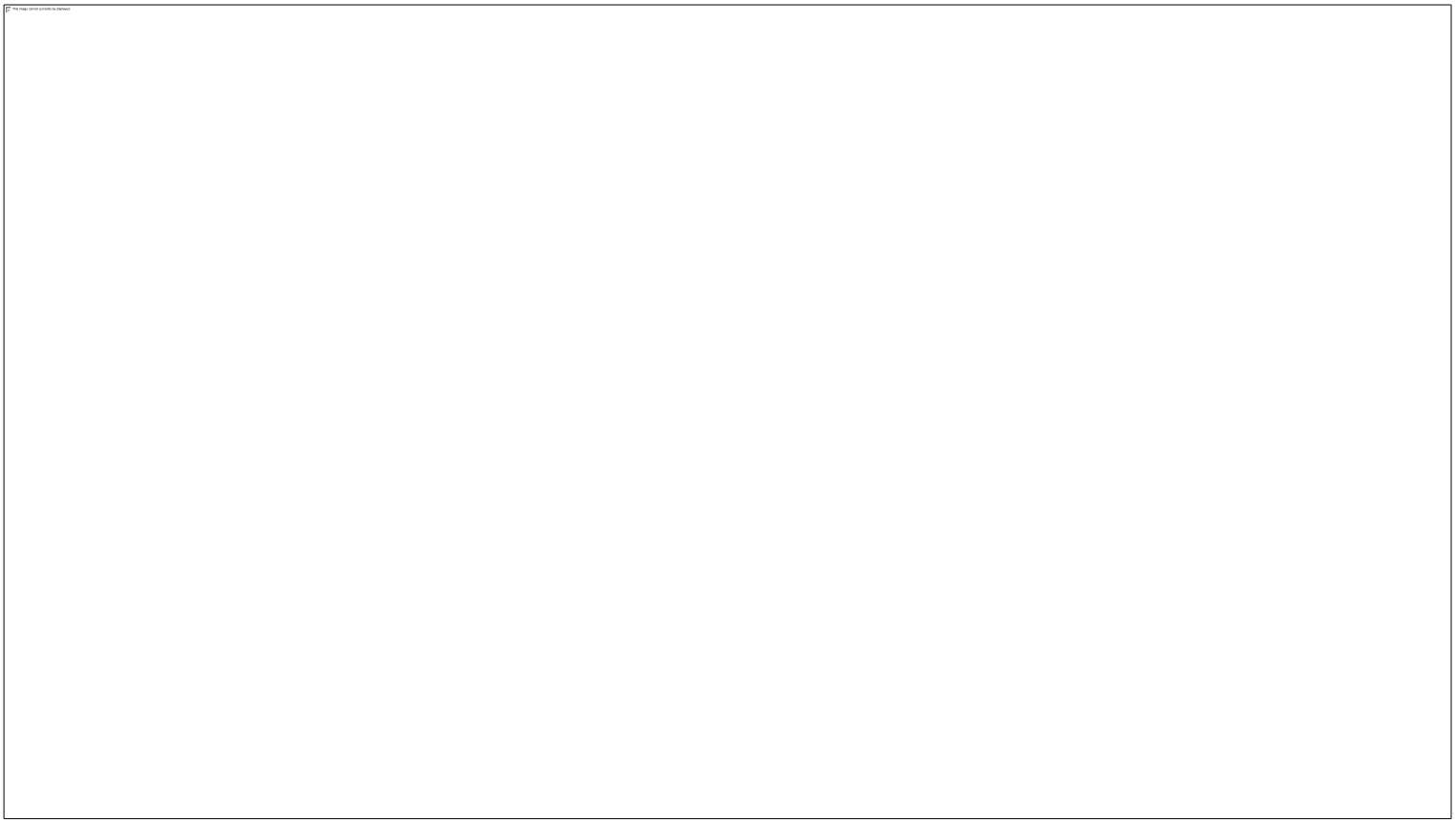
1. Farmers can plan planting dates to encourage flowering at the appropriate season.
2. It helps in selecting suitable crop varieties for particular regions.
3. It assists farmers in planning crop production.

B. Long-day plants

Long-day plants flower when the day length is longer than a particular critical period. They generally flower when nights are sufficiently short.

Examples:

- Spinach.
- Radish.
- Lettuce.
- Some varieties of wheat.



Agricultural importance

1. Farmers can select appropriate planting seasons.
2. It helps in planning the production of crops that flower under longer days.
3. It assists in synchronising flowering and seed production.

C. Day-neutral plants

Day-neutral plants flower without their flowering being strongly controlled by the length of day and night.

Examples include:

- Tomato.
- Cucumber.
- Some varieties of sunflower.



Agricultural importance

1. They can be grown over a wider range of day lengths, provided other conditions are suitable.
2. They may allow greater flexibility in planting schedules.
3. They are useful in crop production where day length varies.

5.3 Role of night length in photoperiodism

In many plants, the length of the uninterrupted dark period is more important than the length of daylight.

For example:

- A short-day plant may flower when it experiences a sufficiently long, uninterrupted night.
- If the long night is interrupted by light, flowering may be prevented.
- A long-day plant may flower when the night is shorter than its critical duration.

5.4 Role of phytochrome in photoperiodism

Phytochrome is a light-sensitive pigment in plants that helps them detect light conditions and regulate growth and flowering.

It exists in two interconvertible forms:

- **Pr:** Absorbs red light.
- **Pfr:** Absorbs far-red light and is generally the physiologically active form in many photoperiodic responses.

The conversion between the two forms helps plants detect changes in light and darkness.

5.5 Applications of photoperiodism in agriculture

Photoperiodism is useful in agriculture in several ways:

1. **Flowering control:** Farmers can manipulate light exposure in controlled environments to encourage or delay flowering.

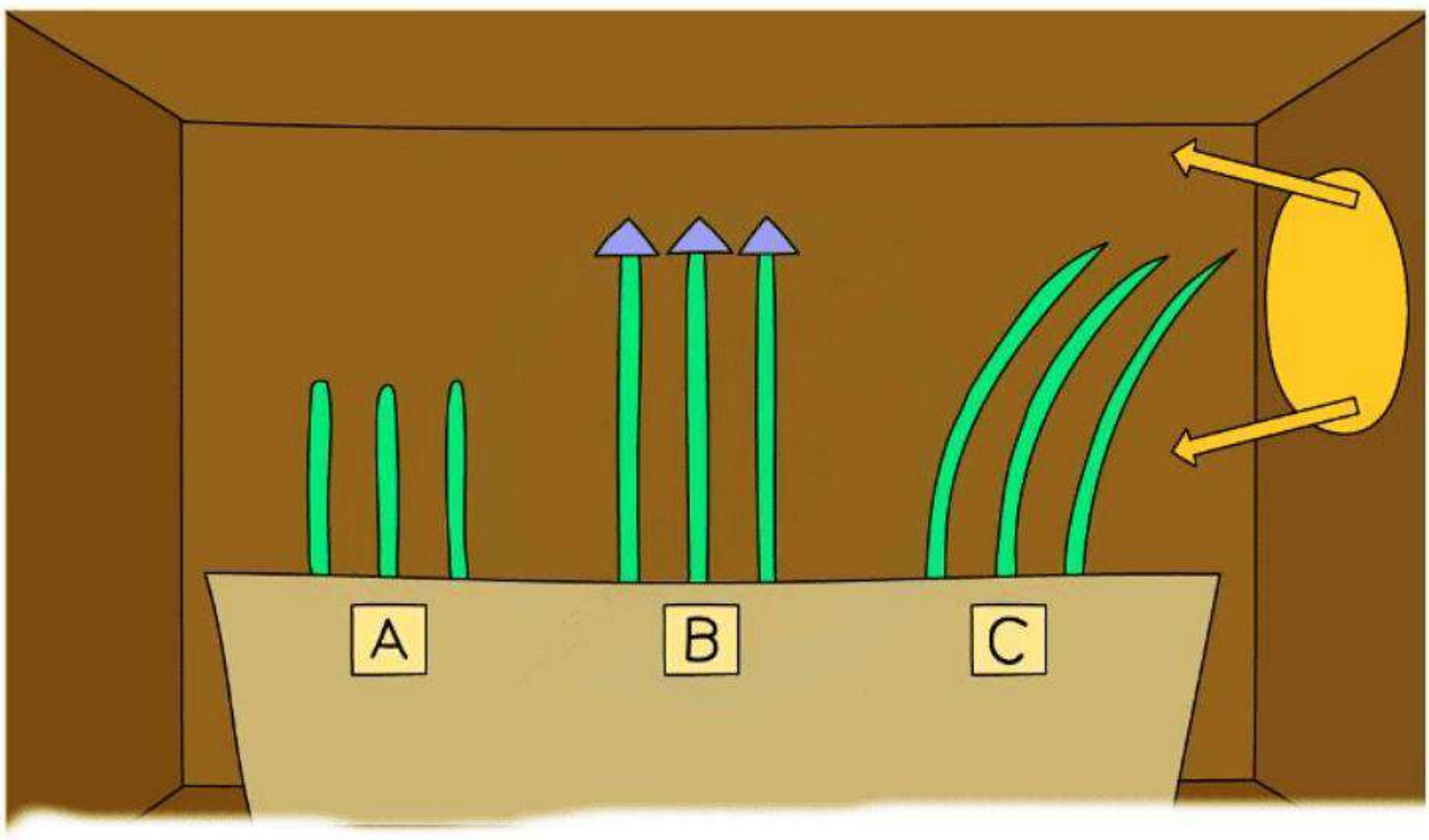
2. **Crop selection:** It helps farmers select crop varieties suited to the local day length.
3. **Seed production:** It helps in planning flowering and seed production.
4. **Greenhouse farming:** Artificial lighting and shading can be used to influence flowering in some crops.
5. **Seasonal planning:** Farmers can plan planting dates to match the flowering requirements of crops.
6. **Ornamental plant production:** Light and darkness can be controlled to produce flowers at desired times.
7. **Crop improvement:** Knowledge of photoperiodism helps plant breeders select varieties adapted to different climatic regions.

Note: Photoperiodism is only one factor affecting flowering. Temperature, water availability, nutrients and the plant's age may also influence flowering.

6.0 INVESTIGATION OF PLANT RESPONSES

Practical investigations help learners observe how plants respond to external stimuli.

6.1 Experiment 1: Investigating phototropism



Investigating the phototropic response set-up

Aim: To investigate the response of a plant shoot to light.

Requirements:

- A young potted seedling.
- A cardboard box.
- A source of light.
- Water.

- A ruler.

Procedure:

1. Place a young potted seedling inside a cardboard box.
2. Make a small opening on one side of the box.
3. Ensure that light enters through the opening only.
4. Water the plant appropriately.
5. Leave the setup for several days.
6. Observe the direction of shoot growth.

Observation:

The shoot bends towards the opening through which light enters.

Conclusion:

The shoot shows positive phototropism because it grows towards light.

Adaptive advantage:

The shoot grows towards light to increase the amount of light received by leaves for photosynthesis.

6.2 Experiment 2: Investigating geotropism



Aim: To investigate the response of roots and shoots to gravity.

Requirements:

- Germinating bean seeds.
- Petri dish or transparent container.
- Moist cotton wool.
- Water.

Procedure:

1. Place moist cotton wool inside a transparent container.
2. Arrange germinating seeds horizontally.

3. Keep the cotton wool moist.
4. Place the container in a suitable environment.
5. Observe the growth direction of the roots and shoots over several days.

Observation:

- Roots bend and grow downwards.
- Shoots bend and grow upwards.

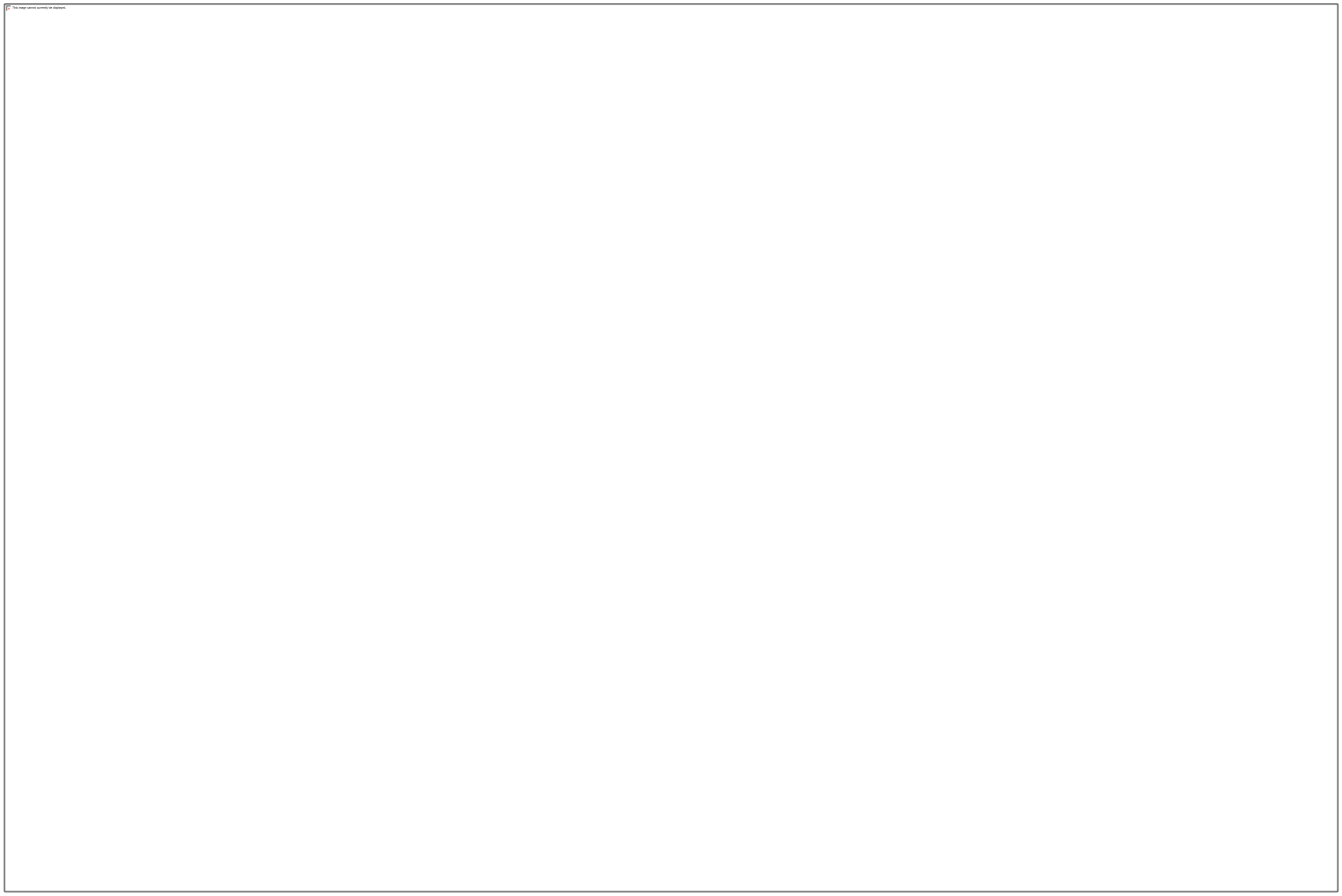
Conclusion:

Roots show positive geotropism while shoots show negative geotropism.

Adaptive advantage:

Roots grow into the soil for anchorage and absorption of water and minerals, while shoots grow upwards towards light.

6.3 Experiment 3: Investigating thigmotropism



Aim: To investigate the response of tendrils to touch.

Requirements:

- A young climbing plant.
- A thin stick or wire.
- Water.

Procedure:

1. Place a thin stick or wire close to the tendrils of a climbing plant.

2. Allow the tendrils to come into contact with the support.
3. Observe the tendrils over several days.

Observation:

The tendrils bend and coil around the support.

Conclusion:

The tendrils show positive thigmotropism.

Adaptive advantage:

The plant obtains support and climbs towards areas with more sunlight.

6.4 Experiment 4: Investigating nastic responses

Aim: To observe touch-induced movement in a sensitive plant.

Requirements:

- A sensitive plant (*Mimosa pudica*).
- A soft object such as a cotton bud.

Procedure:

1. Observe the leaves of the sensitive plant.
2. Gently touch one of the leaflets.
3. Observe the changes in the leaflets and leaf stalk.
4. Allow the plant to recover.
5. Repeat the experiment.



Observation:

The leaflets fold and the leaf stalk may droop after being touched.

Conclusion:

The plant exhibits a touch-induced nastic response, commonly called thigmonasty or seismonasty.

Adaptive advantage:

The movement may discourage herbivores and reduce exposure of the leaves to potential damage.

7.0 SURVIVAL VALUE OF PLANT RESPONSES

Plant responses are adaptations that enable plants to survive under changing environmental conditions.

Plant response	Survival value
Phototropism	Enables shoots to grow towards light for photosynthesis.
Geotropism	Enables roots to grow into the soil for anchorage and absorption.
Thigmotropism	Enables climbing plants to attach themselves to supports.
Photonasty	Enables flowers to open and close according to light conditions.
Thermonasty	Enables flowers to respond to temperature changes.
Chemonasty	Helps some insectivorous plants respond to chemical substances associated with prey.
Haptonasty	Enables certain plant structures to respond to physical contact.
Photoperiodism	Enables plants to time flowering and other seasonal activities appropriately.

General importance of plant responses

1. They enable plants to obtain essential resources such as light, water and mineral salts.
2. They promote successful photosynthesis.
3. They help plants withstand unfavourable environmental conditions.
4. They improve anchorage and support.
5. They assist in capturing prey in insectivorous plants.
6. They promote successful flowering and reproduction.
7. They improve adaptation to seasonal changes.
8. They increase the chances of survival of plants in different habitats.

8.0 APPLICATION OF MODERN TECHNOLOGY IN THE STUDY OF PLANT RESPONSES

Modern technology has improved the way scientists and farmers study plant responses.

Examples include:

1. **Greenhouse technology:** Allows farmers to control light, temperature and other environmental conditions.
2. **Artificial lighting:** Enables farmers to manipulate day and night conditions in controlled environments.
3. **Growth chambers:** Allow scientists to investigate how plants respond to different light and temperature conditions.
4. **Digital sensors:** Measure light intensity, soil moisture and temperature to help farmers manage plant growth.
5. **Time-lapse photography:** Records slow plant movements, such as shoots bending towards light.
6. **Microscopy:** Helps scientists observe plant cells and tissues involved in growth responses.
7. **Plant tissue culture:** Uses controlled conditions and plant hormones, including auxins, to promote root and shoot development.
8. **Precision agriculture:** Uses digital tools to monitor environmental conditions and improve crop production.

REVISION EXERCISES

SECTION A: MULTIPLE-CHOICE QUESTIONS (30 MARKS)

Choose the correct answer from the alternatives provided.

Question 1. Which of the following best describes a response in plants?

A. The process of manufacturing food only.

B. The reaction of a plant to a stimulus.

C. The absorption of water from the soil.

D. The movement of substances through the plant.

Question 2. A nastic response is different from a tropic response because a nastic response:

A. Always involves growth towards light.

B. Depends on the direction of the stimulus.

C. Does not depend on the direction of the stimulus.

D. Occurs only in roots.

Question 3. The opening and closing of flowers in response to changes in light intensity is called:

A. Geotropism.

B. Photonasty.

C. Thigmotropism.

D. Phototropism.

Question 4. The movement of flowers in response to changes in temperature is known as:

A. Thermonasty.

B. Chemonasty.

C. Geotropism.

D. Phototropism.

Question 5. Which type of nastic response involves chemical stimuli?

A. Photonasty.

B. Thermonasty.

C. Chemonasty.

D. Haptonasty.

Question 6. The folding of leaves in a sensitive plant following touch is an example of:

A. Positive geotropism.

B. Thigmonasty.

C. Phototropism.

D. Thermotropism.

Question 7. A directional growth response of a plant to an external stimulus is called:

A. Nastic movement.

B. Transpiration.

C. Tropism.

D. Germination.

Question 8. The growth of a shoot towards light is known as:

A. Negative phototropism.

B. Positive phototropism.

C. Positive geotropism.

D. Negative geotropism.

Question 9. Roots growing towards gravity demonstrate:

A. Positive geotropism.

B. Negative geotropism.

C. Positive phototropism.

D. Negative phototropism.

Question 10. The growth of tendrils around a supporting structure is an example of:

A. Phototropism.

B. Geotropism.

C. Thigmotropism.

D. Thermonasty.

Question 11. The plant hormone mainly responsible for cell elongation in young shoots is:

A. Insulin.

B. Auxin.

C. Adrenaline.

D. Thyroxine.

Question 12. The most common naturally occurring auxin is:

A. IAA.

B. FSH.

C. ADH.

D. ATP.

Question 13. Auxins are mainly produced in:

A. Mature roots only.

B. Dead plant tissues.

C. Young growing regions of plants.

D. Dry leaves only.

Question 14. When light shines on a shoot from one direction, auxin accumulates mainly on the:

A. Illuminated side.

B. Shaded side.

C. Root cap only.

D. Upper surface of the leaves.

Question 15. A shoot bends towards light because:

A. Cells on the illuminated side elongate faster.

B. Cells on the shaded side elongate faster.

C. All cells stop growing.

D. Auxin destroys cells on the illuminated side.

Question 16. In a horizontally placed young shoot, auxin accumulates more on the:

A. Upper side.

B. Lower side.

C. Tip only.

D. Illuminated side only.

Question 17. In a horizontally placed root, high auxin concentration on the lower side causes:

A. Faster cell elongation.

B. Inhibition of cell elongation.

C. Immediate flowering.

D. Increased photosynthesis.

Question 18. The growth of shoots away from gravity is called:

A. Positive geotropism.

B. Negative geotropism.

C. Positive thigmotropism.

D. Negative phototropism.

Question 19. Which plant hormone promotes the formation of adventitious roots in suitable concentrations?

A. Auxin.

B. Insulin.

C. Oestrogen.

D. Testosterone.

Question 20. The suppression of lateral bud growth by the main shoot is known as:

A. Photoperiodism.

B. Apical dominance.

C. Transpiration.

D. Germination.

Question 21. Photoperiodism refers to the response of plants to:

A. Soil acidity.

B. Day and night length.

C. Wind direction.

D. Soil texture.

Question 22. A plant that flowers when the day length is shorter than a critical period is classified as a:

A. Long-day plant.

B. Short-day plant.

C. Day-neutral plant.

D. Desert plant.

Question 23. Which of the following is an example of a short-day plant?

A. Chrysanthemum.

B. Spinach.

C. Radish.

D. Lettuce.

Question 24. Which of the following is commonly classified as a long-day plant?

A. Poinsettia.

B. Chrysanthemum.

C. Spinach.

D. Some varieties of soybean.

Question 25. Which of the following is an example of a day-neutral plant?

A. Tomato.

B. Chrysanthemum.

C. Spinach.

D. Radish.

Question 26. The light-sensitive pigment involved in photoperiodism is:

A. Chlorophyll.

B. Haemoglobin.

C. Phytochrome.

D. Melanin.

Question 27. Which of the following is an agricultural application of photoperiodism?

A. Preventing all plant growth.

B. Planning planting seasons to influence flowering.

C. Stopping photosynthesis permanently.

D. Preventing roots from absorbing water.

Question 28. A plant shoot bends towards a light source in an experiment. This demonstrates:

A. Positive phototropism.

B. Negative phototropism.

C. Positive geotropism.

D. Negative geotropism.

Question 29. Which of the following instruments or techniques can be used to record slow plant movements?

A. Time-lapse photography.

B. Stethoscope.

C. Thermometer only.

D. Barometer only.

Question 30. Which statement best explains the survival value of geotropism?

A. It enables flowers to open at night.

B. It enables roots to grow into the soil for anchorage and absorption.

C. It enables leaves to fold when touched.

D. It enables plants to detect sound.

SECTION B: STRUCTURED QUESTIONS (50 MARKS)

Question 31. Nastic responses (8 marks)

a) Define a nastic response. (2 marks)

b) Name four types of nastic responses in plants. (4 marks)

c) State two survival advantages of nastic responses in plants. (2 marks)

Question 32. Tropic responses (8 marks)

a) Define tropism. (2 marks)

b) Distinguish between positive and negative tropism. (2 marks)

c) Explain how a climbing plant uses thigmotropism to obtain support. (4 marks)

Question 33. Auxins and phototropism (10 marks)

a) What are auxins? (2 marks)

b) State two sites where auxins are produced in plants. (2 marks)

c) Explain how auxins cause a young shoot to bend towards light. (4 marks)

d) State two other roles of auxins in plants. (2 marks)

Question 34. Geotropism (8 marks)

a) Define geotropism. (2 marks)

b) Distinguish between positive and negative geotropism, giving one example of each. (2 marks)

c) Explain how auxins influence the bending of a horizontally placed root. (4 marks)

Question 35. Photoperiodism (8 marks)

a) Define photoperiodism. (2 marks)

b) Name three groups of plants based on their flowering responses to day length. (3 marks)

c) State three ways in which knowledge of photoperiodism is useful in agriculture. (3 marks)

Question 36. Plant responses and survival (8 marks)

a) State four ways in which tropic responses help plants survive. (4 marks)

b) Describe two experiments that can be carried out to demonstrate plant responses to external stimuli. (4 marks)

ANSWERS AND MARKING SCHEME

SECTION A: MULTIPLE-CHOICE ANSWERS

Question	Answer	Correct response
1	B	Reaction of a plant to a stimulus
2	C	Does not depend on direction of stimulus
3	B	Photonasty
4	A	Thermonasty
5	C	Chemonasty
6	B	Thigmonasty
7	C	Tropism
8	B	Positive phototropism
9	A	Positive geotropism
10	C	Thigmotropism
11	B	Auxin
12	A	IAA
13	C	Young growing regions
14	B	Shaded side
15	B	Cells on the shaded side elongate faster
16	B	Lower side
17	B	Inhibition of cell elongation
18	B	Negative geotropism
19	A	Auxin
20	B	Apical dominance
21	B	Day and night length
22	B	Short-day plant
23	A	Chrysanthemum
24	C	Spinach
25	A	Tomato
26	C	Phytochrome
27	B	Planning planting seasons
28	A	Positive phototropism
29	A	Time-lapse photography
30	B	Root growth for anchorage and absorption

SECTION B: SUGGESTED ANSWERS AND MARKING SCHEME

Question 31. Nastic responses (8 marks)

a) A nastic response is a movement of a plant or plant part in response to a stimulus, where the direction of movement does not depend on the direction of the stimulus. (2 marks)

b) Types of nastic responses:

1. Photonasty. (1)
2. Thermonasty. (1)
3. Chemonasty. (1)
4. Haptonasty. (1)

c) Survival advantages:

1. They help plants respond to unfavourable environmental conditions. (1)
2. They help protect plant structures or assist insectivorous plants in capturing prey. (1)

Question 32. Tropic responses (8 marks)

a) Tropism is the directional growth movement of a plant part in response to an external stimulus. (2 marks)

b)

- Positive tropism: Growth towards the stimulus. (1)
- Negative tropism: Growth away from the stimulus. (1)

c) Explanation of thigmotropism:

1. A tendril comes into contact with a supporting structure. (1)
2. Contact stimulates unequal growth on opposite sides of the tendril. (1)
3. The side away from contact elongates faster. (1)
4. The tendril bends and coils around the support. (1)

Question 33. Auxins and phototropism (10 marks)

a) Auxins are plant hormones that regulate growth and development, especially cell elongation. (2 marks)

b) Sites of auxin production:

- Shoot tips. (1)
- Young developing leaves. (1)

Accept developing seeds or young fruits.

c) Explanation of phototropism:

1. Auxin is produced mainly in the shoot tip. (1)
2. When light shines from one direction, auxin accumulates more on the shaded side. (1)
3. Cells on the shaded side elongate faster than those on the illuminated side. (1)
4. The shoot bends towards the light. (1)

d) Other roles of auxins:

1. Promote root formation. (1)
2. Maintain apical dominance. (1)

Accept promotion of fruit development or prevention of premature leaf fall.

Question 34. Geotropism (8 marks)

a) Geotropism is the directional growth of a plant part in response to gravity. (2 marks)

b)

- Positive geotropism: Growth towards gravity, e.g. roots growing downwards. (1)
- Negative geotropism: Growth away from gravity, e.g. shoots growing upwards. (1)

c) Explanation:

1. Gravity causes auxin to accumulate on the lower side of the root. (1)
2. A high concentration of auxin inhibits cell elongation on the lower side. (1)
3. Cells on the upper side elongate faster. (1)
4. The root bends downwards towards gravity. (1)

Question 35. Photoperiodism (8 marks)

a) Photoperiodism is the response of plants to the relative lengths of day and night, especially in relation to flowering. (2 marks)

b) Groups of plants:

1. Short-day plants. (1)
2. Long-day plants. (1)
3. Day-neutral plants. (1)

c) Agricultural applications:

1. Helps farmers select suitable crop varieties for different regions. (1)
2. Helps farmers plan planting seasons to encourage flowering. (1)
3. Allows manipulation of light conditions in greenhouses to influence flowering. (1)

Accept planning seed production or scheduling ornamental flower production.

Question 36. Plant responses and survival (8 marks)

a) Ways tropic responses help plants survive:

1. Phototropism enables shoots to grow towards light for photosynthesis. (1)
2. Geotropism enables roots to grow into the soil for anchorage. (1)
3. Geotropism enables roots to absorb water and mineral salts. (1)
4. Thigmotropism enables climbing plants to obtain support and reach sunlight. (1)

b) Experiments:

Award 2 marks for each correctly described experiment: one mark for the procedure and one mark for the expected observation or conclusion.

Experiment 1: Phototropism

- Place a young potted seedling inside a box with a small opening on one side and observe it for several days. (1)
- The shoot bends towards the opening, demonstrating positive phototropism. (1)

Experiment 2: Geotropism

- Place germinating seeds horizontally in a transparent container containing moist cotton wool. (1)
- Roots grow downwards while shoots grow upwards. (1)

Accept a correctly described investigation of thigmotropism or nastic responses.

PROJECT / PRACTICAL ACTIVITY

Project title: Investigating plant responses to environmental stimuli

Instructions to learners:

In groups, identify three plants within the school or home environment that demonstrate different responses to external stimuli.

For each plant:

1. Identify the plant.
2. Identify the stimulus involved.
3. Name the type of response.
4. Describe the observed movement or growth.
5. Explain the survival value of the response.
6. Present your findings using photographs, drawings or charts.

Suggested assessment rubric

Assessment area	**Marks**
Correct identification of plants	4
Identification of stimuli	4
Correct explanation of plant responses	6
Explanation of survival advantages	4
Presentation and teamwork	2
Total	20

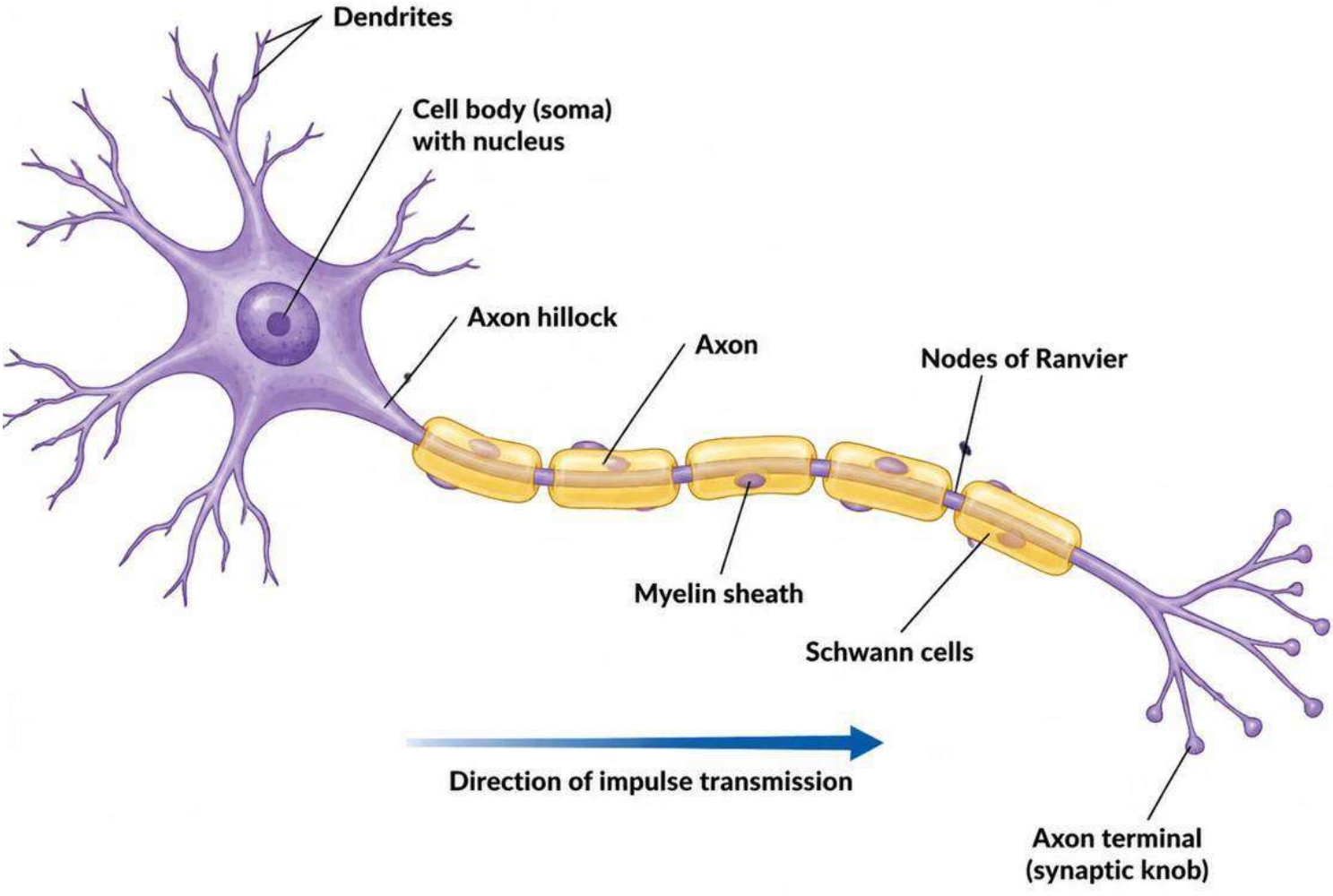
13.0 KEY TAKEAWAYS

By the end of this sub-strand, the learner should be able to:

- Explain the meaning and types of nastic responses.
- Differentiate between nastic and tropic responses.
- Describe phototropism, geotropism and thigmotropism.
- Explain the production and roles of auxins.
- Describe how auxins influence the bending of roots and shoots.
- Explain photoperiodism and its types.
- State the agricultural applications of photoperiodism.
- Explain how plant responses contribute to survival.

STRAND 1.0: LIFE SCIENCE

SUB-STRAND 1.5: HUMAN NERVOUS SYSTEM



1.0 INTRODUCTION TO THE HUMAN NERVOUS SYSTEM

The human body performs many activities every day. These include walking, talking, writing, reading, breathing, eating, responding to danger and maintaining body balance.

For these activities to occur properly, different organs and body systems must work together. The nervous system coordinates and controls many of these activities.

The nervous system enables the body to detect changes in the internal and external environment, process information and produce appropriate responses.

For example:

- When a person touches a hot cooking pot, the hand is quickly withdrawn.
- When a person hears a loud sound, they may turn towards the source.
- When a person sees a ball approaching, they may move out of its path.
- When a person steps on a sharp object, the foot is quickly withdrawn.
- When a learner reads a question, the brain interprets the information and coordinates the response.

1.1 Meaning of the nervous system

The **nervous system** is the body system made up of the brain, spinal cord and nerves that receives information, processes it and coordinates responses to stimuli.

It controls and coordinates activities in the body through electrical signals called **nerve impulses** and chemical communication between nerve cells.

1.2 Meaning of a stimulus

A **stimulus** is any change in the internal or external environment that can be detected by an organism and cause a response.

Examples of stimuli include:

1. Light – detected by the eyes.
2. Sound – detected by the ears.
3. Heat – detected by temperature receptors in the skin.
4. Pressure – detected by pressure receptors in the skin.
5. Pain – detected by pain receptors.
6. Chemicals – detected by receptors in the nose and tongue.
7. Changes in blood composition – detected by specialised receptors in the body.

1.3 Meaning of a response

A **response** is the reaction of an organism to a stimulus.

Examples:

- Withdrawing the hand after touching a hot object.
- Blinking when an object approaches the eye.
- Salivating when food is placed in the mouth.
- Turning the head towards a sound.
- Moving the leg when the knee is tapped.

1.4 Functions of the human nervous system

The nervous system performs several important functions:

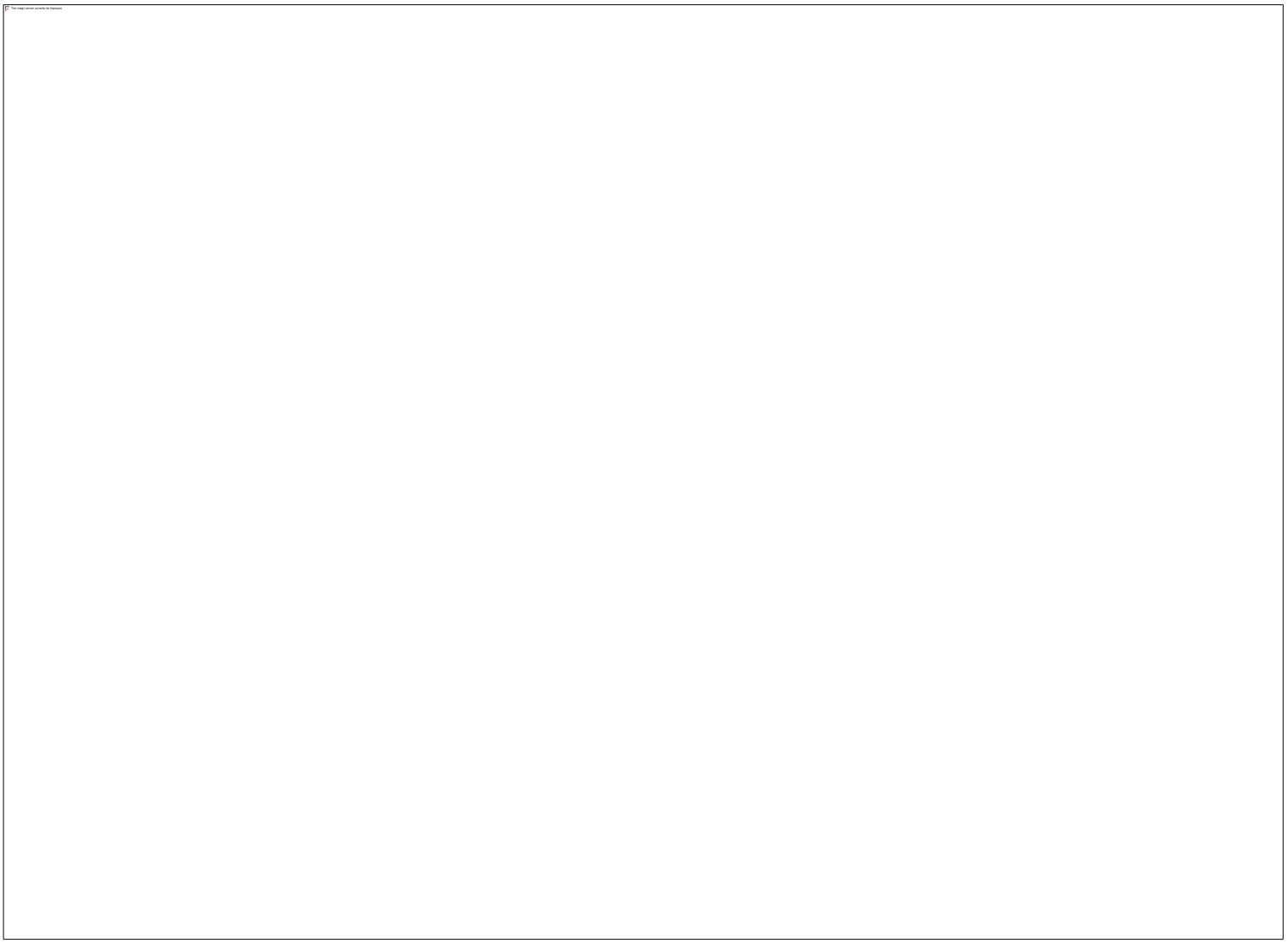
1. **Detecting stimuli:** It detects changes in the environment through specialised sensory receptors.
2. **Receiving information:** It receives information from different parts of the body.
3. **Processing information:** It interprets information and determines the appropriate response.

4. **Coordinating movement:** It controls voluntary and involuntary muscle activities.
5. **Maintaining body balance:** It coordinates posture, movement and balance.
6. **Controlling body activities:** It regulates activities such as breathing, heartbeat and digestion.
7. **Memory and learning:** It enables human beings to remember information and acquire new skills.
8. **Emotions and behaviour:** It contributes to feelings, emotions and behavioural responses.
9. **Protection:** It enables rapid responses to potentially harmful stimuli.
10. **Maintaining homeostasis:** It helps regulate internal conditions such as body temperature and other body functions.

2.0 COMPONENTS OF THE HUMAN NERVOUS SYSTEM

The human nervous system is divided into two major components:

1. Central Nervous System (CNS).
2. Peripheral Nervous System (PNS).



2.1 Central Nervous System (CNS)

The **Central Nervous System (CNS)** consists of the brain and spinal cord.

It is the main processing and coordination centre of the human body.

The CNS receives information from sensory receptors, interprets the information and coordinates appropriate responses.

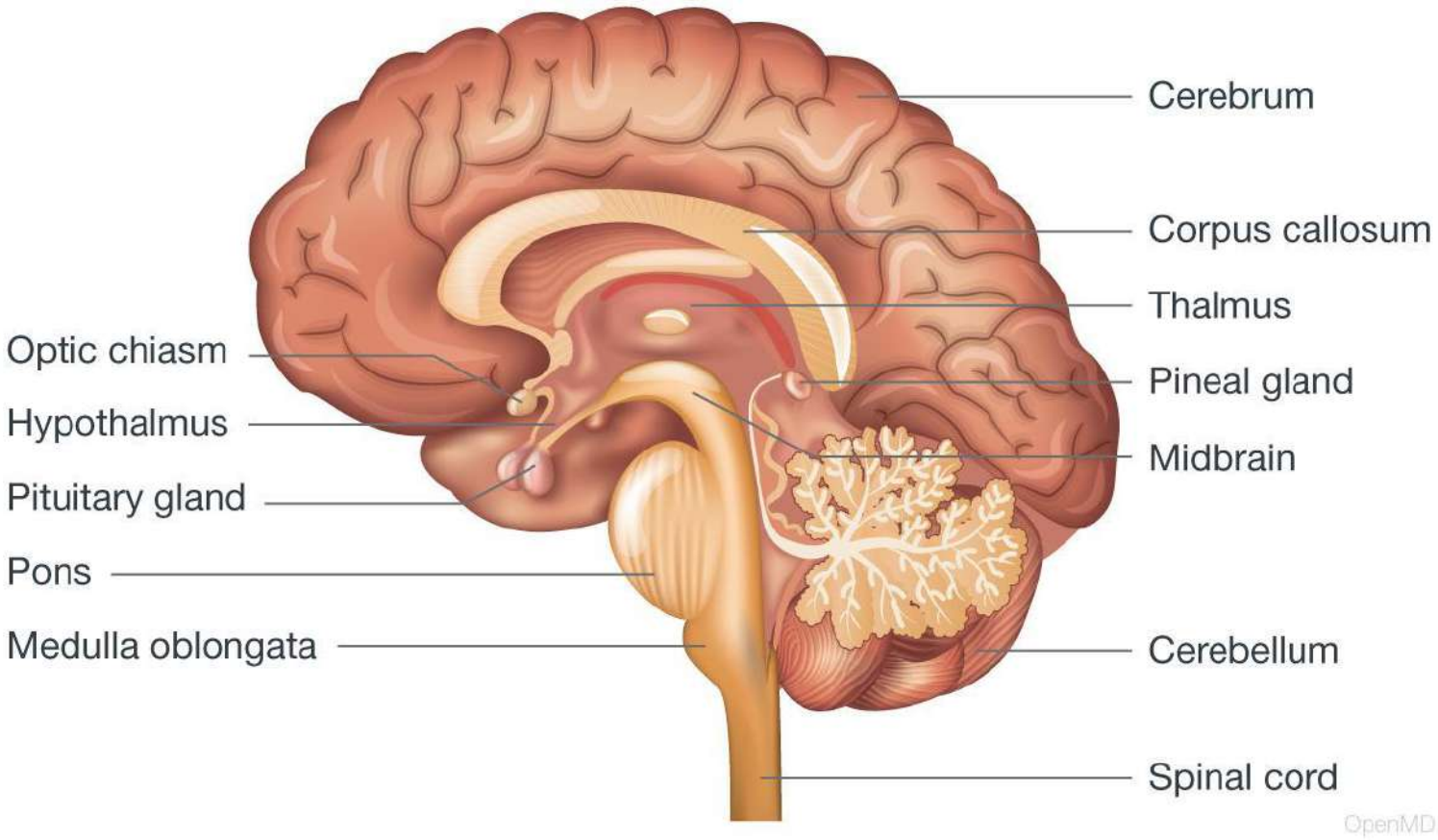
The two major components of the CNS are:

- Brain.
- Spinal cord.

A. The brain

The **brain** is the main control and coordination organ of the nervous system. It is located inside the skull, which protects it from mechanical injury.

The brain is made up of billions of specialised nerve cells called neurons and supporting cells called neuroglia.



Major parts of the brain and their functions

1. Cerebrum

The cerebrum is the largest part of the human brain. It is divided into two cerebral hemispheres: the right and left hemispheres.

Functions of the cerebrum:

1. Controls voluntary movements such as walking, writing and speaking.
2. Receives and interprets sensory information from the sense organs.
3. Responsible for thinking, reasoning and decision-making.
4. Enables memory and learning.
5. Controls speech and language.
6. Responsible for conscious awareness.
7. Plays an important role in emotions and behaviour.

Examples:

- When a learner solves a mathematical problem, the cerebrum is involved.
- When a person recognises a familiar face, the cerebrum processes the information.
- When a person deliberately raises a hand, the cerebrum initiates the voluntary movement.

2. Cerebellum

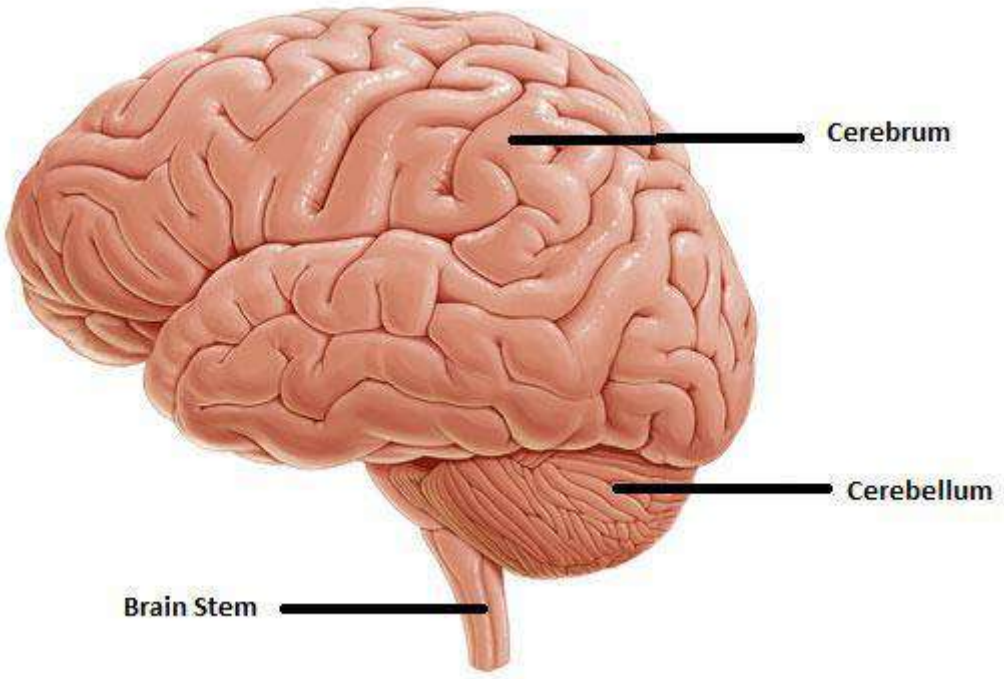
The cerebellum is located at the back of the brain, below the cerebrum.

Functions of the cerebellum:

1. Coordinates voluntary muscular movements.
2. Maintains body balance and posture.
3. Ensures smooth and accurate movements.
4. Helps coordinate movements involving several muscles.
5. Contributes to the learning and refinement of motor skills.

Examples:

- Helps a person maintain balance when walking.
- Coordinates movements when riding a bicycle.
- Helps a football player control movements when kicking a ball.
- Enables a learner to write neatly and accurately.



3. Medulla oblongata

The medulla oblongata is located at the lower part of the brain, where the brain connects to the spinal cord.

Functions of the medulla oblongata:

1. Controls the rate and depth of breathing.
2. Regulates heart rate.
3. Helps regulate blood pressure.
4. Coordinates swallowing.

5. Controls vomiting.
6. Coordinates coughing and sneezing reflexes.

Importance: The medulla oblongata controls several vital involuntary activities that keep a person alive.

4. Hypothalamus

The hypothalamus is a small region located below the thalamus.

Functions of the hypothalamus:

1. Regulates body temperature.
2. Controls hunger and thirst.
3. Helps regulate sleep and wakefulness.
4. Maintains water balance.
5. Regulates certain activities of the endocrine system through its relationship with the pituitary gland.
6. Contributes to emotional and behavioural responses.

5. Pons

The pons is a part of the brainstem located above the medulla oblongata.

Functions:

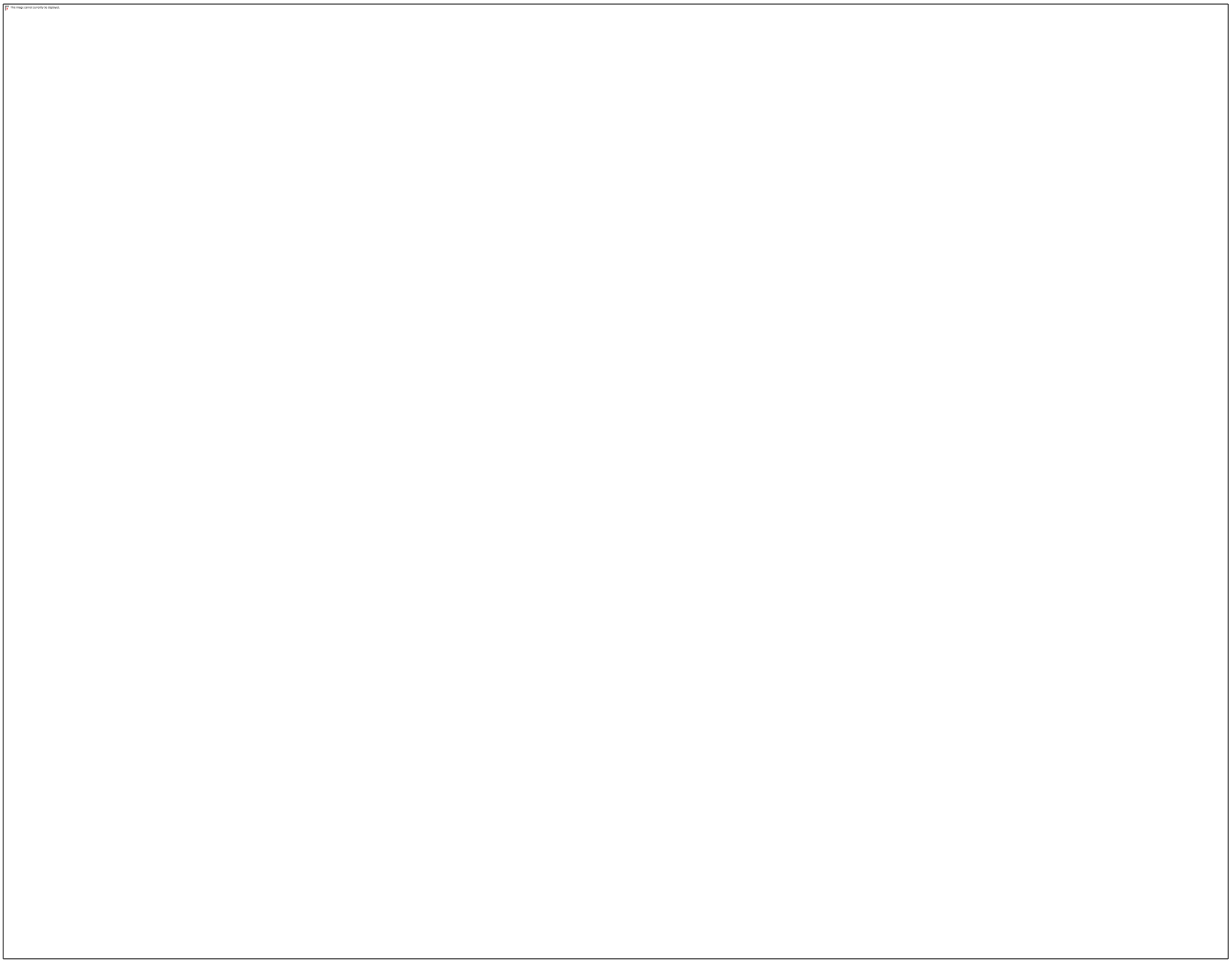
1. Relays information between different parts of the brain.
2. Connects the cerebrum, cerebellum and medulla.
3. Contributes to the regulation of breathing.
4. Participates in sleep and arousal processes.

B. The spinal cord

The **spinal cord** is a long, cylindrical structure of nervous tissue that extends from the brainstem through the vertebral canal of the backbone.

It is protected by:

- The vertebral column.
- Three protective membranes called meninges.
- Cerebrospinal fluid (CSF).



Functions of the spinal cord

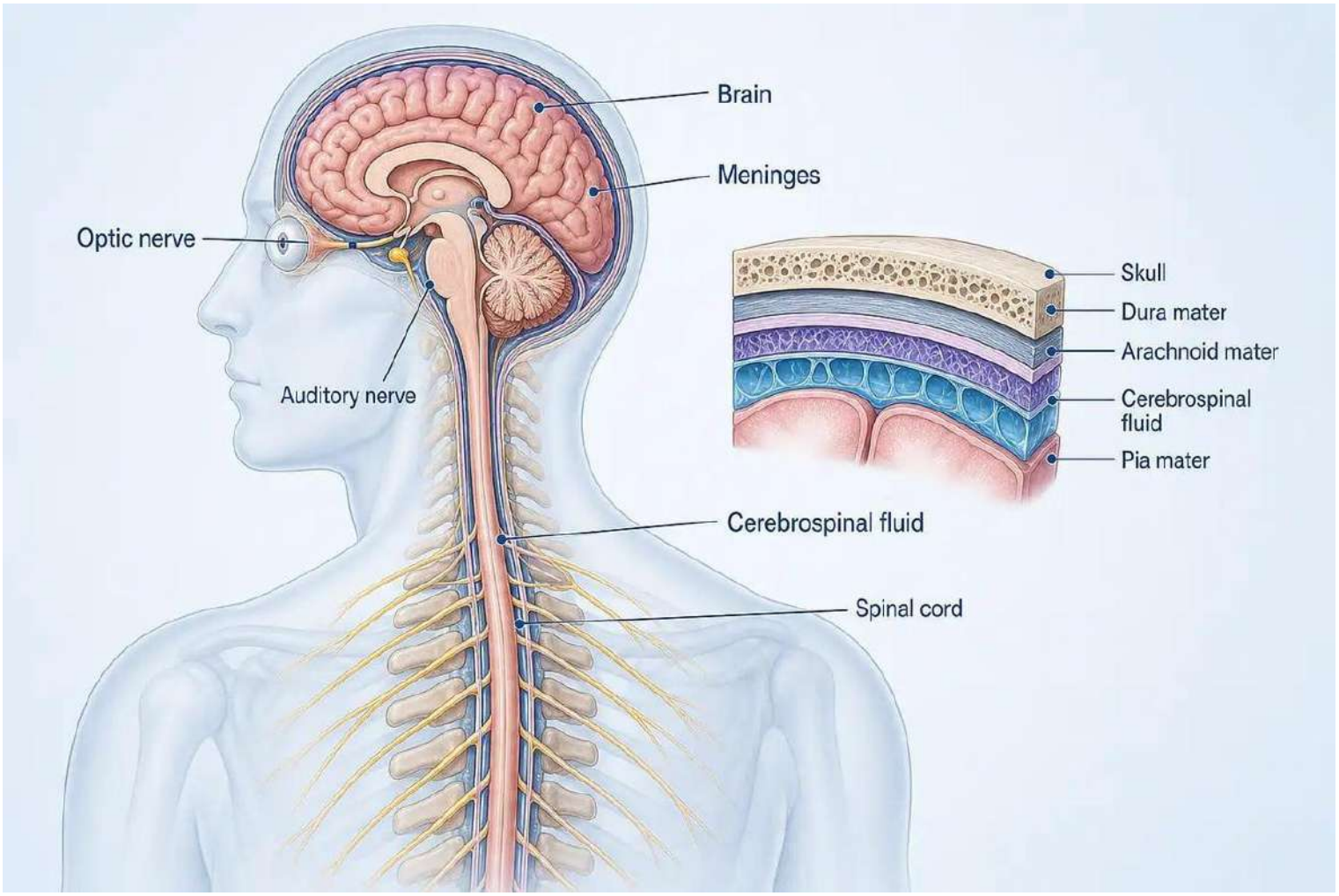
1. **Transmission of impulses:** Carries sensory impulses from the body to the brain.
2. **Transmission of motor impulses:** Carries motor impulses from the brain to muscles and glands.
3. **Reflex centre:** Coordinates many simple reflex actions without requiring the brain to initiate the immediate response.
4. **Communication:** Provides a pathway for communication between the brain and the rest of the body.
5. **Coordination:** Participates in the coordination of certain automatic body responses.

Example: When a person touches a hot object, the spinal cord coordinates the rapid withdrawal of the hand before the person becomes fully aware of the pain.

Protection of the central nervous system

The brain and spinal cord are delicate structures and require protection.

Protective structure	Function
Skull	Protects the brain against mechanical injury.
Vertebral column	Protects the spinal cord.
Meninges	Cover and protect the brain and spinal cord.
Cerebrospinal fluid	Cushions the CNS and helps absorb mechanical shocks.



2.2 Peripheral Nervous System (PNS)

The **Peripheral Nervous System (PNS)** consists of all the nerves and ganglia outside the brain and spinal cord.

It connects the central nervous system to the different parts of the body.

The PNS carries information from sensory receptors to the CNS and carries instructions from the CNS to muscles and glands.

Functions of the peripheral nervous system

1. Carries sensory information from receptors to the CNS.
2. Transmits motor instructions from the CNS to muscles.
3. Connects the brain and spinal cord to the limbs and internal organs.
4. Enables the body to respond to changes in the environment.
5. Coordinates voluntary and involuntary activities.

Main components of the peripheral nervous system

The PNS includes:

A. Cranial nerves

These are nerves that arise directly from the brain or brainstem.

- There are 12 pairs of cranial nerves.
- They mainly supply the head and neck, although the vagus nerve also supplies several organs in the chest and abdomen.

- They carry sensory information, motor instructions or both.

Examples:

1. Optic nerve – carries visual information from the eye to the brain.
2. Olfactory nerve – carries information involved in the sense of smell.
3. Auditory component of the vestibulocochlear nerve – carries information involved in hearing.
4. Facial nerve – controls several facial movements and carries some taste information.

B. Spinal nerves

These are nerves that arise from the spinal cord.

- Humans have 31 pairs of spinal nerves.
- They connect the spinal cord to different body regions.
- Most are mixed nerves, containing both sensory and motor fibres.

Functional divisions of the peripheral nervous system

The peripheral nervous system is functionally divided into:

1. Somatic nervous system.
2. Autonomic nervous system.

A. Somatic nervous system

The **somatic nervous system** is the division of the PNS involved in conscious sensation and the control of skeletal muscles.

Functions:

1. Carries sensory information from the skin, muscles and joints to the CNS.
2. Controls voluntary movements of skeletal muscles.
3. Participates in somatic reflex actions.

Examples:

- Walking.
- Writing.
- Picking up a book.
- Kicking a football.
- Raising a hand in class.

B. Autonomic nervous system

The **autonomic nervous system** controls many involuntary activities of internal organs, glands, smooth muscles and cardiac muscle.

Examples:

- Regulation of heart rate.
- Regulation of digestion.
- Control of pupil size.
- Regulation of sweating.

- Control of certain blood vessel activities.

The autonomic nervous system has two main divisions:

1. Sympathetic nervous system

This prepares the body for situations requiring increased alertness or activity. It is commonly associated with the "fight or flight" response.

Effects include:

- Increases heart rate.
- Dilates the pupils.
- Dilates the airways.
- Reduces digestive activity temporarily.
- Stimulates the release of glucose into the blood.

Example: When a person encounters a dangerous animal, the sympathetic nervous system helps prepare the body to respond quickly.

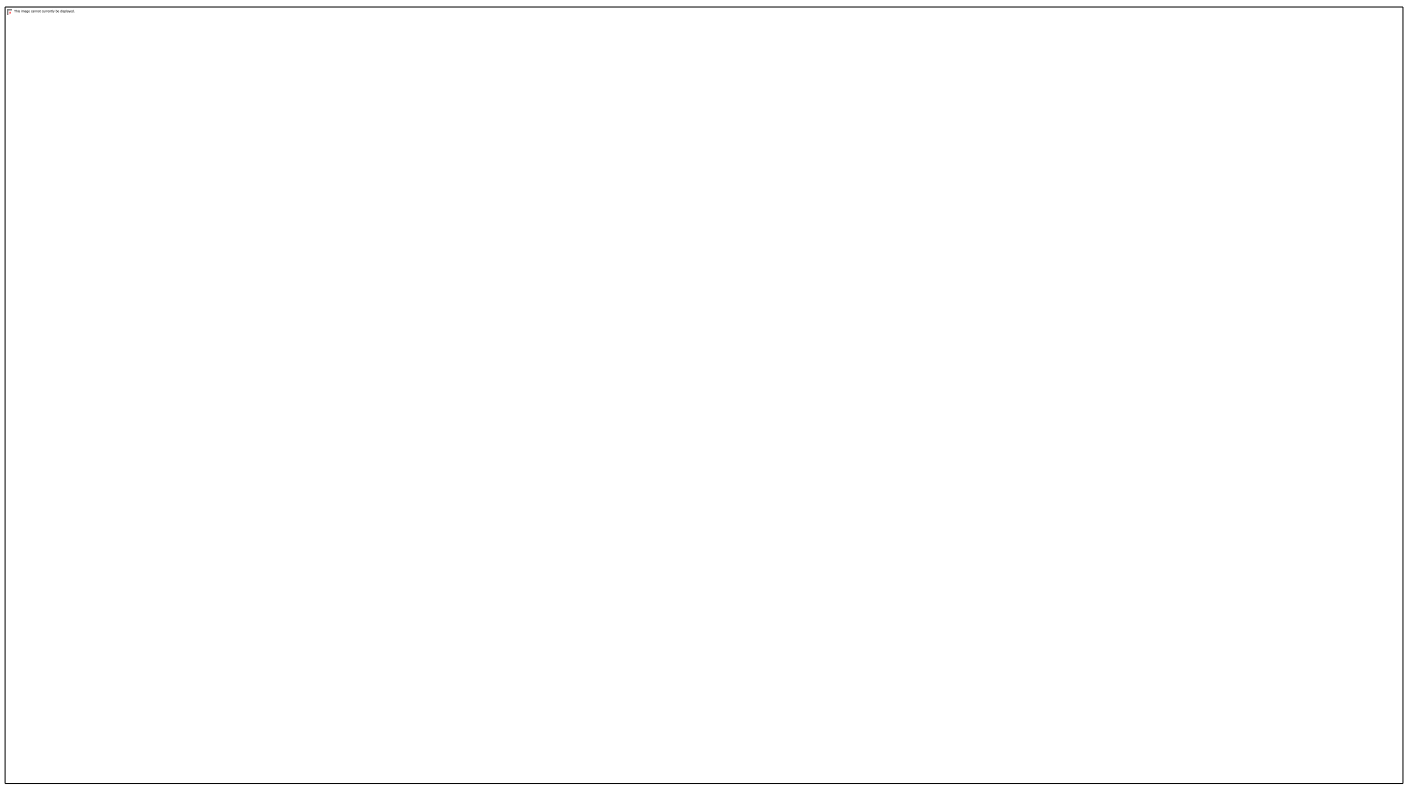
2. Parasympathetic nervous system

This supports activities associated with rest, digestion and energy conservation. It is commonly described as the "rest and digest" division.

Effects include:

- Slows the heart rate in appropriate conditions.
- Stimulates digestive activity.
- Promotes intestinal movement.
- Contributes to energy conservation.
- Supports normal functioning of internal organs.

Example: After eating lunch, parasympathetic activity helps promote digestion.



Differences between the central and peripheral nervous systems

Central Nervous System	Peripheral Nervous System
Consists of the brain and spinal cord.	Consists of nerves and ganglia outside the CNS.
Processes and coordinates information.	Connects the CNS to the rest of the body.
Protected by the skull and vertebral column.	Nerves extend through different parts of the body.
Coordinates responses.	Carries sensory and motor impulses.
Acts as the main control centre.	Acts as the communication network.

3.0 STRUCTURE AND FUNCTIONS OF NEURONS

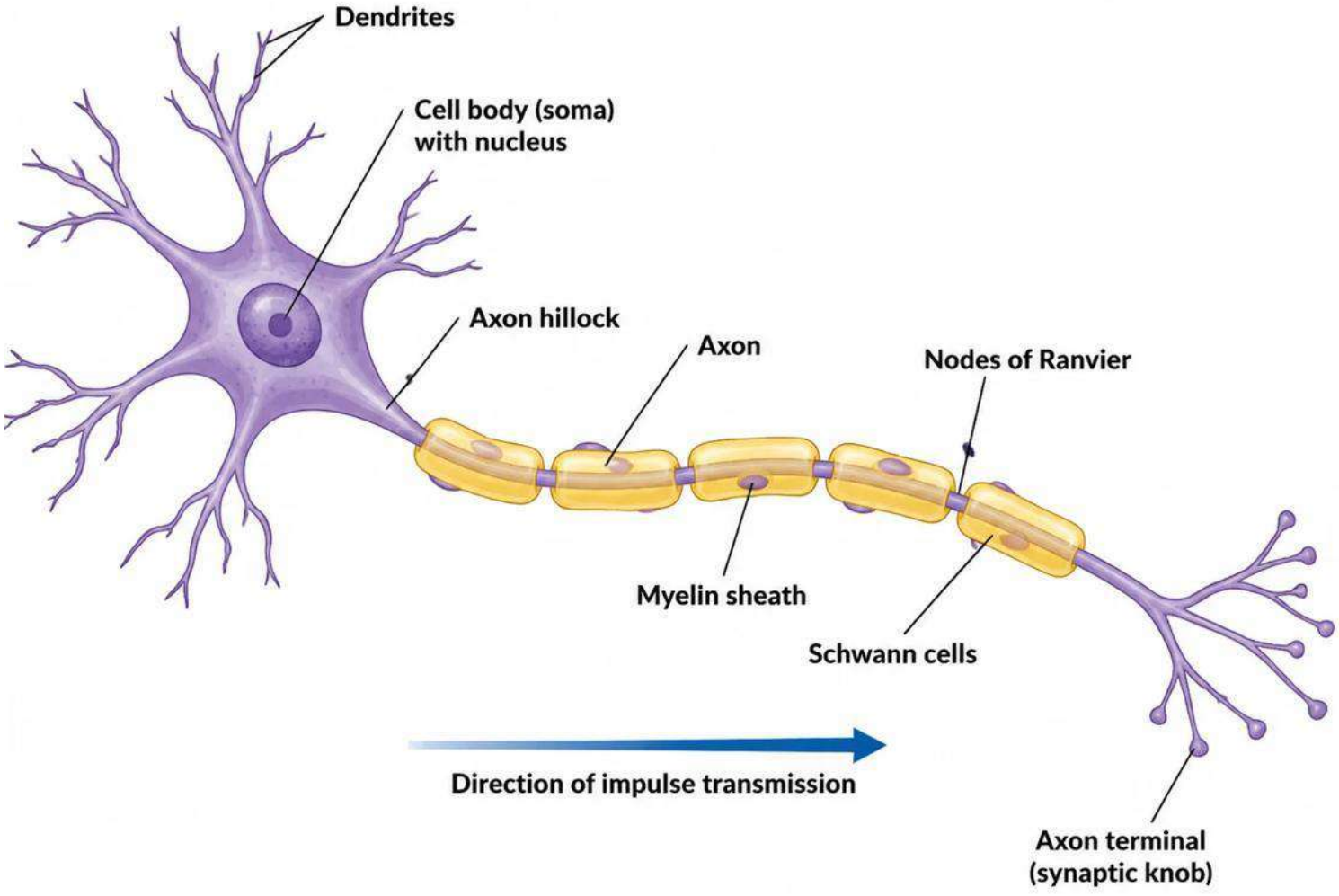
3.1 Meaning of a neuron

A **neuron** is a specialised cell of the nervous system that receives, processes and transmits information through electrical and chemical signals.

Neurons are the basic structural and functional units of the nervous system.

They are adapted to transmit nerve impulses rapidly from one part of the body to another.

The human nervous system contains billions of neurons.



3.2 Structure of a typical neuron

A typical neuron consists of the following parts:

1. Dendrites

Dendrites are short, branched extensions that arise from the cell body.

Functions:

1. Receive signals from receptors or other neurons.
2. Carry signals towards the cell body.
3. Increase the surface area available for receiving information.

2. Cell body (Cyton or Soma)

The cell body is the main part of the neuron containing the nucleus and cytoplasm.

Functions:

1. Contains the nucleus, which controls the activities of the neuron.
2. Contains cell organelles responsible for metabolic activities.
3. Maintains the life of the neuron.
4. Integrates incoming signals.

3. Nucleus

The nucleus is found inside the cell body.

Functions:

1. Controls the activities of the neuron.
2. Contains genetic material.
3. Regulates protein production and cell maintenance.

4. Axon

An axon is a long extension of a neuron that carries nerve impulses away from the cell body.

Functions:

1. Transmits impulses away from the cell body.
2. Carries information to another neuron, muscle or gland.
3. Enables communication over long distances in the body.

5. Myelin sheath

The myelin sheath is a fatty insulating covering found around the axons of many neurons.

It is formed by specialised supporting cells:

- Schwann cells in the peripheral nervous system.
- Oligodendrocytes in the central nervous system.

Functions:

1. Insulates the axon electrically.
2. Increases the speed of nerve impulse conduction.
3. Helps prevent interference between adjacent nerve fibres.
4. Protects and supports the axon.

6. Nodes of Ranvier

These are small gaps between adjacent sections of the myelin sheath along an axon.

Functions:

1. Allow the regeneration of electrical signals along the axon.
2. Enable impulses to travel rapidly by saltatory conduction.
3. Help increase the speed of nerve transmission.

7. Axon terminals

These are branched endings of the axon.

Functions:

1. Transmit signals to another neuron or an effector.
2. Contain synaptic vesicles filled with neurotransmitters.
3. Release neurotransmitters into the synaptic cleft.

8. Synaptic knobs

These are small swellings at the ends of axon terminals.

Functions:

1. Store neurotransmitters in synaptic vesicles.
2. Release neurotransmitters when an impulse reaches the terminal.
3. Help transmit signals across a synapse.

3.3 Adaptations of neurons to their functions

Neurons are structurally adapted to transmit impulses efficiently.

Adaptation	Importance
Long axon	Enables transmission of impulses over long distances.
Branched dendrites	Increase the surface area for receiving signals.
Myelin sheath	Insulates the axon and increases conduction speed.
Nodes of Ranvier	Allow rapid saltatory conduction.
Synaptic terminals	Enable communication with other cells.
Numerous mitochondria in active regions	Provide energy needed for cellular activities and neurotransmitter release.
Specialised membrane proteins	Enable the generation and transmission of electrical signals.

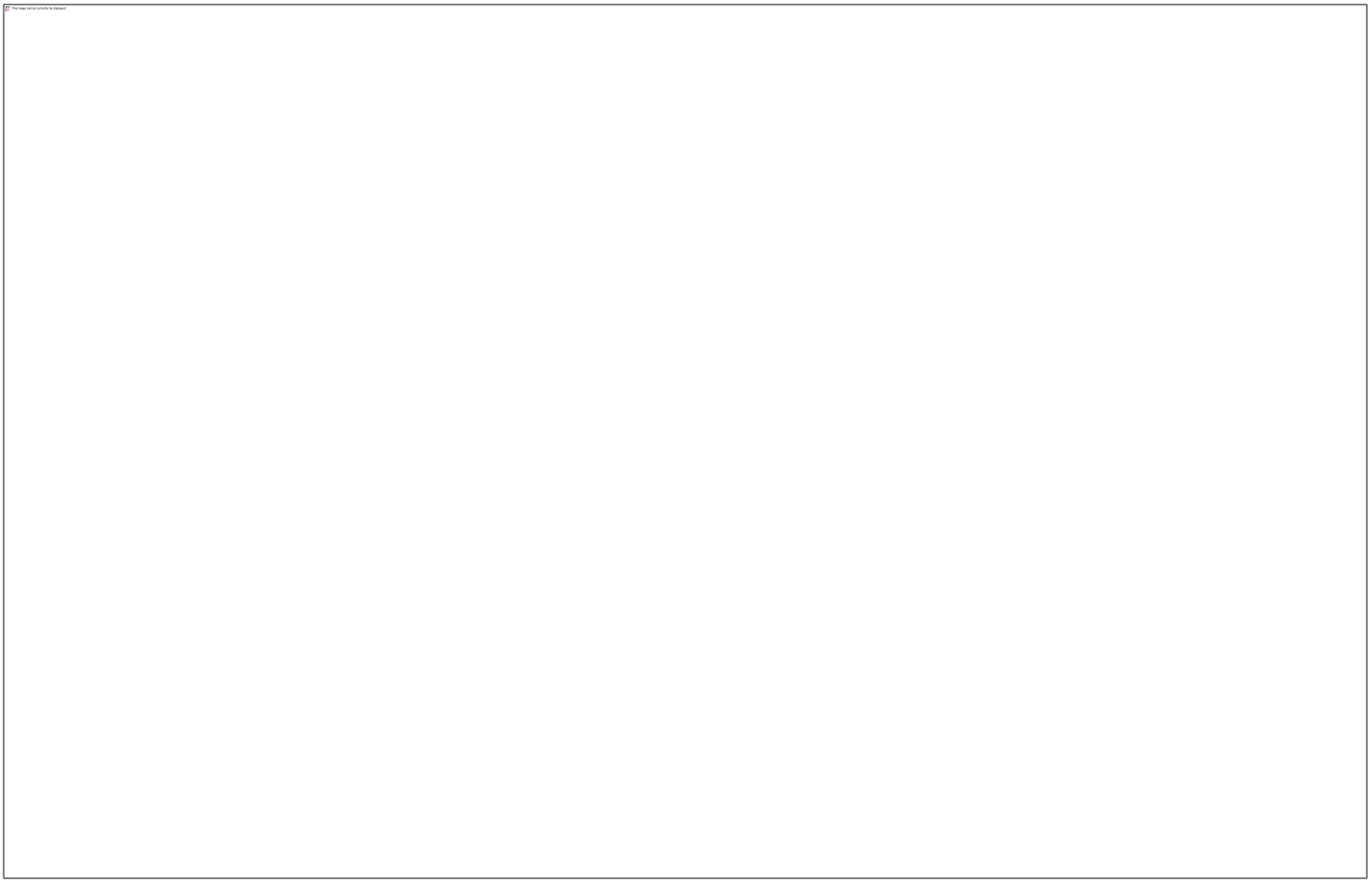
4.0 TYPES OF NEURONS

Neurons can be classified according to their structure or the direction in which they transmit nerve impulses and their functions.

4.1 Classification according to function

There are three main functional types of neurons:

1. Sensory neurons.
2. Motor neurons.
3. Relay neurons (interneurons).



A. Sensory neurons

Sensory neurons are neurons that carry nerve impulses from sensory receptors towards the central nervous system.

They transmit information from sense organs and other receptors to the brain or spinal cord.

Functions:

1. Detect and transmit information about environmental changes.
2. Carry impulses from receptors to the CNS.
3. Enable the body to detect touch, pain, heat, cold, light and sound.

Examples:

- A sensory neuron carries information from the skin when a person touches a hot object.
- Sensory neurons in the eye carry visual information towards the brain.
- Sensory neurons in the ear carry information involved in hearing.

Structural features:

- Many sensory neurons have a long peripheral process and a shorter central process.
- Their cell bodies are usually located in sensory ganglia outside the CNS, such as the dorsal root ganglia of spinal nerves.

B. Motor neurons

Motor neurons are neurons that carry nerve impulses away from the central nervous system to effectors such as muscles and glands.

Functions:

1. Carry instructions from the CNS to muscles.
2. Cause muscles to contract or relax.
3. Stimulate glands to release substances.
4. Enable voluntary and involuntary responses.

Examples:

- Motor neurons carry impulses to arm muscles when a person lifts a book.
- They transmit impulses to leg muscles when a person walks.
- They transmit impulses to muscles during withdrawal of the hand from a hot object.

Structural features:

- Usually have a cell body with many dendrites.
- Have a long axon.
- Their axons may be covered by a myelin sheath.

C. Relay neurons (Interneurons)

Relay neurons are neurons found mainly within the central nervous system that connect sensory neurons to motor neurons or to other neurons.

Functions:

1. Connect sensory neurons to motor neurons.
2. Process and integrate information within the CNS.
3. Help coordinate reflex actions.
4. Allow communication between different neurons.

Example: During withdrawal of the hand from a hot object, relay neurons in the spinal cord help transmit information from sensory neurons to motor neurons.

Differences between sensory, motor and relay neurons

Sensory neurons	Motor neurons	Relay neurons
Carry impulses towards the CNS.	Carry impulses away from the CNS.	Connect neurons within the CNS.
Connect receptors to the CNS.	Connect the CNS to effectors.	Connect sensory and motor pathways.
Cell bodies commonly occur in sensory ganglia.	Cell bodies are found in the CNS.	Cell bodies are found within the CNS.
Detect and transmit sensory information.	Cause muscles or glands to respond.	Process and transfer information.

4.2 Classification according to structure

Neurons can also be classified according to the number and arrangement of their processes.

A. Unipolar or pseudounipolar neurons

These neurons have one process extending from the cell body, which divides into two branches.

- Commonly found among sensory neurons.
- Carry sensory information towards the CNS.

B. Bipolar neurons

These neurons have two processes:

- One dendritic process.
- One axon.

They are found in specialised sensory structures.

Examples:

- Retina of the eye.
- Olfactory epithelium of the nose.

C. Multipolar neurons

These neurons have many dendrites and one axon.

They are the most common structural type of neuron.

Examples:

- Motor neurons.
- Many relay neurons in the brain and spinal cord.



5.0 NERVE IMPULSES AND THEIR TRANSMISSION

5.1 Meaning of a nerve impulse

A **nerve impulse** is a rapid electrical signal that travels along the membrane of a neuron to transmit information.

It is produced by changes in the electrical potential across the neuron's cell membrane due to the movement of charged particles called ions.

The main ions involved are:

- Sodium ions (Na^+).
- Potassium ions (K^+).

5.2 Resting potential

Resting potential is the electrical potential difference across the membrane of a neuron when it is not transmitting an action potential.

In a typical neuron:

1. The inside of the cell is more negative than the outside.
2. Sodium ions are more concentrated outside the neuron.
3. Potassium ions are more concentrated inside the neuron.
4. The cell membrane is more permeable to potassium ions than to sodium ions at rest.
5. The sodium-potassium pump helps maintain these concentration differences.

The resting membrane potential of many neurons is approximately −70 millivolts (mV), although it varies.

Role of the sodium-potassium pump

The sodium-potassium pump is a membrane protein that uses energy from ATP to transport ions across the neuronal membrane.

For each cycle:

- Three sodium ions are pumped out of the neuron.
- Two potassium ions are pumped into the neuron.

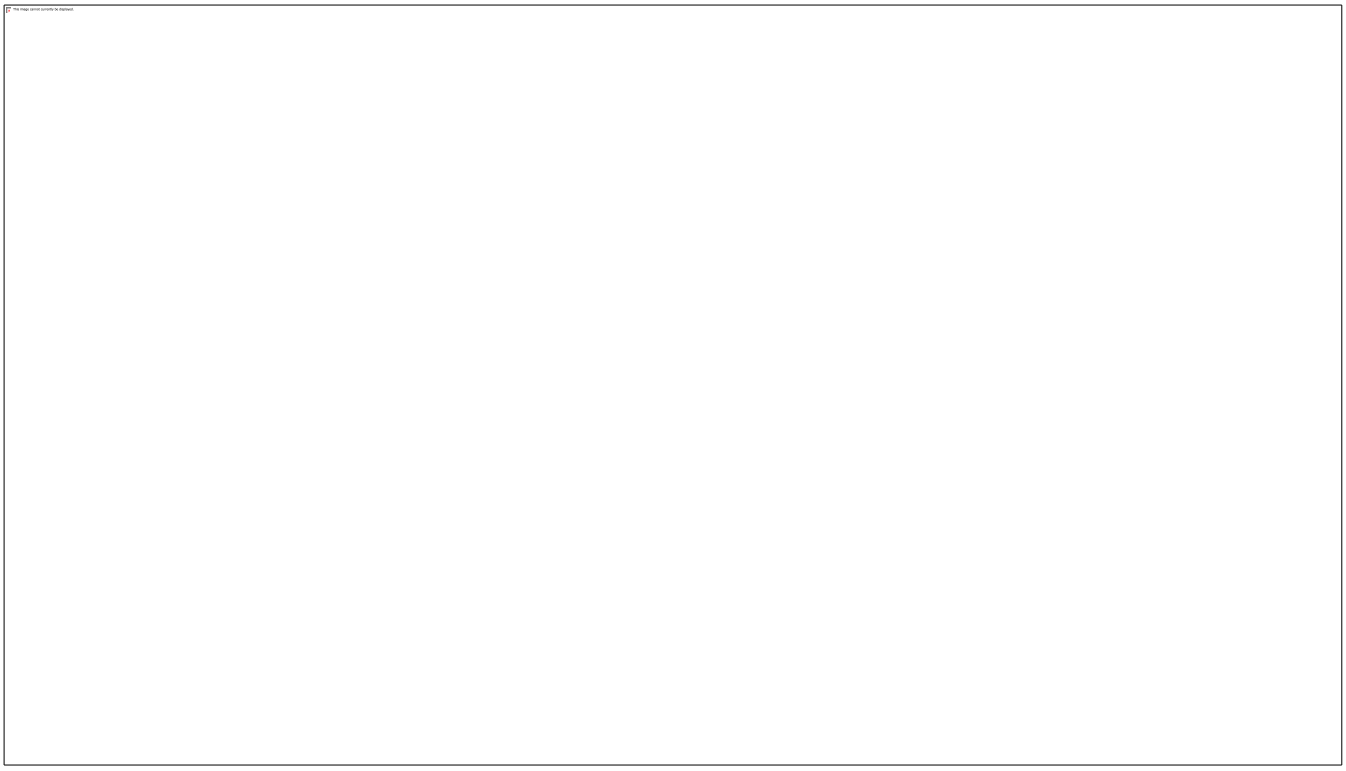
This helps maintain the ion concentration gradients necessary for nerve impulse transmission.

5.3 Action potential

An **action potential** is a rapid, temporary change in the electrical potential across the membrane of a neuron that occurs when the neuron is sufficiently stimulated.

It is the electrical event that travels along the axon.

Stages of an action potential



Stage 1: Resting state

1. The neuron is not transmitting an action potential.
2. The inside of the membrane is negatively charged relative to the outside.
3. Sodium ions are more concentrated outside.
4. Potassium ions are more concentrated inside.

Stage 2: Depolarisation

1. A sufficiently strong stimulus brings the membrane to threshold.
2. Voltage-gated sodium channels open.
3. Sodium ions move rapidly into the neuron.
4. The inside of the membrane becomes less negative and then positive relative to the outside.
5. An action potential is generated.

Stage 3: Repolarisation

1. Sodium channels become inactivated.
2. Voltage-gated potassium channels open.
3. Potassium ions move out of the neuron.
4. The inside of the membrane becomes negative again.

Stage 4: Hyperpolarisation

1. Potassium channels may remain open briefly.
2. More potassium ions leave the neuron than are needed to return to the resting level.
3. The membrane becomes temporarily more negative than its normal resting potential.
4. The membrane gradually returns to its resting state.

Important: An action potential follows the all-or-none principle. Once the threshold is reached, a full action potential occurs. A stronger stimulus generally increases the frequency of action potentials rather than the size of each action potential.

5.4 Transmission of impulses along a neuron

The transmission of an impulse along a neuron involves electrical changes in the neuron's membrane.

The sequence is as follows:

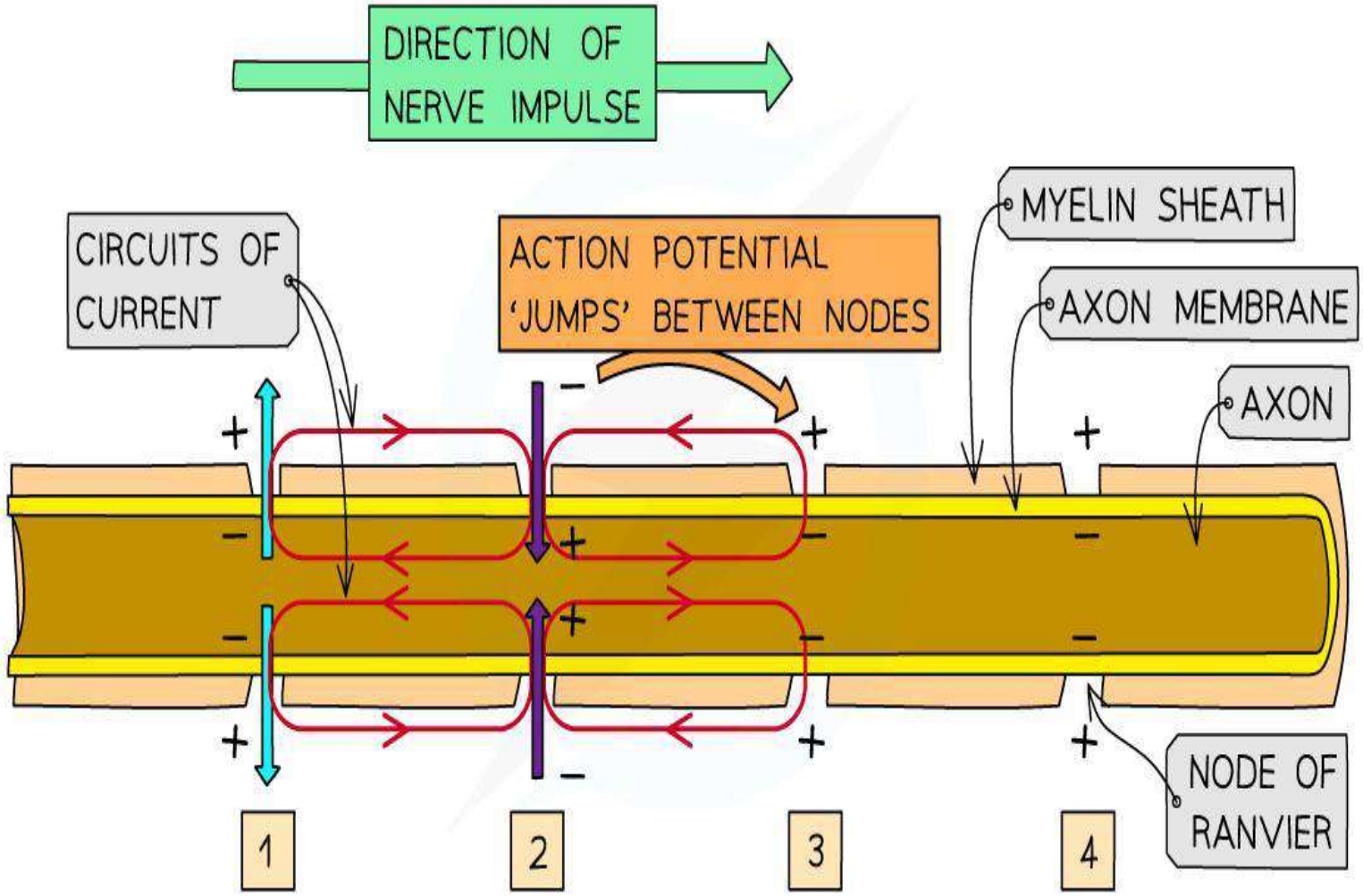
1. A suitable stimulus is received by the neuron.
2. If the stimulus reaches the threshold, an action potential is generated.
3. Sodium ions enter the stimulated region, causing depolarisation.
4. This creates electrical changes that stimulate the adjacent region of the membrane.
5. A new action potential is generated in the adjacent region.
6. The process continues along the axon.
7. The impulse eventually reaches the axon terminals.

Transmission in myelinated neurons

In myelinated neurons, the myelin sheath acts as an electrical insulator.

Action potentials are regenerated at the nodes of Ranvier, making the impulse appear to jump from one node to the next.

This is called **saltatory conduction**.



Advantages of saltatory conduction:

1. Increases the speed of nerve impulse transmission.
2. Reduces the amount of energy needed to restore ion gradients along the axon.
3. Makes communication within the nervous system more efficient.

Transmission in non-myelinated neurons

In non-myelinated neurons:

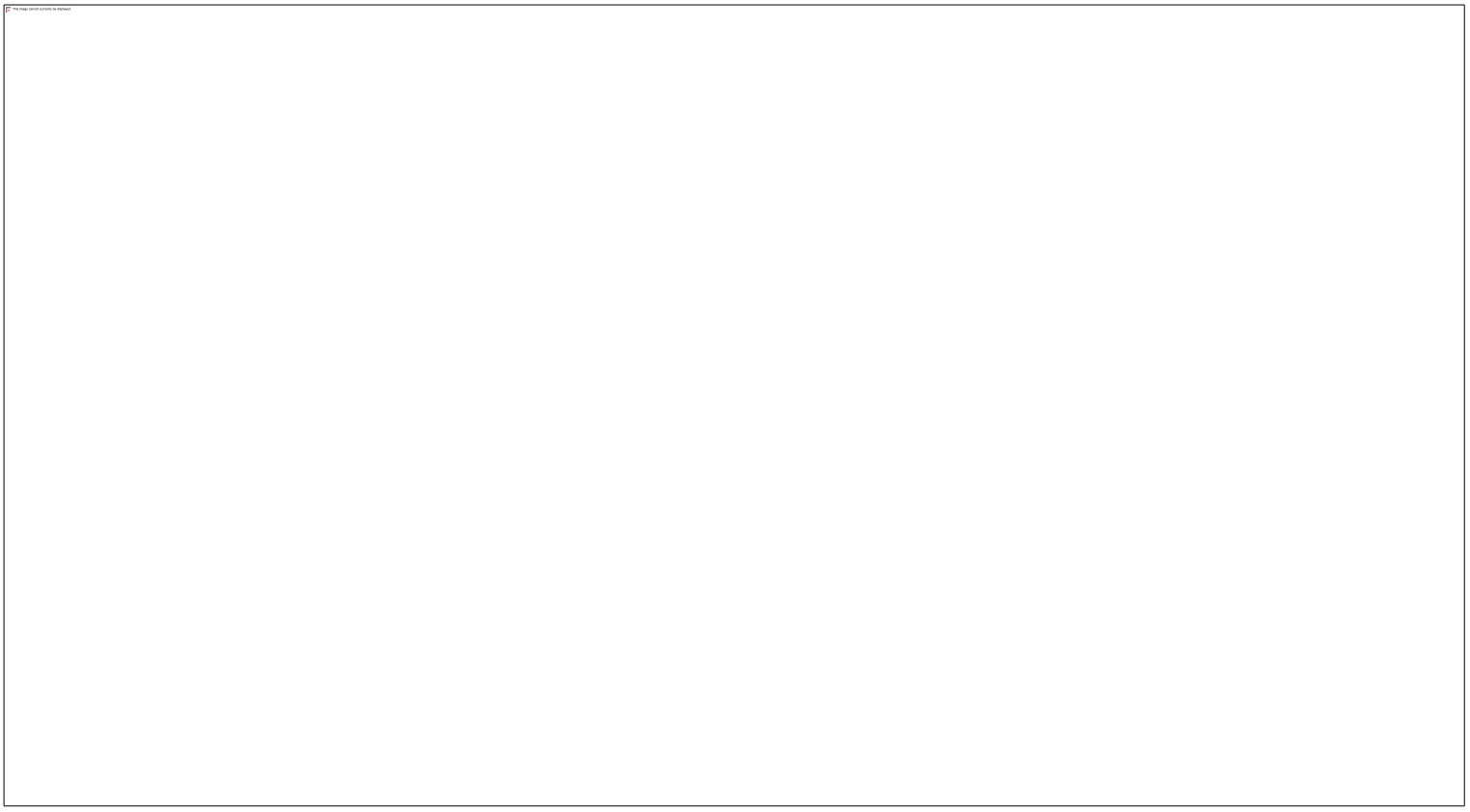
1. The axon lacks a continuous myelin sheath.
2. Depolarisation occurs along successive sections of the membrane.
3. The impulse travels continuously along the axon.
4. Transmission is generally slower than in comparable myelinated axons.

6.0 TRANSMISSION OF IMPULSES ACROSS A SYNAPSE

6.1 Meaning of a synapse

A **synapse** is a specialised junction through which a neuron communicates with another neuron or with an effector cell, such as a muscle or gland cell.

Most synapses in the nervous system transmit information chemically using neurotransmitters.



Main parts of a chemical synapse

1. Presynaptic terminal

This is the end of the transmitting neuron.

It contains synaptic vesicles that store neurotransmitters.

2. Synaptic vesicles

These are small membrane-bound sacs containing chemical messenger substances called neurotransmitters.

3. Synaptic cleft

This is the tiny gap between the presynaptic terminal and the postsynaptic membrane.

4. Postsynaptic membrane

This is the membrane of the receiving neuron or effector cell.

It contains receptor proteins that bind specific neurotransmitters.

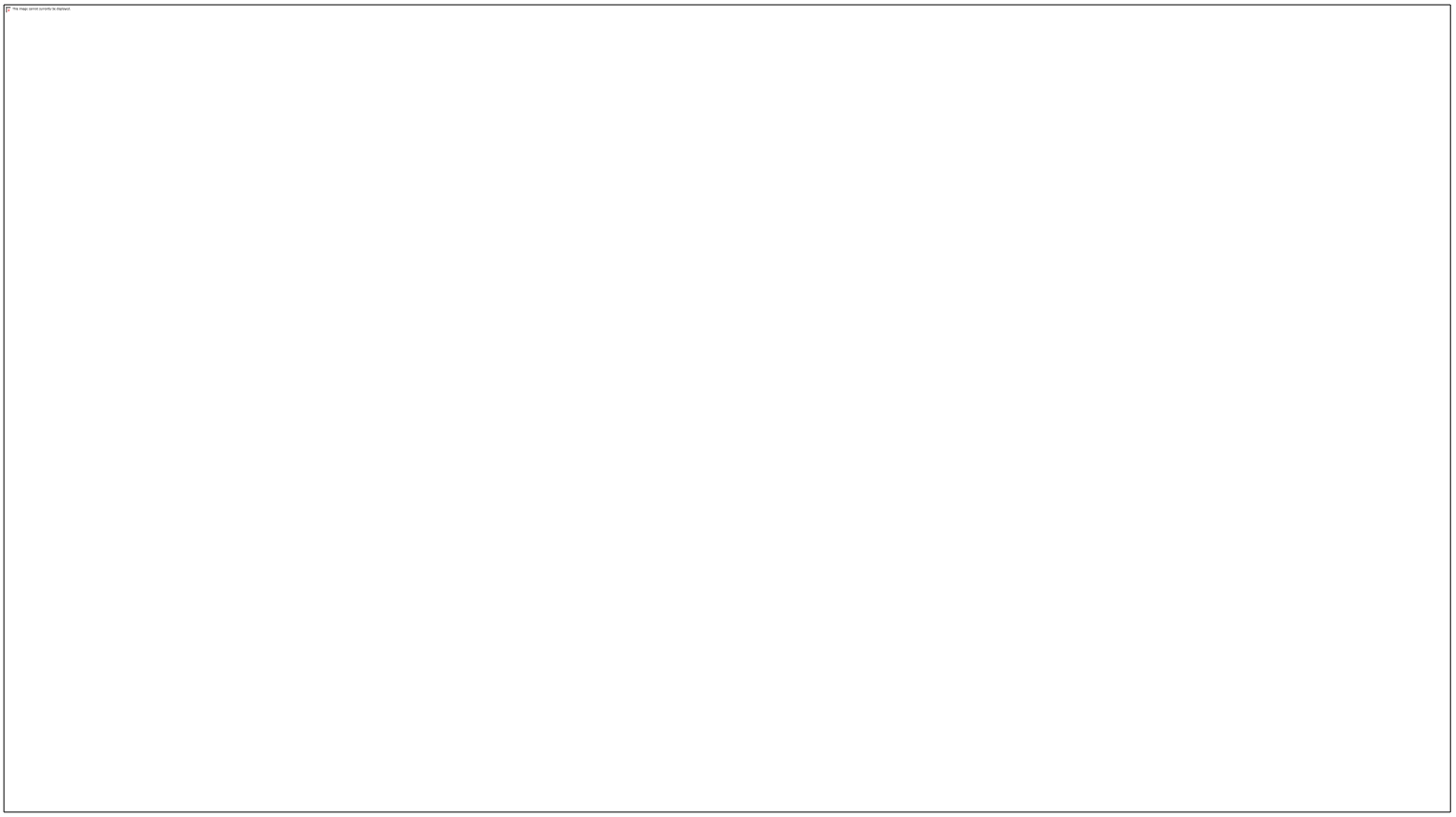
5. Neurotransmitters

These are chemical substances released by neurons to transmit signals across chemical synapses.

Examples include:

- Acetylcholine.
- Dopamine.
- Serotonin.
- Noradrenaline.
- Gamma-aminobutyric acid (GABA).
- Glutamate.

6.2 Process of transmission across a chemical synapse



The transmission of an impulse across a chemical synapse occurs in the following stages:

1. An action potential reaches the presynaptic terminal.
2. Voltage-gated calcium channels open.
3. Calcium ions enter the presynaptic terminal.
4. Calcium causes synaptic vesicles to move towards and fuse with the presynaptic membrane.
5. Neurotransmitters are released into the synaptic cleft by exocytosis.
6. Neurotransmitters diffuse across the synaptic cleft.
7. They bind to specific receptors on the postsynaptic membrane.
8. This causes ion channels to open or close, changing the electrical state of the receiving cell.
9. If the resulting change reaches threshold, an action potential is generated in the receiving neuron.
10. Neurotransmitters are removed through breakdown, reuptake or diffusion, allowing the synapse to function again.

Importance of synapses

1. Enable communication between neurons.
2. Allow information to pass from one neuron to another.
3. Enable communication between neurons and muscles.
4. Enable communication between neurons and glands.
5. Help integrate and process information in the nervous system.
6. Allow the nervous system to modify the strength of connections during learning and memory.

Why is transmission across a chemical synapse usually one-way?

Neurotransmitters are released from the presynaptic terminal, while their receptors are located on the postsynaptic membrane.

This arrangement causes transmission to occur in one direction across a typical chemical synapse.

6.3 Differences between transmission along a neuron and across a synapse

Along a neuron	Across a chemical synapse
Mainly electrical transmission.	Mainly chemical transmission.
Involves changes in membrane potential.	Involves release of neurotransmitters.
Occurs along the neuron's membrane.	Occurs across the synaptic cleft.
May be very rapid.	Usually introduces a small synaptic delay.
Involves movement of ions across the membrane.	Involves neurotransmitter release and receptor activation.

Factors affecting nerve impulse transmission

1. **Temperature:** Very low temperatures can slow nerve activity and chemical reactions.
2. **Myelination:** Myelinated axons generally conduct impulses faster than comparable non-myelinated axons.
3. **Axon diameter:** Larger-diameter axons generally conduct impulses faster than smaller-diameter axons.
4. **Chemical substances:** Some drugs and toxins affect neurotransmitter release, receptors or ion channels.
5. **Damage to neurons:** Injury or disease affecting neurons or myelin can interfere with impulse transmission.

7.0 REFLEX ACTIONS IN HUMAN BEINGS

7.1 Meaning of a reflex action

A **reflex action** is a rapid, automatic and involuntary response to a stimulus, usually occurring without conscious decision.

Reflex actions help protect the body from injury and maintain normal body functioning.

Examples of reflex actions include:

1. Withdrawing the hand after touching a hot object.
2. Blinking when an object approaches the eye.
3. Sneezing when dust enters the nose.
4. Coughing when the respiratory tract is irritated.
5. The knee-jerk response when the tendon below the kneecap is tapped.
6. Constriction of the pupil when exposed to bright light.

Characteristics of reflex actions

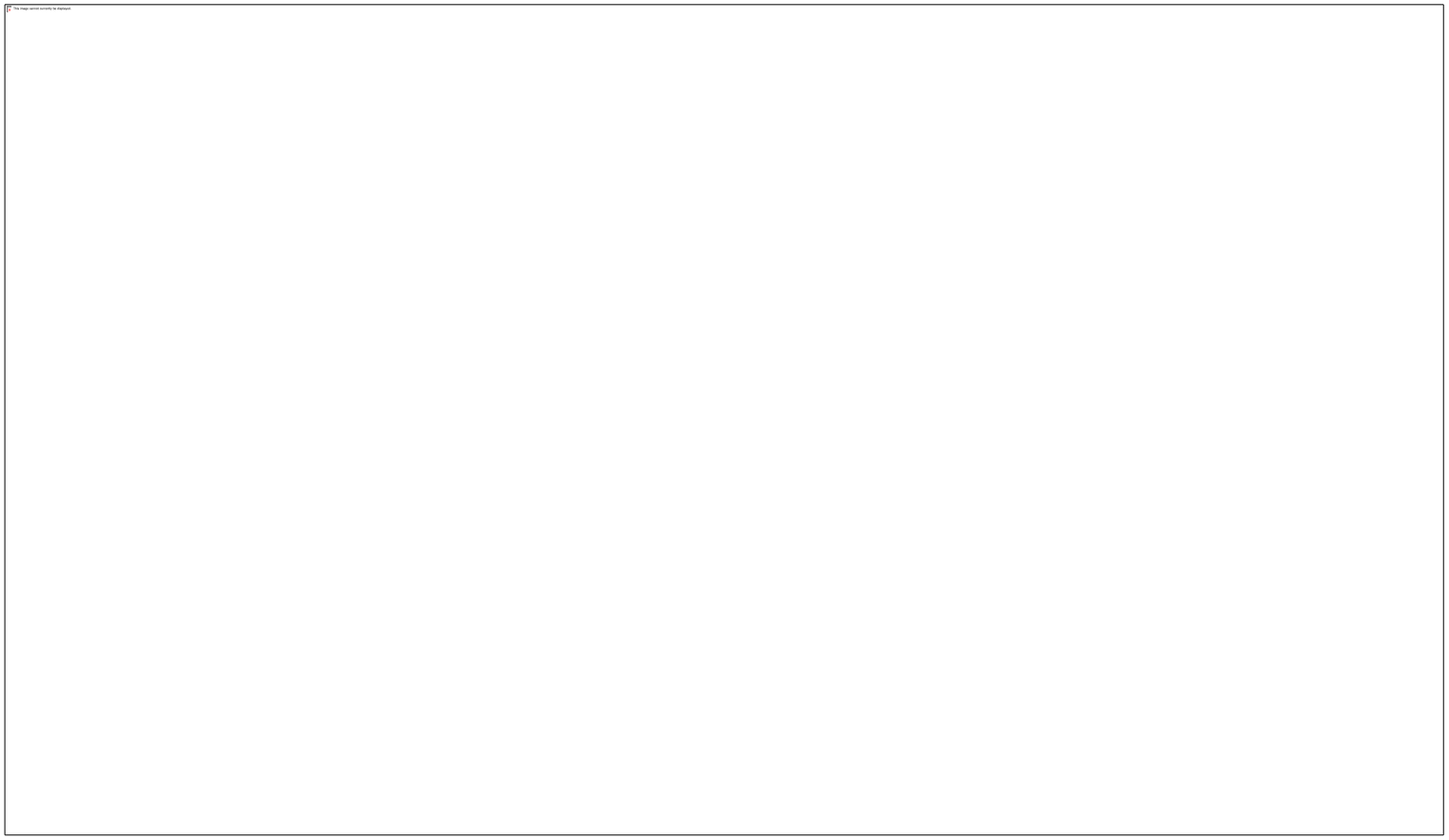
1. They are rapid responses to stimuli.
2. They are automatic and involuntary.
3. They follow a specific pathway.
4. They help protect the body from harm.
5. Many are coordinated by the spinal cord or brainstem.
6. They do not normally require conscious thought before the initial response.

7.2 Meaning of a reflex arc

A **reflex arc** is the pathway followed by nerve impulses during a reflex action, from the receptor to the effector.

A typical spinal reflex arc consists of five main components:

1. Receptor.
2. Sensory neuron.
3. Relay neuron.
4. Motor neuron.
5. Effector.



Components of a reflex arc and their functions

1. Receptor

A receptor is a specialised cell or nerve ending that detects a stimulus.

Examples:

- Pain receptors in the skin detect harmful heat or injury.
- Pressure receptors detect mechanical pressure.
- Photoreceptors in the eye detect light.

Function: Detects the stimulus and initiates a sensory signal.

2. Sensory neuron

Carries nerve impulses from the receptor towards the central nervous system.

Function: Transmits information about the stimulus to the spinal cord or brainstem.

3. Relay neuron

Located within the central nervous system.

Function: Connects the sensory neuron to the motor neuron and helps coordinate the response.

Note: Some reflexes, such as the knee-jerk reflex, involve a direct connection between a sensory neuron and a motor neuron without an intervening relay neuron in the main pathway.

4. Motor neuron

Carries impulses away from the central nervous system towards an effector.

Function: Transmits instructions that produce a response.

5. Effector

An effector is a muscle or gland that carries out a response.

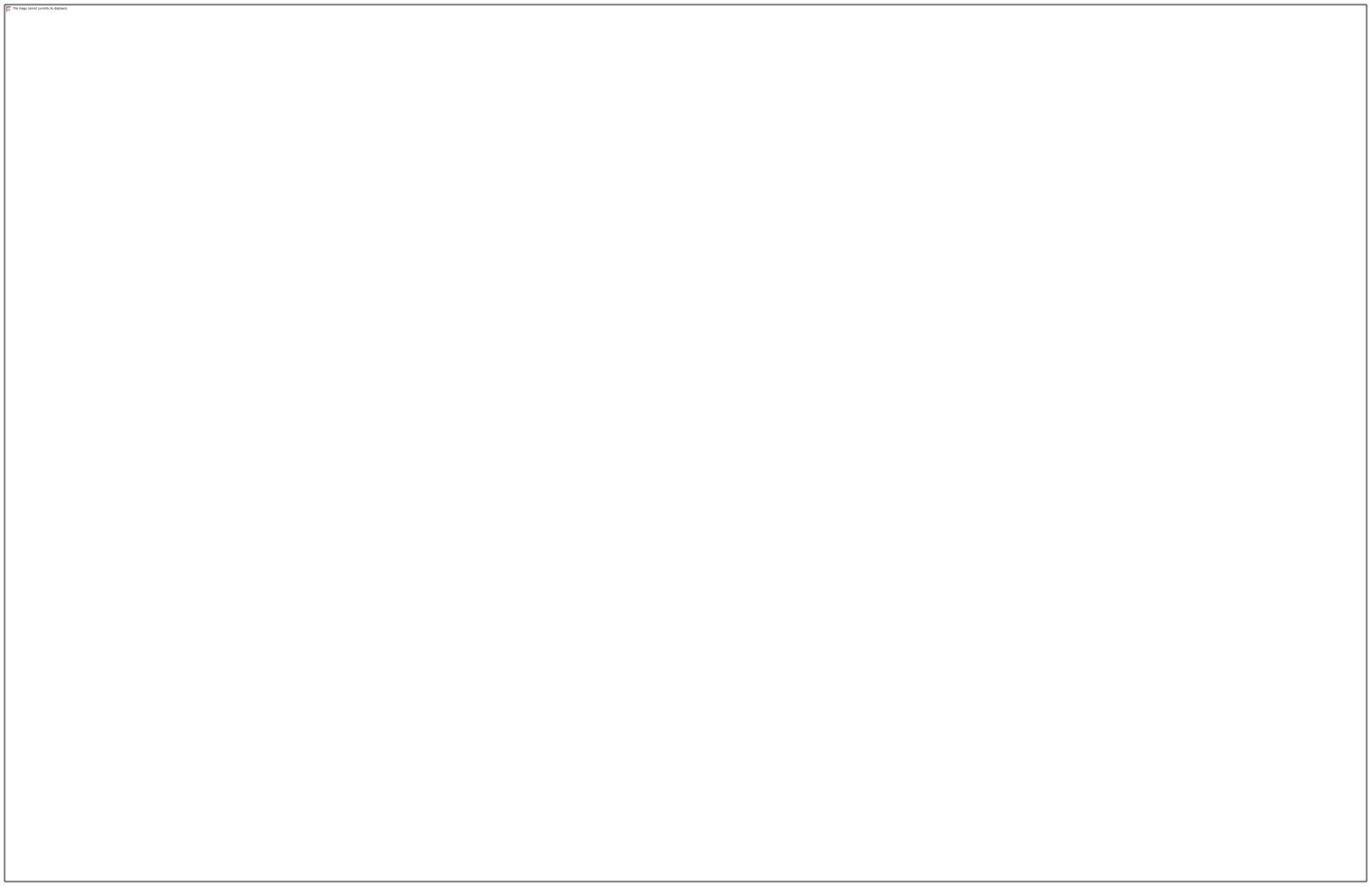
Examples:

- Skeletal muscles contract to withdraw a hand.
- Glands release secretions in response to appropriate nerve signals.

Function: Produces the actual response to the stimulus.

7.3 Example: Withdrawal reflex

When a person accidentally touches a hot cooking pot:



The following events occur:

1. Pain and temperature receptors in the skin detect the harmful heat.
2. A nerve impulse is generated and carried along a sensory neuron.
3. The sensory neuron carries the impulse to the spinal cord.
4. A relay neuron passes the information to a motor neuron.
5. The motor neuron carries impulses to the arm muscles.

6. The appropriate muscles contract.
7. The hand is quickly withdrawn from the hot object.
8. Information is also transmitted to the brain, allowing the person to become consciously aware of the pain.

Importance: The withdrawal reflex reduces the time that the body remains in contact with a harmful stimulus, helping to minimise injury.

7.4 Simple reflex actions

A **simple reflex action** is an automatic, rapid and involuntary response to a stimulus that occurs through a relatively direct neural pathway.

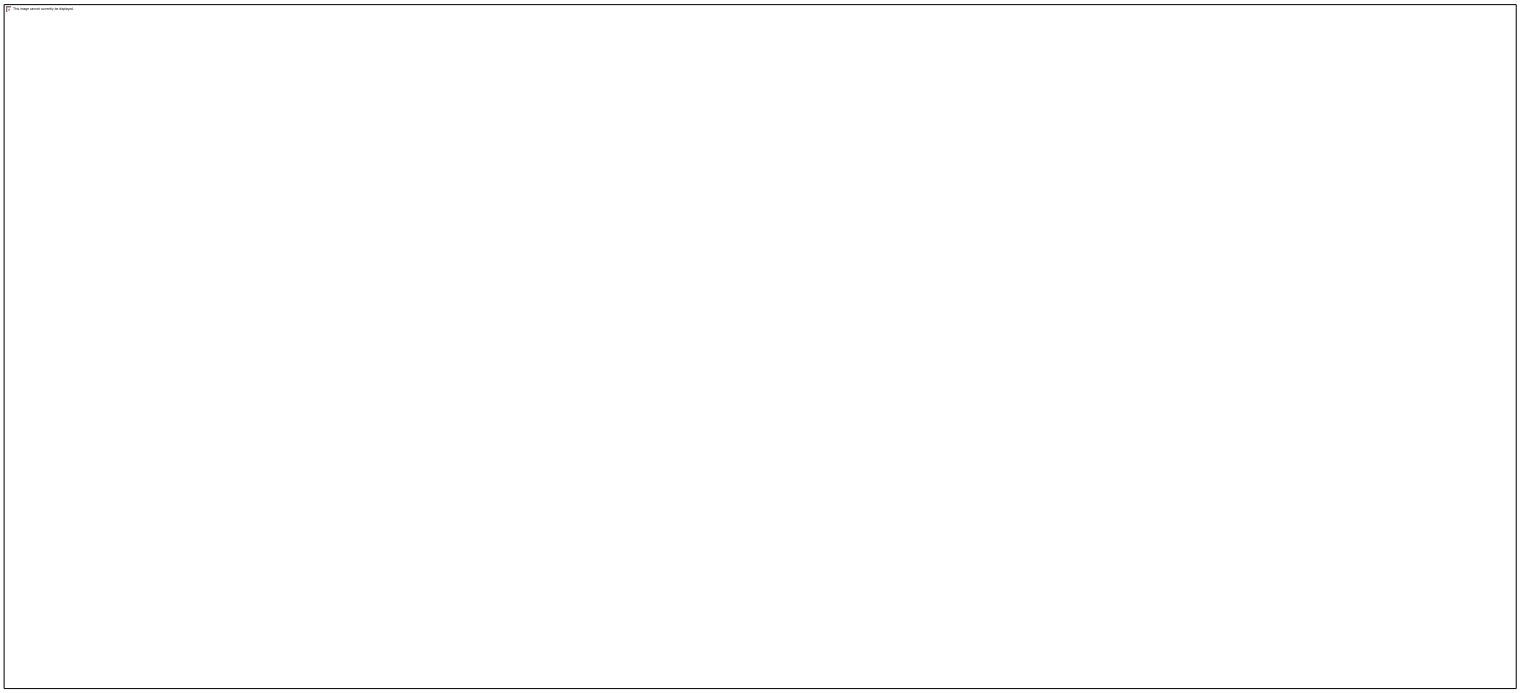
Examples include:

- Knee-jerk reflex.
- Withdrawal reflex.
- Blinking reflex.
- Pupil reflex.
- Sneezing reflex.

A. Knee-jerk reflex

The knee-jerk reflex is also called the patellar reflex.

It occurs when the tendon below the kneecap is tapped gently, causing the lower leg to extend.



Procedure:

1. A person sits on a chair with the lower legs hanging freely.
2. The examiner gently taps the patellar tendon just below the kneecap using a reflex hammer.
3. The quadriceps muscle in the front of the thigh is stretched.
4. Stretch receptors in the muscle detect the stretching.
5. Sensory impulses travel to the spinal cord.
6. The sensory neuron communicates with a motor neuron.

7. Motor impulses travel back to the quadriceps muscle.
8. The quadriceps contracts, causing the lower leg to extend.

Importance of the knee-jerk reflex:

1. Helps maintain posture and balance.
2. Helps maintain normal muscle tone.
3. Protects muscles and joints from excessive stretching.
4. Provides useful information during neurological examinations.

B. Withdrawal reflex

This occurs when a body part is rapidly moved away from a harmful stimulus.

Example: Withdrawing a foot after stepping on a sharp object.

Importance:

- Protects the body from further injury.
- Reduces exposure to painful or harmful stimuli.

C. Blinking reflex

This occurs when the eyelids close automatically in response to certain stimuli.

Examples:

- An object approaching the eye.
- Dust entering the eye.
- Sudden bright light.

Importance:

1. Protects the eyes from injury.
2. Helps prevent foreign particles from entering the eyes.
3. Keeps the surface of the eye moist by spreading tears.

D. Pupil reflex

The pupil changes size depending on light intensity.

- In bright light, the pupil constricts.
- In dim light, the pupil dilates.



Importance:

1. Regulates the amount of light entering the eye.
2. Protects the light-sensitive retina from excessive light.
3. Helps maintain effective vision under different lighting conditions.

7.5 Simple reflex actions involving the brain

Not all reflex actions are controlled by the spinal cord.

Some reflexes are coordinated by the brainstem.

Examples:

- Sneezing.
- Coughing.
- Swallowing.
- Some eye reflexes.

These are also involuntary responses that help protect the body and maintain normal functioning.

8.0 CONDITIONED REFLEX ACTIONS

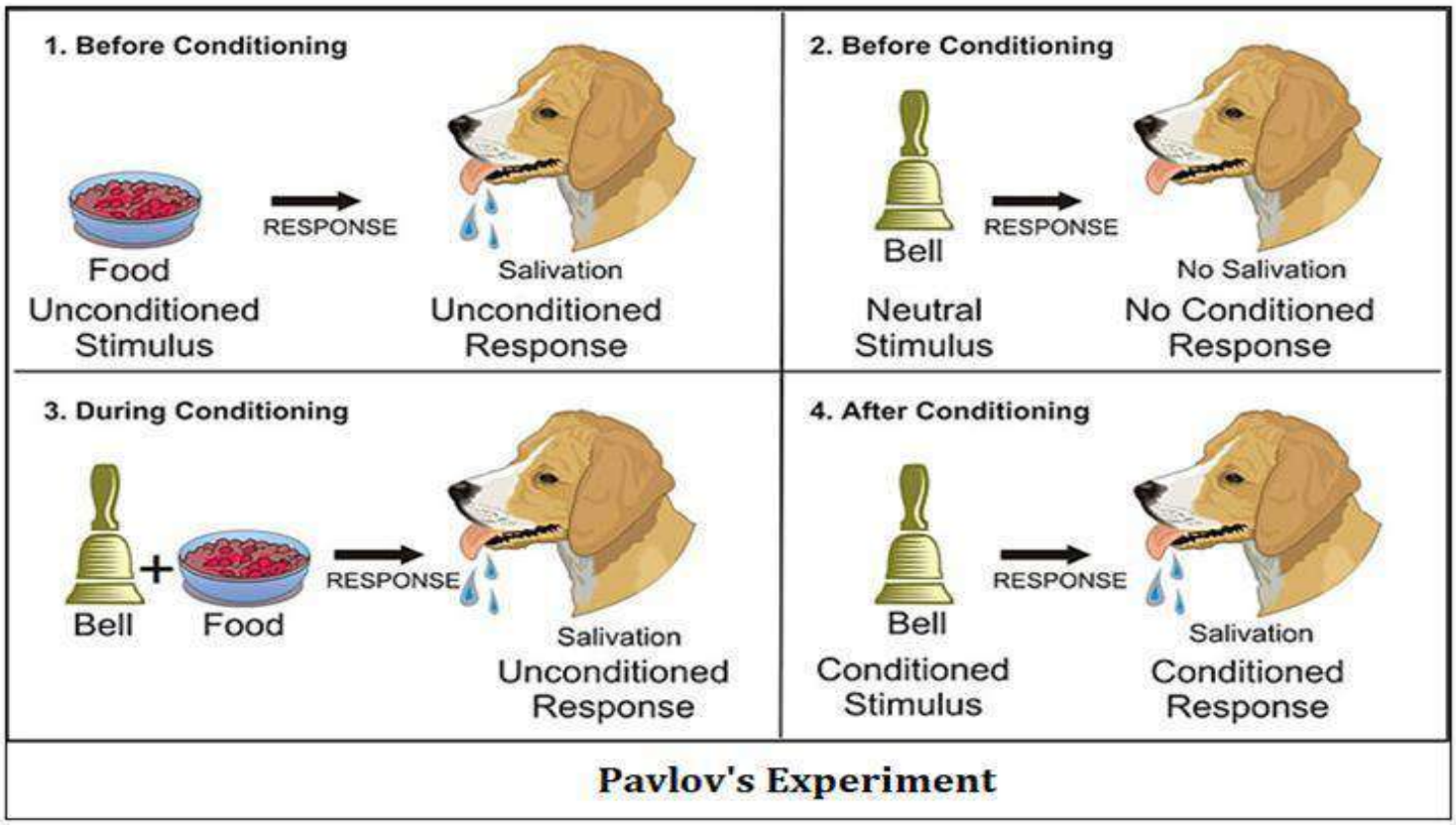
8.1 Meaning of a conditioned reflex action

A **conditioned reflex action** is a learned automatic response that develops when a previously neutral stimulus is repeatedly associated with a stimulus that naturally produces a response.

Conditioned reflexes are acquired through experience, learning and repeated association.

They are commonly associated with the work of the Russian scientist **Ivan Pavlov**, who investigated learning in dogs.

8.2 Pavlov's experiment



Pavlov investigated how dogs could learn to associate a sound with the arrival of food.

Stage 1: Before conditioning

- Food is presented to a dog.
- The dog naturally salivates.
- Food is an unconditioned stimulus.
- Salivation is an unconditioned response.

Stage 2: Neutral stimulus

- A bell is rung without presenting food.
- Initially, the sound of the bell does not naturally cause the dog to salivate.

Stage 3: During conditioning

- The bell is rung.
- Food is presented shortly afterwards.
- The dog salivates.
- The bell and food are repeatedly associated.

Stage 4: After conditioning

- The bell is rung without presenting food.
- The dog salivates in response to the bell.
- The bell has become a conditioned stimulus.
- Salivation in response to the bell is a conditioned response.

Important terms in classical conditioning

Term	Meaning	Example in Pavlov's experiment
Unconditioned stimulus	A stimulus that naturally produces a response.	Food
Unconditioned response	A natural response to an unconditioned stimulus.	Salivation caused by food
Neutral stimulus	A stimulus that initially does not produce the target response.	Bell before learning
Conditioned stimulus	A previously neutral stimulus that produces a learned response after association.	Bell after conditioning
Conditioned response	A learned response to the conditioned stimulus.	Salivation when the bell rings

8.3 Examples of conditioned responses in human beings

1. **School bell:** Learners may automatically prepare to change lessons when they hear the school bell.
2. **Alarm clock:** A person may wake up when a familiar alarm sound is heard after repeated association with waking time.
3. **Traffic signals:** Drivers learn to stop when they see a red traffic light.
4. **School routines:** Learners may automatically line up when they hear a familiar assembly signal.
5. **Food-related cues:** A familiar smell associated with a favourite meal may cause salivation.
6. **Sports training:** Athletes may respond automatically to a familiar whistle or starting signal.

Important distinction: Some examples, such as stopping at a red traffic light, involve learned habits and voluntary decisions as well as learned associations. Not every automatic-looking behaviour is a classical conditioned reflex.

8.4 Characteristics of conditioned reflex actions

1. They are acquired through learning and experience.
2. They develop through repeated association between stimuli.
3. They may become automatic after sufficient learning.
4. They can be modified by experience.
5. They may weaken if the association is no longer reinforced.
6. They differ among individuals depending on their experiences.

8.5 Extinction of conditioned reflexes

Extinction is the gradual weakening of a conditioned response when the conditioned stimulus is repeatedly presented without the original unconditioned stimulus.

For example:

- If a bell is repeatedly rung without giving food to Pavlov's dog, the dog's salivation response to the bell gradually decreases.

8.6 Generalisation and discrimination

Stimulus generalisation occurs when an organism responds to stimuli that are similar to the conditioned stimulus.

Example: A dog conditioned to respond to one bell sound may also respond to a similar bell sound.

Stimulus discrimination occurs when an organism learns to respond to a specific stimulus but not to similar stimuli.

Example: A learner responds to the particular school bell used to signal the end of a lesson but not to an unrelated sound.

9.0 DIFFERENCES BETWEEN SIMPLE AND CONDITIONED REFLEX ACTIONS

Simple reflex action	Conditioned reflex action
Usually innate or present without prior learning.	Acquired through learning and experience.
Does not require previous association between stimuli.	Develops through association between stimuli.
Often occurs through a relatively direct neural pathway.	Involves learning-related changes in neural connections.
Usually protects the body or maintains normal functions.	Helps organisms learn and adapt to their environment.
Examples include knee-jerk and withdrawal reflexes.	Examples include salivation to a learned signal.

Importance of simple reflex actions

1. Protect the body from harmful stimuli.
2. Help maintain balance and posture.
3. Protect sensitive organs such as the eyes.
4. Help regulate certain automatic body activities.
5. Enable rapid responses without conscious decision-making.

Importance of conditioned reflex actions

1. Help human beings learn appropriate responses.
2. Enable individuals to adapt to their environment.
3. Help establish useful habits and routines.

4. Improve response to familiar warning signals.
5. Support learning and behaviour modification.
6. Help individuals develop skills through repeated practice and experience.

10.0 IMPORTANCE OF REFLEX ACTIONS IN DAILY LIFE

Reflex actions are important in homes, schools, workplaces and public places.

A. Safety at home

- Withdrawing the hand from a hot cooking pot helps prevent burns.
- Blinking protects the eyes from dust and foreign objects.
- Coughing helps remove irritants from the respiratory tract.

B. Safety in schools

- Learners may blink when chalk dust approaches the eyes.
- Reflex responses help protect learners during practical activities.
- Conditioned responses to school bells help learners follow established routines.

C. Road safety

- Rapid responses to unexpected obstacles help reduce the risk of accidents.
- Learned responses to traffic signals support safe road use.
- Drivers develop trained responses through practice and experience.

D. Sports and physical activities

- Reflex responses help athletes maintain posture and balance.
- Rapid responses help players react to moving balls.
- Conditioned responses help athletes respond to starting signals and familiar instructions.

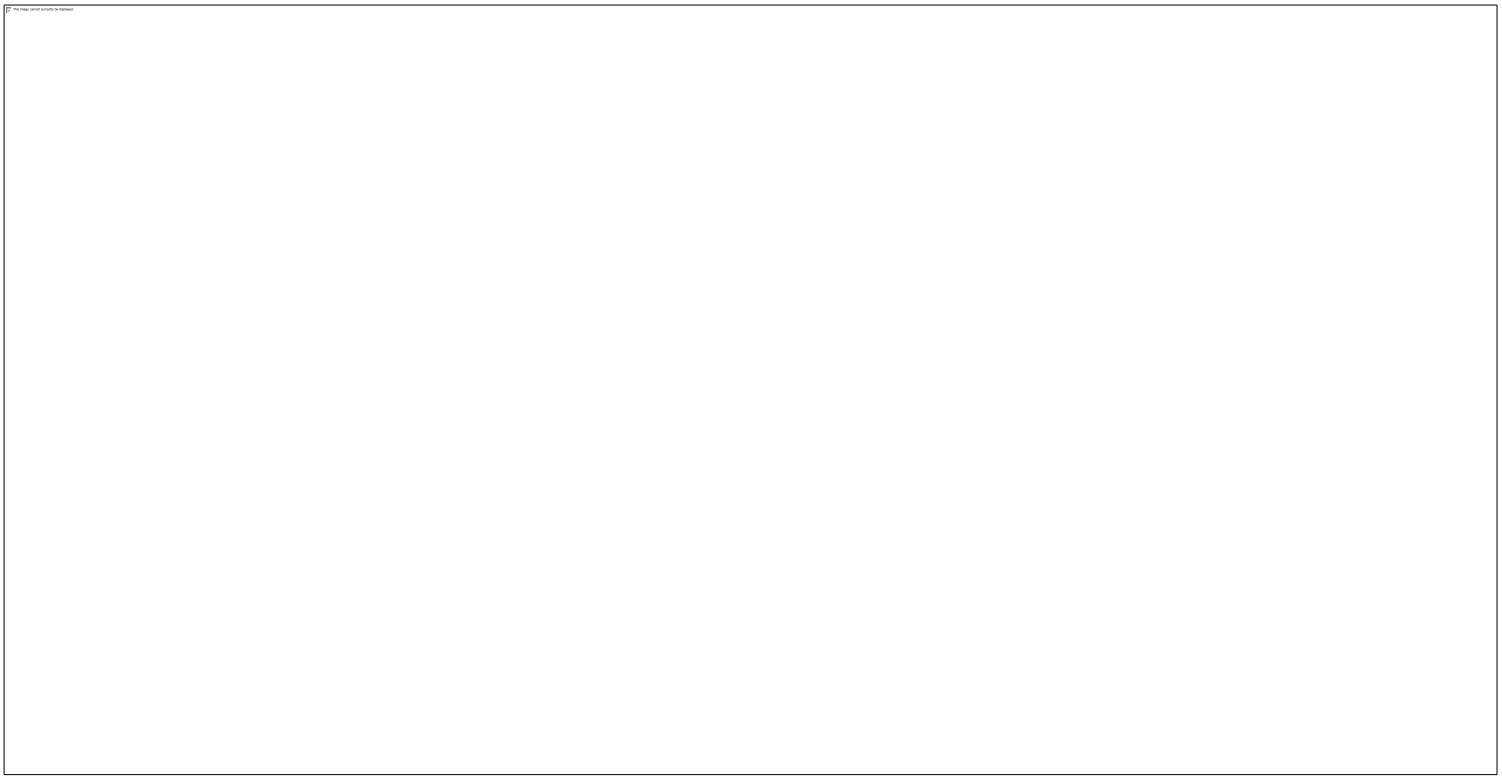
E. Medical importance

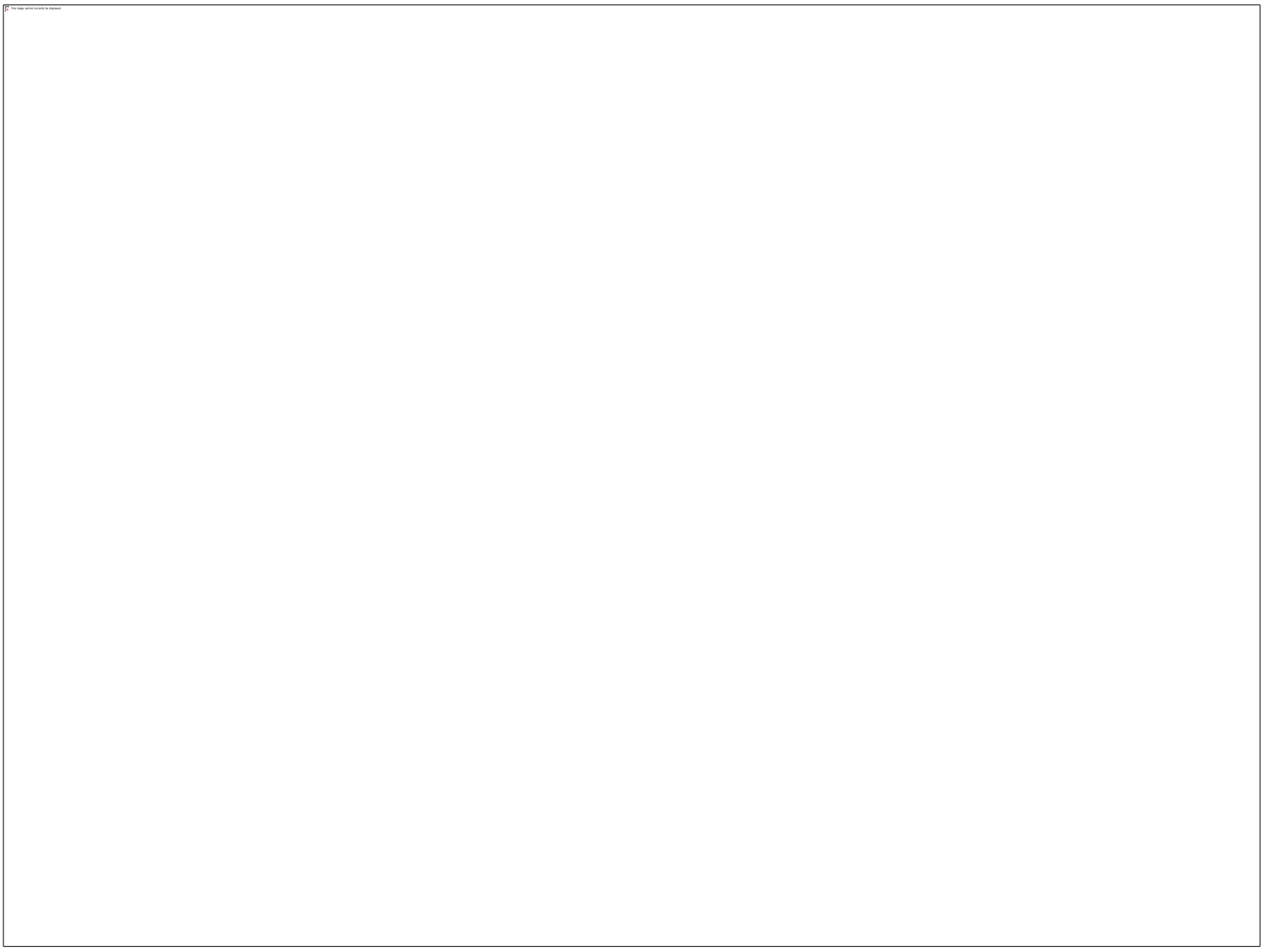
- Doctors and other health professionals examine reflexes to assess the functioning of parts of the nervous system.
- Changes in reflex responses may provide clues about nerve or spinal cord problems.
- The knee-jerk reflex is commonly tested during neurological examinations.

11.0 DISORDERS AND CONDITIONS AFFECTING THE NERVOUS SYSTEM

The nervous system is delicate and may be affected by injury, infections, genetic conditions and other diseases.

Understanding these conditions helps learners appreciate the importance of protecting the nervous system and seeking appropriate medical care.





A. Stroke

A **stroke** occurs when blood supply to part of the brain is interrupted or when a blood vessel in the brain ruptures.

Possible causes:

- Blockage of a blood vessel supplying the brain.
- Rupture of a blood vessel in the brain.

Possible signs and symptoms:

1. Sudden weakness or numbness of the face, arm or leg, especially on one side.
2. Difficulty speaking or understanding speech.
3. Sudden loss of vision.

4. Sudden difficulty walking or maintaining balance.
5. Sudden severe headache, particularly in some haemorrhagic strokes.

Prevention and control:

- Regular medical check-ups.
- Control of high blood pressure.
- Avoidance of tobacco.
- Healthy eating and regular physical activity.
- Prompt medical attention when warning signs appear.

Important: A suspected stroke is a medical emergency. Immediate medical assistance is essential.

B. Epilepsy

Epilepsy is a neurological condition characterised by a tendency to experience recurrent unprovoked seizures.

A seizure results from abnormal excessive or synchronised electrical activity in the brain.

Possible features:

- Uncontrolled body movements.
- Temporary loss of awareness.
- Staring episodes.
- Sudden changes in sensation or behaviour.
- Temporary confusion after a seizure.

Management:

1. Medical assessment and diagnosis.
2. Appropriate anti-seizure medication when prescribed.
3. Regular follow-up.
4. Avoidance of known triggers where possible.
5. Support and understanding from family, school and community members.

First aid during a seizure:

- Stay calm and protect the person from nearby hazards.
- Cushion the head.
- Do not restrain the person.
- Do not put objects or fingers in the person's mouth.
- Turn the person onto their side when it is safe to do so.
- Seek emergency medical assistance for a prolonged seizure, repeated seizures without recovery, injury or breathing difficulties.

C. Parkinson's disease

Parkinson's disease is a progressive neurological disorder associated with the loss of dopamine-producing neurons in a region of the brain called the substantia nigra.

Possible signs and symptoms:

1. Trembling or shaking, often at rest.
2. Muscle stiffness.
3. Slowness of movement.
4. Difficulty with balance and posture.
5. Changes in walking pattern.

Management:

- Medical assessment.
- Prescribed medication.
- Physiotherapy and occupational therapy.
- Regular physical activity suited to the person's condition.
- Support from family and caregivers.

D. Multiple sclerosis (MS)

Multiple sclerosis is a disease in which the immune system damages the protective myelin covering of nerve fibres in the central nervous system.

Possible effects:

1. Weakness of muscles.
2. Visual disturbances.
3. Difficulty with coordination and balance.
4. Numbness or tingling sensations.
5. Fatigue.

Management:

- Specialist medical care.
- Prescribed medication.
- Physiotherapy.
- Rehabilitation and supportive care.

E. Spinal cord injury

A spinal cord injury occurs when the spinal cord is damaged through trauma or disease.

Possible causes:

- Road traffic accidents.
- Falls.
- Sports injuries.
- Workplace accidents.

Possible effects:

1. Loss of movement below the injury.
2. Loss of sensation.
3. Difficulty controlling bladder or bowel functions.

4. Breathing difficulties in severe injuries affecting high spinal regions.

Prevention:

- Observing road safety rules.
- Using appropriate protective equipment during sports.
- Following safety procedures at workplaces.
- Preventing falls at home and in public places.

F. Meningitis

Meningitis is inflammation of the membranes covering the brain and spinal cord.

It may be caused by bacteria, viruses and other infectious agents.

Possible signs and symptoms:

- Fever.
- Severe headache.
- Stiff neck.
- Vomiting.
- Sensitivity to light.
- Confusion or reduced consciousness.

Prevention and control:

1. Appropriate vaccination.
2. Good hygiene practices.
3. Early diagnosis.
4. Prompt medical treatment.
5. Seeking urgent medical attention when symptoms suggest meningitis.

Important: Bacterial meningitis can be life-threatening and requires urgent medical treatment.

General ways of protecting the nervous system

1. Wear seat belts when travelling in vehicles.
2. Wear helmets when riding motorcycles or bicycles.
3. Follow safety rules during sports and physical activities.
4. Avoid misuse of alcohol and harmful drugs.
5. Eat a balanced diet.
6. Get adequate sleep.
7. Exercise regularly.
8. Seek medical attention when experiencing unusual neurological symptoms.
9. Protect the head and spine from injury.
10. Maintain healthy blood pressure and other cardiovascular health indicators.

12.0 PRACTICAL ACTIVITIES AND INVESTIGATIONS

Practical activities help learners understand how the nervous system works through observation and experimentation.

Experiment 1: Investigating the knee-jerk reflex



Aim: To demonstrate a simple reflex action in human beings.

Requirements:

- A chair.
- A reflex hammer, preferably used under teacher or trained health professional supervision.
- A willing participant.

Procedure:

1. Ask a volunteer to sit on a chair with the lower legs hanging freely.
2. Ensure that the volunteer is relaxed.
3. Gently tap the patellar tendon below the kneecap.
4. Observe the movement of the lower leg.
5. Repeat carefully on the other leg if appropriate.

Observation:

The lower leg moves forward due to contraction of the quadriceps muscle.

Conclusion:

The knee-jerk response is a simple stretch reflex coordinated mainly by the spinal cord.

Precautions:

- Do not strike the kneecap directly.
- Use gentle taps.
- Do not perform the test on anyone with knee pain or injury.

- Participation should be voluntary.
- The activity should be supervised by a competent teacher.

Experiment 2: Investigating reaction time using a ruler



Aim: To investigate the time taken by a person to respond to a visual stimulus.

Requirements:

- A ruler marked in centimetres.
- A partner.
- A recording table.

Procedure:

1. One learner holds a ruler vertically.
2. Another learner places the thumb and index finger near the zero mark without touching the ruler.
3. The first learner releases the ruler without warning.
4. The second learner catches it as quickly as possible.
5. Record the distance the ruler falls before being caught.
6. Repeat the experiment several times and calculate the average distance.

Observation:

The ruler falls through a certain distance before being caught.

Conclusion:

The time taken to respond to a visual stimulus varies among individuals and may be affected by attention, practice, fatigue and other factors.

Discussion questions:

1. Why does the ruler fall before being caught?

2. What factors may affect reaction time?
3. Why is a quick response important when crossing a road?

Safety: Carry out the activity in a safe area and avoid using sharp or heavy objects.

Experiment 3: Investigating conditioned responses

Aim: To demonstrate how repeated association can influence learned responses.

Suggested classroom activity:

1. Select a familiar signal, such as a short sound.
2. Associate the signal with a consistent classroom activity over a period of time.
3. Observe whether learners begin preparing for the activity when they hear the signal.
4. Discuss how learning and repeated association influence behaviour.

Conclusion:

Repeated association between a signal and an activity can help develop learned responses and routines.

Note: This classroom demonstration illustrates learned associations and habits. It is not necessarily a controlled demonstration of classical conditioning.

14.0 SUMMARY OF THE SUB-STRAND

Concept	Main points
Nervous system	Receives, processes and transmits information to coordinate body activities.
Central nervous system	Consists of the brain and spinal cord.
Peripheral nervous system	Consists of nerves and ganglia outside the CNS.
Cerebrum	Controls thinking, memory, sensory interpretation and voluntary movement.
Cerebellum	Coordinates movement, posture and balance.
Medulla oblongata	Regulates vital involuntary activities such as breathing and heart rate.
Spinal cord	Transmits impulses and coordinates many reflex actions.
Neuron	Basic structural and functional unit of the nervous system.
Sensory neuron	Carries impulses from receptors to the CNS.
Motor neuron	Carries impulses from the CNS to effectors.
Relay neuron	Connects neurons within the CNS.
Nerve impulse	Electrical signal transmitted along a neuron.
Synapse	Junction through which a neuron communicates with another cell.
Neurotransmitter	Chemical messenger that transmits signals across a chemical synapse.
Reflex action	Rapid, automatic and involuntary response to a stimulus.
Reflex arc	Pathway followed by impulses during a reflex action.
Conditioned reflex	Learned response developed through association between stimuli.

REVISION EXERCISES

SECTION A: MULTIPLE-CHOICE QUESTIONS (30 MARKS)

Instructions: Answer all questions. Choose the correct answer from the alternatives A, B, C and D.

Question 1. Which of the following best describes the human nervous system?

A. A system responsible only for digestion.

B. A system that receives information and coordinates body responses.

C. A system responsible only for blood circulation.

D. A system responsible for producing hormones only.

Question 2. Which two structures form the central nervous system?

A. Brain and spinal cord.

B. Brain and heart.

C. Spinal cord and muscles.

D. Nerves and muscles.

Question 3. The largest part of the human brain is the:

A. Cerebellum.

B. Medulla oblongata.

C. Cerebrum.

D. Hypothalamus.

Question 4. Which part of the brain is mainly responsible for coordinating muscular movements and maintaining balance?

A. Cerebrum.

B. Cerebellum.

C. Medulla oblongata.

D. Hypothalamus.

Question 5. The part of the brain that regulates breathing and heart rate is the:

A. Cerebrum.

B. Cerebellum.

C. Medulla oblongata.

D. Thalamus.

Question 6. The spinal cord is protected by the:

A. Rib cage.

B. Vertebral column.

C. Pelvic girdle.

D. Sternum.

Question 7. Which of the following forms part of the peripheral nervous system?

A. Brain.

B. Spinal cord.

C. Spinal nerves.

D. Cerebellum.

Question 8. The autonomic nervous system mainly controls:

A. Voluntary writing movements only.

B. Involuntary activities of internal organs.

C. Conscious thinking.

D. Memory and learning only.

Question 9. Which division of the autonomic nervous system prepares the body for emergency situations?

A. Parasympathetic.

B. Sympathetic.

C. Somatic.

D. Sensory.

Question 10. The basic structural and functional unit of the nervous system is the:

A. Nephron.

B. Neuron.

C. Alveolus.

D. Platelet.

Question 11. Which part of a neuron receives signals from other neurons?

A. Axon.

B. Dendrites.

C. Myelin sheath.

D. Synaptic cleft.

Question 12. The function of the myelin sheath is to:

A. Produce blood cells.

B. Insulate the axon and increase impulse conduction speed.

C. Digest neurotransmitters.

D. Receive light stimuli.

Question 13. The gaps between sections of the myelin sheath are called:

A. Synaptic knobs.

B. Nodes of Ranvier.

C. Dendrites.

D. Cell bodies.

Question 14. Which neuron carries impulses from sensory receptors towards the central nervous system?

A. Motor neuron.

B. Relay neuron.

C. Sensory neuron.

D. Multipolar neuron.

Question 15. The main function of a motor neuron is to:

A. Carry impulses from receptors to the CNS.

B. Carry impulses from the CNS to effectors.

C. Produce hormones.

D. Protect the brain.

Question 16. Relay neurons are mainly located in the:

A. Skin.

B. Central nervous system.

C. Muscles.

D. Glands.

Question 17. A neuron with many dendrites and one axon is classified structurally as:

A. Unipolar.

B. Bipolar.

C. Multipolar.

D. Non-polar.

Question 18. The resting potential of a typical neuron is approximately:

A. +70 mV.

B. −70 mV.

C. 0 mV.

D. +100 mV.

Question 19. During depolarisation, which ions move rapidly into the neuron?

A. Sodium ions.

B. Potassium ions.

C. Calcium ions only.

D. Chloride ions only.

Question 20. During repolarisation, potassium ions generally:

A. Move into the neuron.

B. Move out of the neuron.

C. Remain permanently outside the neuron.

D. Change into sodium ions.

Question 21. The movement of an impulse from one node of Ranvier to another in a myelinated axon is called:

A. Diffusion.

B. Saltatory conduction.

C. Osmosis.

D. Active transport.

Question 22. The junction between two communicating neurons is called a:

A. Receptor.

B. Synapse.

C. Dendrite.

D. Ganglion.

Question 23. Which substance is released into the synaptic cleft to transmit a signal?

A. Haemoglobin.

B. Neurotransmitter.

C. Insulin only.

D. Glycogen.

Question 24. Which ion enters the presynaptic terminal to trigger neurotransmitter release?

A. Calcium.

B. Chloride.

C. Iron.

D. Iodide.

Question 25. A reflex action is best described as a:

A. Slow voluntary response.

B. Rapid automatic and involuntary response.

C. Learned decision that always requires conscious thought.

D. Movement that occurs only during sleep.

Question 26. The pathway followed by nerve impulses during a reflex action is called the:

A. Reflex arc.

B. Synaptic cleft.

C. Cerebral cortex.

D. Myelin pathway.

Question 27. Which of the following is an example of a simple reflex action?

A. Solving a mathematical problem.

B. Writing an essay.

C. Withdrawing the hand from a hot object.

D. Reading a textbook.

Question 28. The knee-jerk reflex is mainly coordinated by the:

A. Cerebrum.

B. Spinal cord.

C. Stomach.

D. Cerebellum.

Question 29. Pavlov's experiment involving a bell and a dog demonstrated:

A. A simple withdrawal reflex.

B. A conditioned reflex.

C. Positive phototropism.

D. A voluntary movement.

Question 30. Which of the following is an important way of protecting the nervous system?

A. Riding a motorcycle without a helmet.

B. Ignoring road safety rules.

C. Wearing protective helmets and seat belts.

D. Misusing harmful drugs.

SECTION B: STRUCTURED QUESTIONS (50 MARKS)

Instructions: Answer all questions. Show clear understanding and use appropriate biological terms.

Question 31. Components of the nervous system (8 marks)

a) Define the human nervous system. (2 marks)

b) Name the two major components of the human nervous system. (2 marks)

c) State two functions of the spinal cord. (2 marks)

d) State two functions of the cerebellum. (2 marks)

Question 32. Structure and types of neurons (8 marks)

a) Define a neuron. (2 marks)

b) State four functions of the following parts of a neuron: (4 marks)

i. Dendrites.

ii. Axon.

iii. Myelin sheath.

iv. Axon terminals.

c) Name the three main types of neurons according to their functions. (2 marks)

Question 33. Transmission of nerve impulses (8 marks)

a) Define a nerve impulse. (2 marks)

b) State two roles of sodium and potassium ions in the transmission of nerve impulses. (2 marks)

c) Explain how an impulse is transmitted along a myelinated neuron. (4 marks)

Question 34. Transmission across a synapse (8 marks)

a) Define a synapse. (2 marks)

b) Name two structures found at a chemical synapse. (2 marks)

c) Explain how an impulse is transmitted across a chemical synapse. (4 marks)

Question 35. Simple reflex actions (9 marks)

a) Define a reflex action. (2 marks)

b) Draw a labelled diagram of a simple reflex arc. (3 marks)

c) Explain what happens when a person accidentally touches a hot object. (4 marks)

Question 36. Conditioned reflex actions (9 marks)

a) Define a conditioned reflex action. (2 marks)

b) Describe Pavlov's experiment to demonstrate conditioned reflexes. (4 marks)

c) State three ways in which reflex actions are important in human beings. (3 marks)

TOTAL: 50 MARKS

16.0 ANSWERS AND MARKING SCHEME

SECTION A: MULTIPLE-CHOICE ANSWERS

Question	Answer	Correct response
1	B	Receives information and coordinates responses
2	A	Brain and spinal cord
3	C	Cerebrum
4	B	Cerebellum
5	C	Medulla oblongata
6	B	Vertebral column
7	C	Spinal nerves
8	B	Involuntary activities of internal organs
9	B	Sympathetic
10	B	Neuron
11	B	Dendrites
12	B	Insulates axon and increases conduction speed
13	B	Nodes of Ranvier
14	C	Sensory neuron
15	B	Carries impulses to effectors
16	B	Central nervous system
17	C	Multipolar
18	B	−70 mV
19	A	Sodium ions
20	B	Move out of the neuron
21	B	Saltatory conduction
22	B	Synapse
23	B	Neurotransmitter
24	A	Calcium
25	B	Rapid automatic and involuntary response
26	A	Reflex arc
27	C	Withdrawing the hand from a hot object
28	B	Spinal cord
29	B	Conditioned reflex
30	C	Wearing protective helmets and seat belts

SECTION B: SUGGESTED ANSWERS AND MARKING SCHEME

Question 31. Components of the nervous system (8 marks)

a) The nervous system is the body system consisting of the brain, spinal cord and nerves that receives information, processes it and coordinates responses to stimuli. (2 marks)

b)

1. Central Nervous System (CNS). (1)

2. Peripheral Nervous System (PNS). (1)

c) Functions of the spinal cord:

1. Transmits sensory impulses to the brain. (1)
2. Coordinates many reflex actions. (1)

Accept transmission of motor impulses from the brain to effectors.

d) Functions of the cerebellum:

1. Coordinates voluntary muscular movements. (1)
2. Maintains body balance and posture. (1)

Question 32. Structure and types of neurons (8 marks)

a) A neuron is a specialised nerve cell that receives, processes and transmits information through electrical and chemical signals. (2 marks)

b) Functions:

i. Dendrites – receive signals and carry them towards the cell body. (1)

ii. Axon – carries impulses away from the cell body. (1)

iii. Myelin sheath – insulates the axon and increases the speed of impulse transmission. (1)

iv. Axon terminals – transmit signals to another neuron or an effector cell. (1)

c) Types of neurons:

1. Sensory neurons. (1)
2. Motor neurons. (1)
3. Relay neurons. (Accept all three; award 2 marks for any two correctly named if the marking is adjusted to the full list.)

Question 33. Transmission of nerve impulses (8 marks)

a) A nerve impulse is a rapid electrical signal transmitted along the membrane of a neuron. (2 marks)

b) Roles of sodium and potassium ions:

1. Sodium ions enter the neuron during depolarisation. (1)
2. Potassium ions move out during repolarisation. (1)

c) Transmission along a myelinated neuron:

1. An action potential is generated when the membrane reaches threshold. (1)
2. Electrical signals are regenerated at the nodes of Ranvier. (1)
3. The impulse appears to jump from one node to the next. (1)
4. This is called saltatory conduction and increases the speed of transmission. (1)

Question 34. Transmission across a synapse (8 marks)

a) A synapse is a specialised junction through which a neuron communicates with another neuron or an effector cell. (2 marks)

b) Structures of a chemical synapse:

1. Presynaptic terminal. (1)
2. Synaptic cleft. (1)

Accept synaptic vesicles, postsynaptic membrane or receptors.

c) Transmission across a chemical synapse:

1. An impulse reaches the presynaptic terminal. (1)
2. Calcium ions enter the presynaptic terminal. (1)
3. Synaptic vesicles release neurotransmitters into the synaptic cleft. (1)
4. Neurotransmitters bind to receptors on the postsynaptic membrane, producing a response. (1)

Question 35. Simple reflex actions (9 marks)

a) A reflex action is a rapid, automatic and involuntary response to a stimulus. (2 marks)

b) Labelled reflex arc (3 marks):

Award marks for a correctly drawn pathway containing the following:

- Receptor. (½)
- Sensory neuron. (½)
- Spinal cord/relay neuron. (1)
- Motor neuron. (½)
- Effector. (½)

c) Response to touching a hot object:

1. Receptors in the skin detect the harmful heat. (1)
2. A sensory neuron carries impulses to the spinal cord. (1)
3. The spinal cord relays impulses through the appropriate motor pathway. (1)
4. Motor impulses cause muscles to contract, withdrawing the hand. (1)

Question 36. Conditioned reflex actions (9 marks)

a) A conditioned reflex action is a learned automatic response that develops through repeated association between stimuli. (2 marks)

b) Pavlov's experiment:

1. Food naturally causes a dog to salivate. (1)
2. A bell is repeatedly rung before food is presented. (1)
3. The dog learns to associate the bell with food. (1)
4. Eventually, the bell alone causes the dog to salivate. (1)

c) Importance of reflex actions:

1. Protect the body from harmful stimuli. (1)
2. Help maintain balance and posture. (1)
3. Protect sensitive organs such as the eyes. (1)

Accept support for learning and adaptation, or regulation of involuntary activities.

STRAND 1.0: LIFE SCIENCE

SUB-STRAND 1.6: SENSORY AND ENDOCRINE SYSTEM IN HUMAN BEINGS

1.0 INTRODUCTION

Human beings interact with their environment through specialised sense organs and the coordination systems of the body. These systems enable people to detect changes, interpret information and respond appropriately.

For example:

- When a learner sees a moving vehicle approaching, the eyes detect the vehicle and the nervous system coordinates a response.

- When a person hears a school bell, the ears detect sound and the brain interprets the message.
- When a person faces danger, the adrenal glands release adrenaline, preparing the body for rapid action.
- When the body needs to regulate its rate of metabolism, the thyroid gland releases thyroxine.

The sensory system and endocrine system work together with the nervous system to coordinate body activities and maintain a stable internal environment.

Learning outcomes

By the end of this sub-strand, the learner should be able to:

1. Describe the structure of sense organs in human beings.
2. Relate the structure of sense organs to their functions.
3. Describe common ear disorders and their interventions.
4. Relate the components of the endocrine system to their roles in human beings.
5. Evaluate the effects of variations in the secretion of adrenaline and thyroxine.
6. Compare the nervous and endocrine systems in human beings.
7. Appreciate the role of sense organs and the endocrine system in coordinating body activities.

Key inquiry question

How is the endocrine system important to human beings?

Other guiding questions:

- How do the eyes and ears help human beings interact with their environment?
- How does the body detect and respond to changes?
- Why is the correct secretion of hormones important for good health?
- How do the nervous and endocrine systems work together?

PART A: SENSORY SYSTEM IN HUMAN BEINGS

2.0 MEANING OF A SENSORY SYSTEM

A **sensory system** is a group of specialised organs, receptors, nerves and parts of the brain that detect stimuli and enable the body to interpret information from the internal and external environment.

A **stimulus** is any detectable change in the internal or external environment that can produce a response.

Examples of stimuli include:

- Light.
- Sound.
- Heat.
- Cold.
- Pressure.
- Pain.
- Chemicals in food and air.
- Changes in body position.

A **sensory receptor** is a specialised cell or nerve ending that detects a particular type of stimulus and converts it into an electrical signal.

Examples:

Receptor	Stimulus detected
Photoreceptors	Light
Mechanoreceptors	Mechanical pressure, vibration or movement
Chemoreceptors	Chemicals
Thermoreceptors	Temperature changes
Nociceptors	Potentially harmful stimuli associated with pain

2.1 Importance of the sensory system

The sensory system is important because it:

1. Enables human beings to detect changes in their environment.
2. Helps people recognise objects, people and places.
3. Supports communication through hearing and vision.
4. Helps people maintain balance and body posture.
5. Warns the body about possible danger.
6. Supports learning, reading and writing.
7. Helps individuals identify food, smells and other environmental conditions.
8. Enables people to respond appropriately to changes in their surroundings.

The two sense organs covered in this sub-strand are:

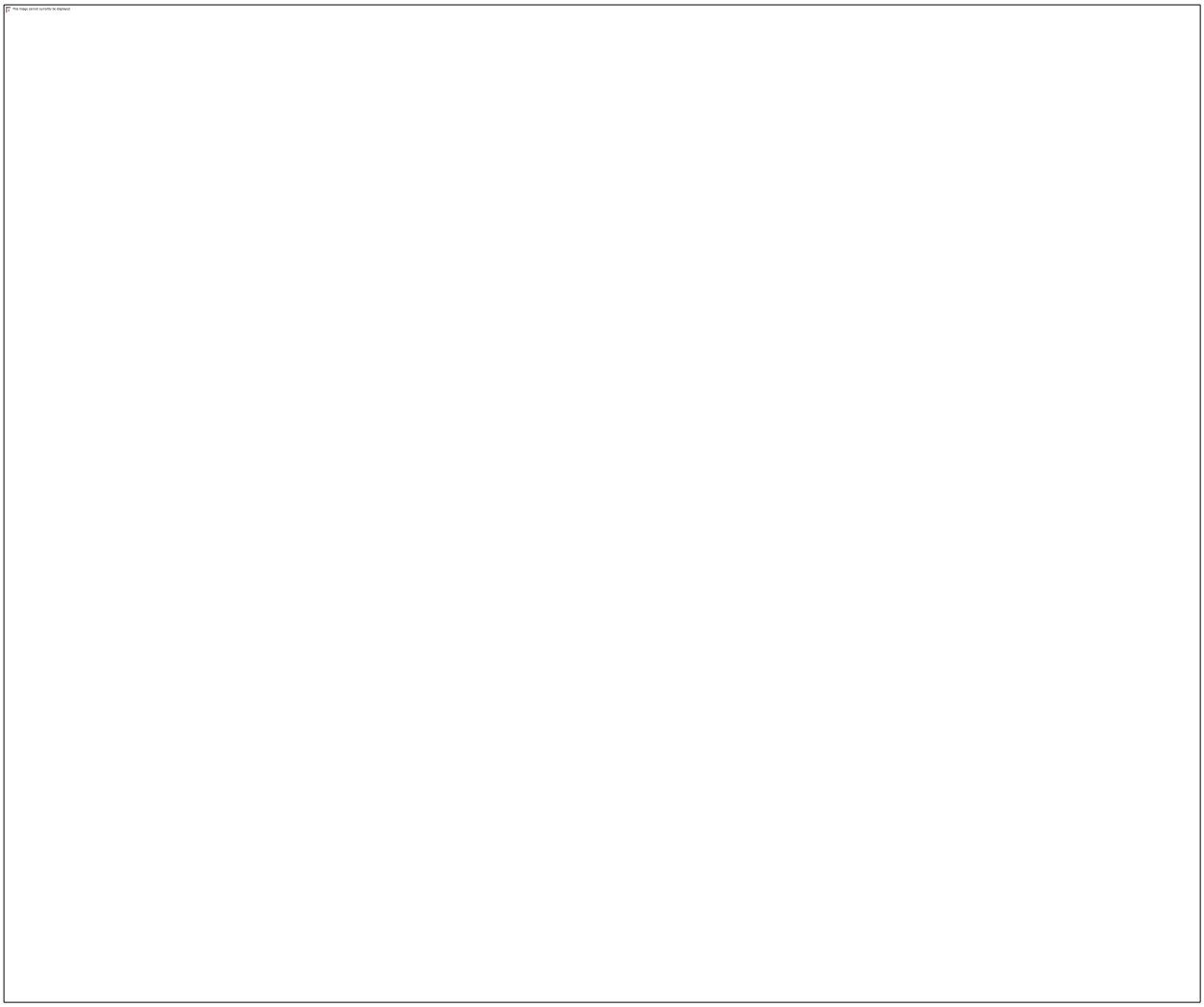
- The eye, which is responsible for vision.
- The ear, which is responsible for hearing and balance.

3.0 THE HUMAN EYE

3.1 Meaning of the eye

The **eye** is a specialised sense organ that detects light and enables human beings to see objects, colours, shapes, movement and distance.

The eye contains light-sensitive cells called photoreceptors, which convert light into electrical impulses. These impulses are transmitted to the brain for interpretation.



3.2 External structures of the eye

The external structures protect the eye and assist in its proper functioning.

1. Eyebrows

Eyebrows are strips of hair found above the eyes.

Functions:

1. Prevent sweat from flowing directly into the eyes.
2. Help protect the eyes from dust and other foreign particles.
3. Assist in facial expressions and communication.

2. Eyelids

Eyelids are movable folds of skin that cover the front of the eyes.

Functions:

1. Protect the eyes from injury and foreign particles.
2. Spread tears over the surface of the eye during blinking.
3. Prevent excessive light from entering when the eyes are closed.
4. Help keep the cornea moist.

3. Eyelashes

These are short hairs found along the edges of the eyelids.

Functions:

1. Trap dust and other small particles.
2. Help trigger blinking when touched by foreign objects.
3. Protect the surface of the eye.

4. Conjunctiva

The conjunctiva is a thin, transparent membrane covering the front of the sclera and lining the inner surfaces of the eyelids.

Functions:

1. Protects the front surface of the eye.
2. Helps keep the eye moist.
3. Provides a protective barrier against foreign particles and infection.

5. Lacrimal glands

These glands produce tears.

Functions of tears:

1. Lubricate the surface of the eye.
2. Wash away dust and small foreign particles.
3. Help protect the eye against microorganisms.
4. Prevent the cornea from drying out.

3.3 Internal structure of the eye and their functions

1. Cornea

The cornea is the transparent, curved front part of the eye covering the iris and pupil.

Functions:

1. Allows light to enter the eye.
2. Refracts (bends) incoming light towards the retina.
3. Protects the internal structures of the eye.
4. Provides much of the eye's focusing power.

Adaptation: Its transparency allows light to pass through, while its curved shape helps focus light.

2. Iris

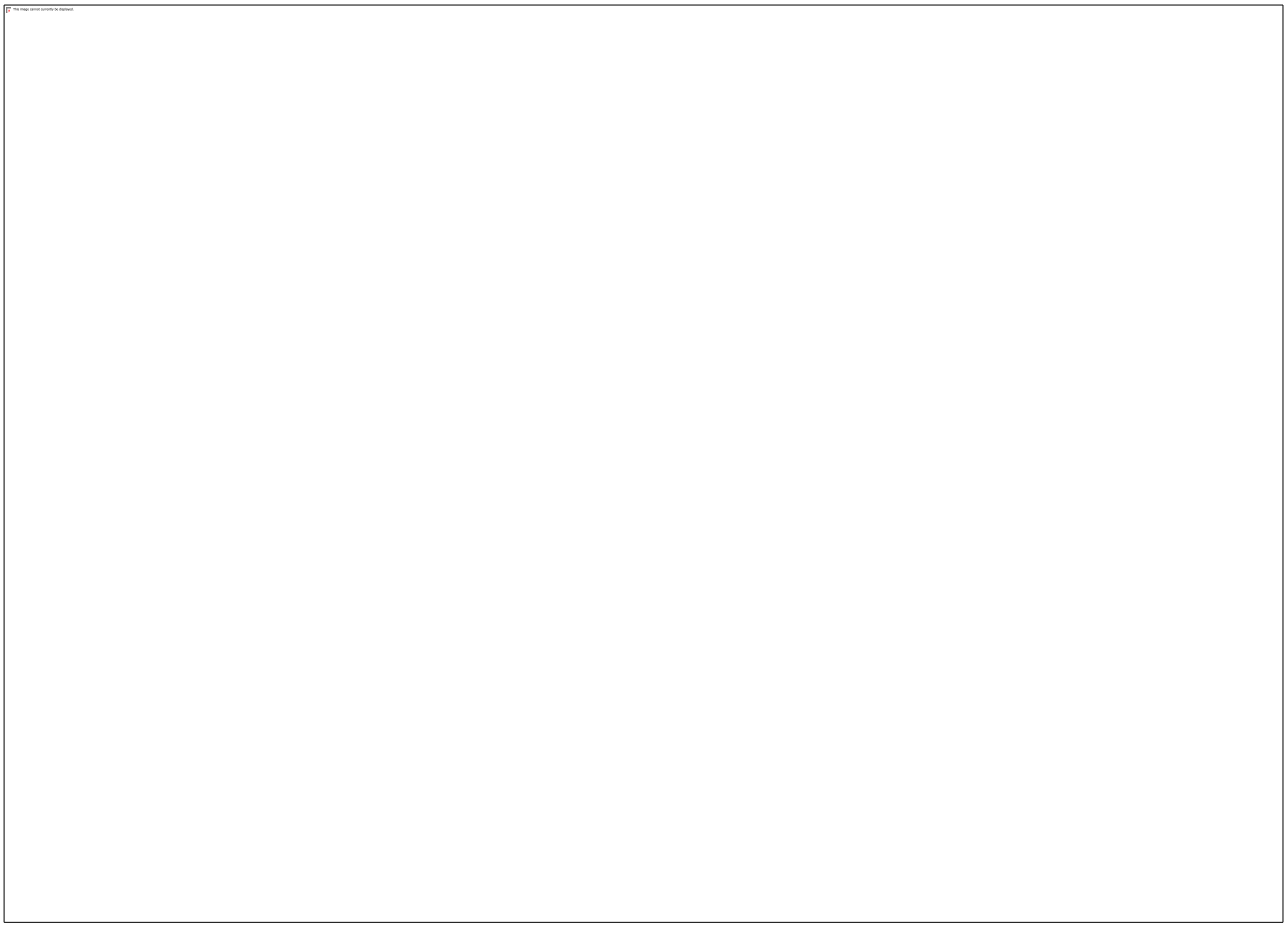
The iris is the coloured circular part of the eye surrounding the pupil.

Functions:

1. Controls the size of the pupil.
2. Regulates the amount of light entering the eye.
3. Helps protect the retina from excessive light.

The iris contains muscles that adjust pupil size.

- In bright light, circular muscles contract and the pupil becomes smaller.
- In dim light, radial muscles contract and the pupil becomes larger.



3. Pupil

The pupil is the opening at the centre of the iris through which light enters the eye.

Functions:

1. Allows light to enter the eye.
2. Regulates the quantity of light entering through changes in its diameter.

Important: The pupil is an opening, not a separate tissue or a lens.

4. Lens

The lens is a transparent, flexible, biconvex structure found behind the iris and pupil.

Functions:

1. Refracts light to focus it on the retina.
2. Changes its shape to focus on objects at different distances.
3. Helps produce a clear image on the retina.

Adaptation: The lens is transparent and flexible, allowing it to change curvature during accommodation.

5. Ciliary body and ciliary muscles

The ciliary body is a structure surrounding the lens. It contains ciliary muscles.

Functions:

1. Controls the curvature of the lens during accommodation.
2. Produces aqueous humour.
3. Helps support the lens through suspensory ligaments.

6. Suspensory ligaments

These are fibres connecting the lens to the ciliary body.

Functions:

1. Hold the lens in position.
2. Transmit tension from the ciliary muscles to the lens.
3. Assist in changing the shape of the lens during accommodation.

7. Retina

The retina is the light-sensitive layer lining the back of the eye.

It contains specialised photoreceptor cells:

- Rods.
- Cones.

Functions:

1. Detects light.
2. Converts light energy into electrical signals.
3. Initiates nerve impulses that travel to the brain.
4. Supports vision in different lighting conditions.

Rod cells

Rod cells are photoreceptors that are highly sensitive to low light intensity.

Functions:

1. Enable vision in dim light.
2. Help detect movement.
3. Provide black-and-white vision rather than colour discrimination.

Adaptations:

- They are highly sensitive to light.
- They contain the light-sensitive pigment rhodopsin.
- They are numerous in the peripheral retina.

Cone cells

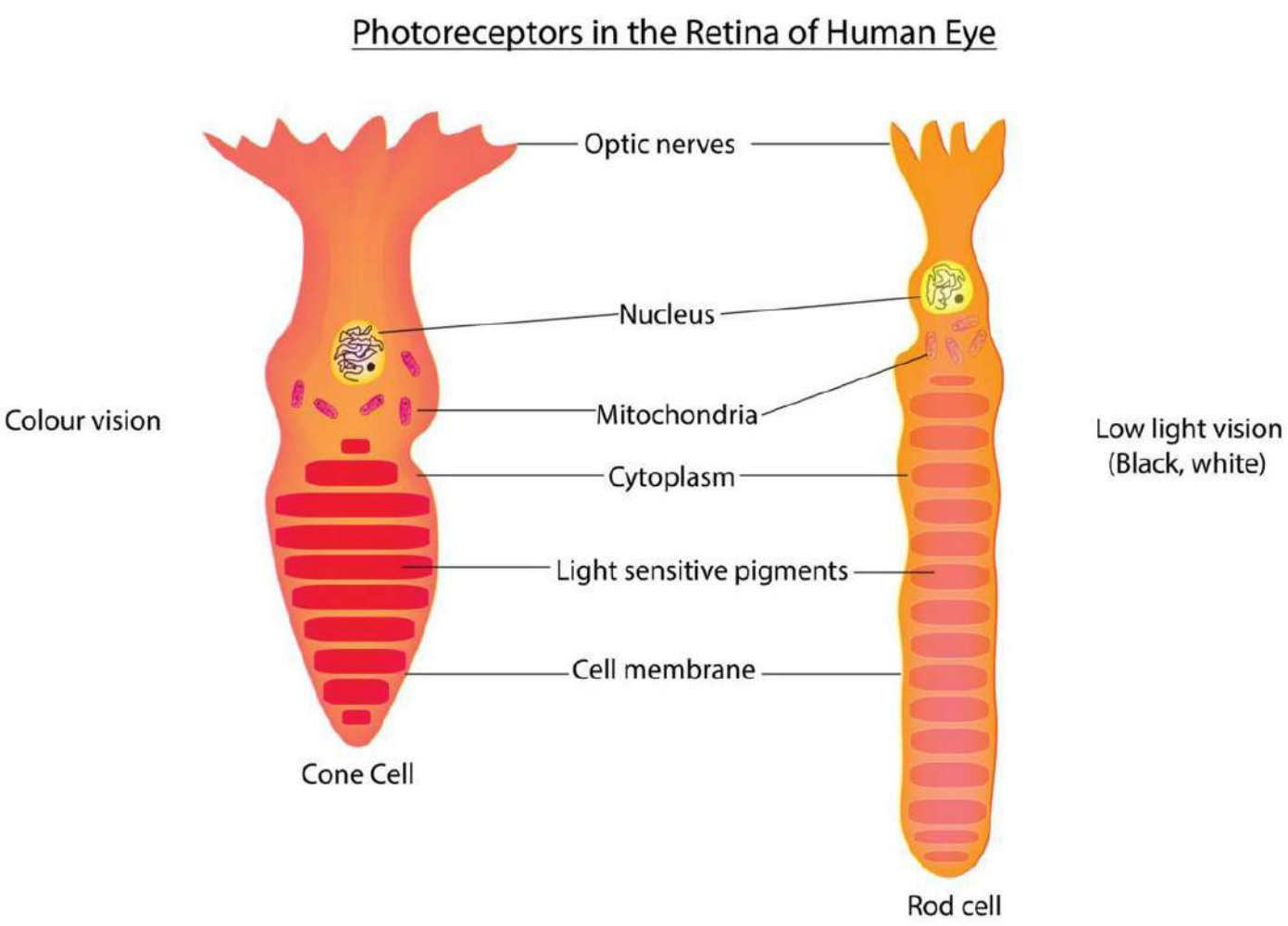
Cone cells are photoreceptors responsible for colour vision and detailed vision, especially in bright light.

Functions:

1. Enable colour vision.
2. Help distinguish fine details.
3. Provide sharp vision in bright light.

Adaptations:

- They function best in bright light.
- They contain different types of light-sensitive pigments.
- They are concentrated in the fovea, which supports sharp central vision.



8. Fovea (Yellow spot)

The fovea is a small central depression in the retina with a high concentration of cone cells.

Functions:

1. Provides the sharpest central vision.
2. Enables detailed observation of objects.
3. Supports accurate colour discrimination.

9. Blind spot (Optic disc)

The blind spot is the point on the retina where the optic nerve leaves the eye.

Functions and features:

1. Allows nerve fibres to leave the eye.
2. Contains no rods or cones.
3. Does not detect light.
4. Produces a small area of the visual field where an image cannot be detected by that eye.

10. Optic nerve

The optic nerve is a bundle of nerve fibres that carries visual information from the retina to the brain.

Functions:

1. Transmits electrical signals from the retina.
2. Carries visual information towards the brain.

3. Enables the brain to interpret what the eyes detect.

11. Choroid

The choroid is a dark, blood-vessel-rich layer between the sclera and retina.

Functions:

1. Supplies oxygen and nutrients to the retina.
2. Absorbs stray light to reduce internal reflection.
3. Helps maintain the health of the eye.

12. Sclera

The sclera is the tough, white outer covering of the eyeball.

Functions:

1. Protects the internal parts of the eye.
2. Maintains the shape of the eyeball.
3. Provides attachment points for eye muscles.

13. Aqueous humour

Aqueous humour is a clear watery fluid found in the front part of the eye, between the cornea and lens.

Functions:

1. Maintains pressure and shape in the front part of the eye.
2. Supplies nutrients to the cornea and lens.
3. Removes some metabolic wastes.
4. Allows light to pass through.

14. Vitreous humour

Vitreous humour is a transparent, jelly-like substance filling the large space behind the lens.

Functions:

1. Maintains the shape of the eyeball.
2. Supports the retina.
3. Allows light to pass towards the retina.
4. Helps maintain the internal structure of the eye.

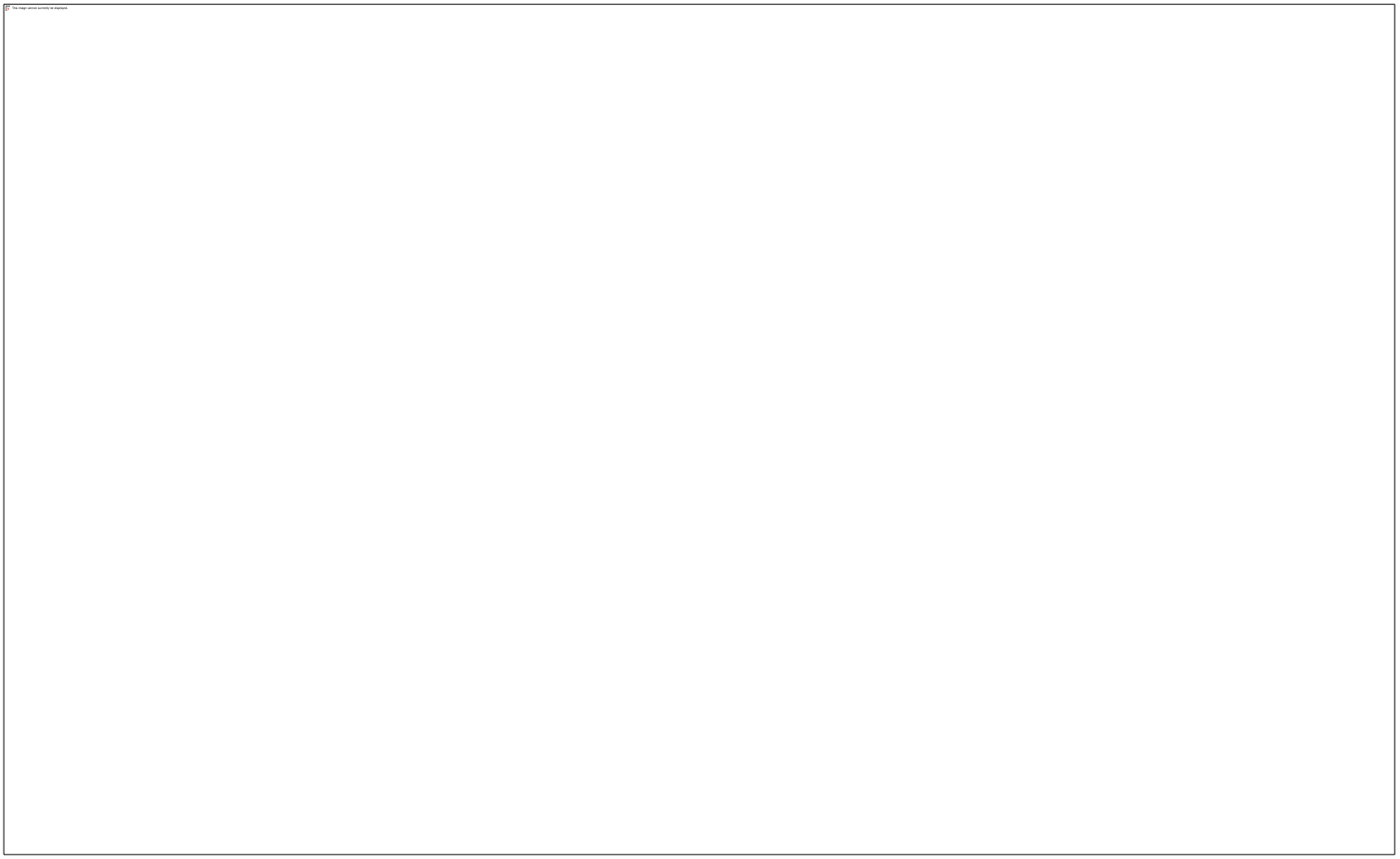
3.4 Adaptations of the eye to its functions

Structure	Adaptation	Advantage
Cornea	Transparent and curved	Allows light entry and refracts light.
Iris	Contains circular and radial muscles	Controls pupil size.
Pupil	Adjustable opening	Regulates light entering the eye.
Lens	Transparent and flexible	Focuses light on the retina.
Retina	Contains rods and cones	Detects light and colour.
Fovea	High concentration of cones	Provides sharp central vision.
Choroid	Contains many blood vessels and dark pigment	Nourishes the retina and absorbs stray light.
Sclera	Tough, fibrous outer coat	Protects and maintains the shape of the eye.
Optic nerve	Contains many nerve fibres	Transmits visual information to the brain.

Eyelids	Movable protective folds	Protect the eye and spread tears.

3.5 How the eye forms an image

Vision occurs when light from an object enters the eye and is focused on the retina.



Process of image formation

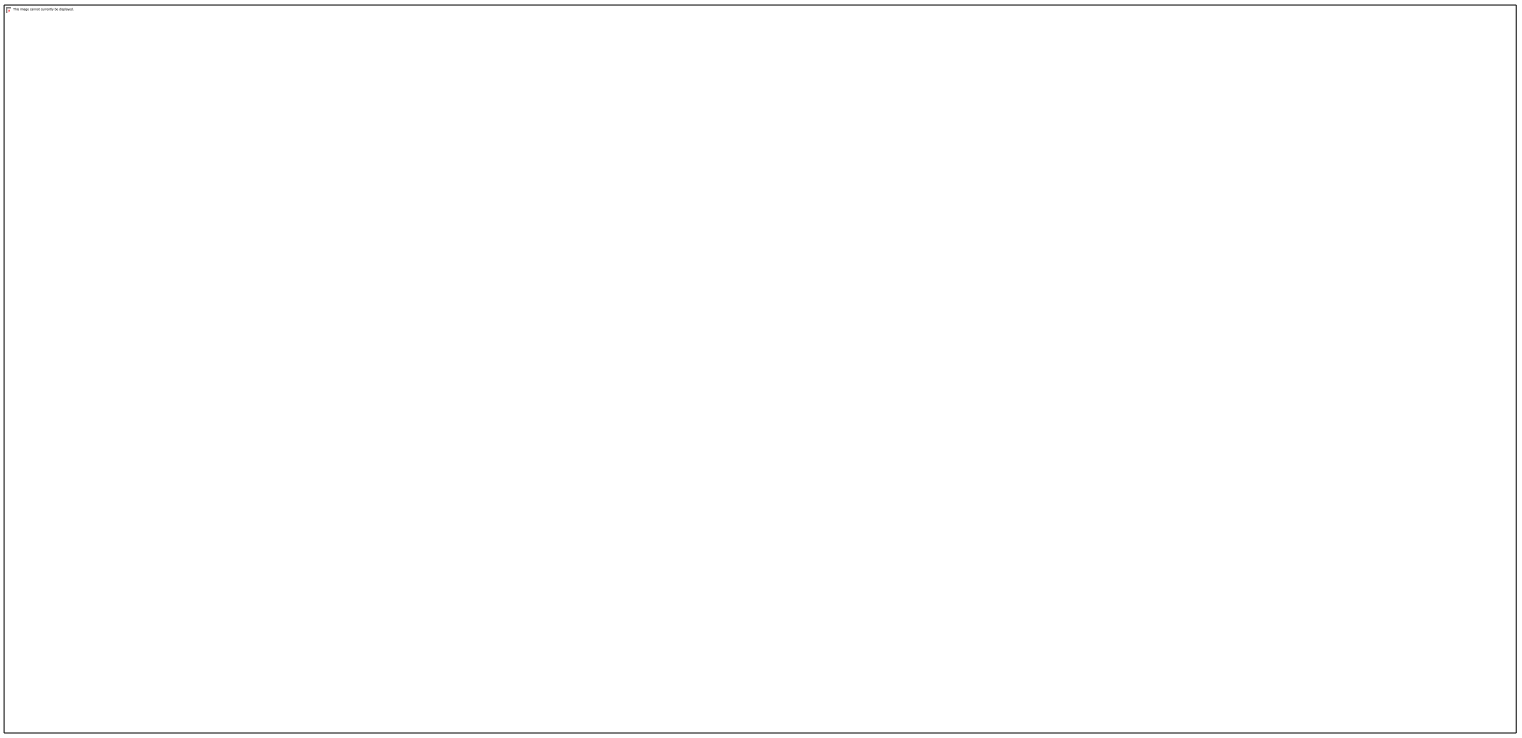
1. Light rays from an object enter the eye through the cornea.
2. The cornea refracts the light rays.
3. Light passes through the aqueous humour and pupil.
4. The lens further refracts the light to focus it on the retina.
5. A real, inverted and usually diminished image is formed on the retina.
6. Rods and cones detect the light.
7. Photoreceptors convert light into electrical signals.
8. Impulses travel along the optic nerve to the brain.
9. The brain interprets the signals, enabling a person to recognise the object.

Important: The retina receives an inverted image, but the brain processes the information so that we perceive the world in its normal orientation.

3.6 Accommodation of the eye

Accommodation is the ability of the eye to change the curvature of its lens so that objects at different distances are focused clearly on the retina.

This occurs through the action of the ciliary muscles and suspensory ligaments.



A. Focusing on a distant object

When a person looks at a distant object:

1. Ciliary muscles relax.
2. Suspensory ligaments become tight.
3. The lens becomes thinner and less convex.
4. The refractive power of the lens decreases.
5. Light is focused on the retina.

Example: Looking at a mountain from a distance or observing a building across a field.

B. Focusing on a near object

When a person looks at a nearby object:

1. Ciliary muscles contract.
2. Suspensory ligaments become less tight.
3. The lens becomes thicker and more convex.
4. The refractive power of the lens increases.
5. Light is focused on the retina.

Example: Reading a textbook, writing in an exercise book or examining a small object.

Differences between near and distant vision

Near vision	**Distant vision**
Ciliary muscles contract.	Ciliary muscles relax.
Suspensory ligaments loosen.	Suspensory ligaments become tight.
Lens becomes thicker and more convex.	Lens becomes thinner and less convex.
Refractive power increases.	Refractive power decreases.

3.7 Pupil reflex

The pupil reflex is the automatic adjustment of pupil size in response to changes in light intensity.

In bright light

1. Bright light stimulates photoreceptors in the retina.
2. Nerve impulses travel to the brain.
3. The brain sends signals to the muscles of the iris.
4. Circular muscles of the iris contract.
5. Radial muscles relax.
6. The pupil becomes smaller.
7. Less light enters the eye.

In dim light

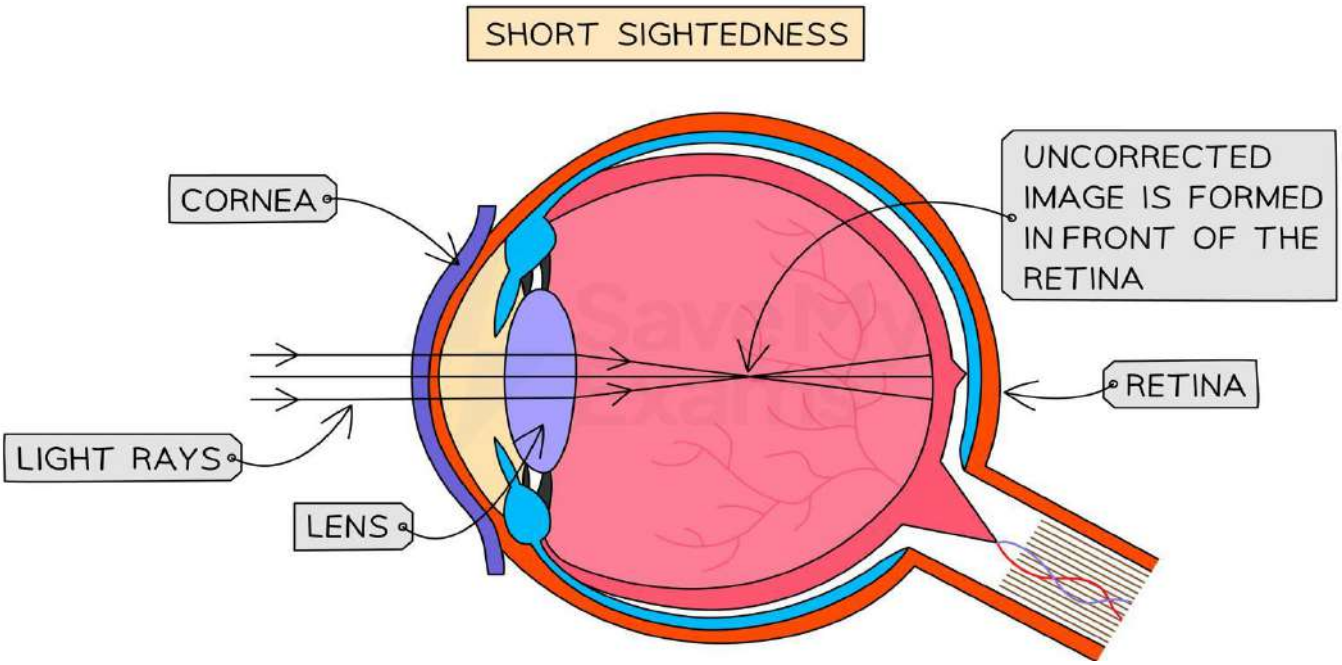
1. Reduced light intensity is detected by the retina.
2. Signals are transmitted to the brain.
3. Radial muscles of the iris contract.
4. Circular muscles relax.
5. The pupil becomes larger.
6. More light enters the eye.

Importance of the pupil reflex:

- Helps regulate the amount of light entering the eye.
- Protects the retina from excessive light.
- Helps the eye adapt to changing light conditions.

3.8 Common defects and disorders of the eye

The eye may be affected by defects of vision, infections, injuries and other diseases.



A. Myopia (Short-sightedness)

Myopia is a defect of vision in which a person sees nearby objects clearly but distant objects appear blurred.

Causes:

1. The eyeball may be too long.
2. The cornea or lens may refract light too strongly.
3. Light from distant objects is focused in front of the retina.

Correction:

- Use of concave (diverging) lenses.
- Appropriate contact lenses.
- Refractive surgery for suitable individuals following professional assessment.

B. Hyperopia (Long-sightedness)

Hyperopia is a defect of vision in which nearby objects are difficult to see clearly, while distant objects may be clearer.

Causes:

1. The eyeball may be too short.
2. The cornea or lens may have insufficient refractive power.
3. Light would be focused behind the retina if accommodation did not compensate.

Correction:

- Use of convex (converging) lenses.
- Contact lenses.
- Other appropriate treatment following an eye examination.

C. Astigmatism

Astigmatism is a vision defect caused by an irregular curvature of the cornea or lens.

Effects:

- Blurred vision.
- Distorted images.
- Difficulty seeing fine details.
- Eye strain or headaches in some people.

Correction:

- Cylindrical or toric lenses.
- Contact lenses.
- Suitable refractive procedures when recommended by an eye specialist.

D. Presbyopia

Presbyopia is an age-related reduction in the ability of the eye to focus on nearby objects.

Cause:

- The lens gradually loses flexibility with age.
- The eye becomes less able to increase the curvature of the lens during accommodation.

Effects:

1. Difficulty reading small print.
2. Need to hold reading materials farther away.
3. Eye strain during close work.

Correction:

- Reading glasses.
- Bifocal or progressive lenses.
- Other suitable optical correction.

E. Cataracts

A cataract is the clouding of the normally transparent lens of the eye.

Causes and risk factors:

- Ageing.
- Eye injuries.
- Certain medical conditions.
- Long-term use of some medicines, such as corticosteroids.
- Excessive exposure to ultraviolet radiation.

Effects:

1. Blurred or cloudy vision.
2. Difficulty seeing in dim light.
3. Increased sensitivity to glare.
4. Faded colours.
5. Difficulty reading and recognising objects.

Intervention:

- Professional eye examination.
- Cataract surgery, in which the cloudy lens is removed and usually replaced with an artificial lens.

F. Glaucoma

Glaucoma is a group of eye conditions that damage the optic nerve, often associated with increased pressure inside the eye, although it can also occur without high eye pressure.

Effects:

1. Gradual loss of peripheral vision in many cases.
2. Damage to the optic nerve.
3. Possible severe vision loss if untreated.

Intervention:

- Regular eye examinations.
- Prescribed eye drops.
- Laser treatment.
- Surgery where necessary.

Important: Glaucoma may develop without obvious early symptoms. Regular eye examinations are important, particularly for people at increased risk.

G. Conjunctivitis

Conjunctivitis is inflammation of the conjunctiva.

Possible causes:

- Viral infections.
- Bacterial infections.
- Allergic reactions.
- Irritants such as dust or smoke.

Symptoms:

1. Redness of the eye.
2. Itching or irritation.
3. Watery discharge.
4. Swelling of the eyelids.
5. Sticky discharge in some infections.

Prevention and management:

- Wash hands regularly.
- Avoid rubbing the eyes.
- Avoid sharing towels and personal items.
- Seek medical advice to determine the cause and appropriate treatment.

General measures for maintaining healthy eyes

1. Read and work in adequate lighting.
2. Avoid looking directly at the sun or intense light sources.
3. Wash hands before touching the eyes.
4. Avoid sharing towels and eye cosmetics.
5. Wear appropriate protective eyewear when working in laboratories and workshops.
6. Eat a balanced diet containing vitamin A and other essential nutrients.
7. Seek medical attention for persistent eye pain, redness or blurred vision.
8. Attend regular eye examinations.
9. Take suitable breaks during prolonged close work and screen use.
10. Use prescribed spectacles and contact lenses correctly.

4.0 THE HUMAN EAR

4.1 Meaning of the ear

The **ear** is a specialised sense organ responsible for hearing and maintaining balance and body orientation.

It detects sound waves and changes in the position and movement of the head.

The ear has three main divisions:

1. Outer ear.
2. Middle ear.
3. Inner ear.



4.2 The outer ear

The outer ear collects sound waves and directs them towards the eardrum.

It consists of the following structures:

1. Pinna (Auricle)

The pinna is the visible, flexible part of the ear found on the outside of the head.

Functions:

1. Collects sound waves from the surroundings.
2. Directs sound waves into the auditory canal.
3. Helps in identifying the direction from which sound originates.

Adaptation: Its curved shape helps collect and direct sound waves.

2. Auditory canal (External auditory meatus)

This is a tube-like passage that leads from the pinna to the eardrum.

Functions:

1. Directs sound waves towards the eardrum.
2. Contains hairs and glands that help trap dust and foreign particles.
3. Helps protect the deeper parts of the ear.

3. Ceruminous glands

These glands are found in the skin lining the auditory canal.

They produce earwax, also known as cerumen.

Functions of earwax:

1. Traps dust and small foreign particles.
2. Helps prevent insects and other objects from entering the ear.
3. Lubricates the ear canal.
4. Provides some protection against microorganisms.

4. Tympanic membrane (Eardrum)

The tympanic membrane is a thin membrane separating the outer ear from the middle ear.

Functions:

1. Vibrates when struck by sound waves.
2. Converts sound waves into mechanical vibrations.
3. Transmits vibrations to the middle-ear ossicles.

4.3 The middle ear

The middle ear is an air-filled cavity containing three small bones called auditory ossicles.

1. Malleus (Hammer)

The malleus is the first ossicle and is attached to the eardrum.

Function: Receives vibrations from the eardrum and passes them to the incus.

2. Incus (Anvil)

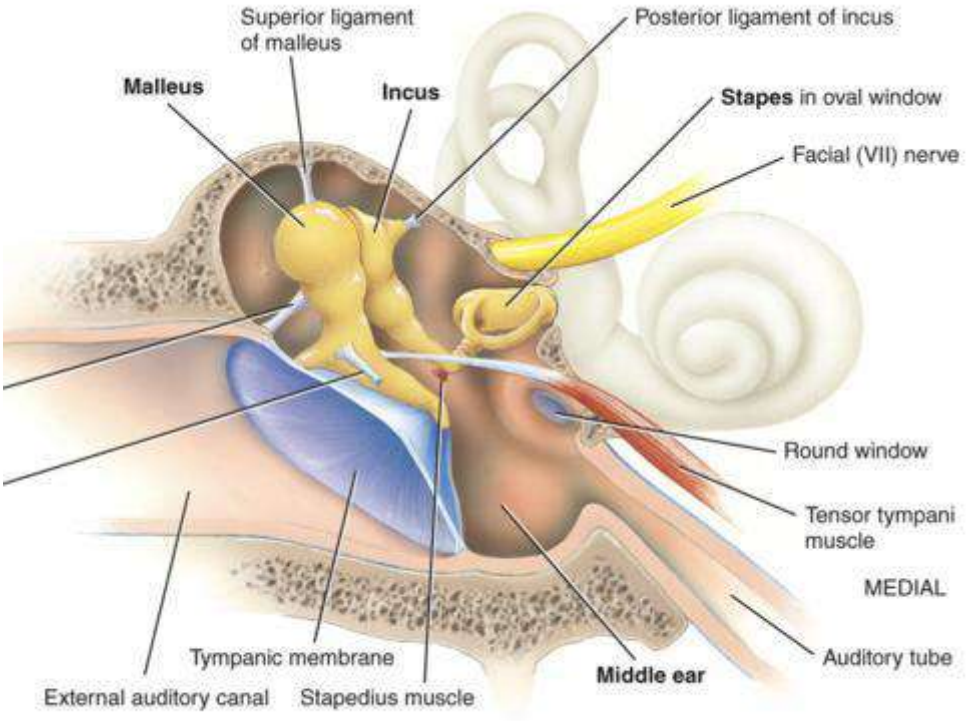
The incus is the middle ossicle.

Function: Transmits vibrations from the malleus to the stapes.

3. Stapes (Stirrup)

The stapes is the smallest of the three auditory ossicles and is connected to the oval window.

Function: Transmits vibrations to the inner ear through the oval window.



Frontal section showing location of auditory ossicles in the middle ear

Functions of the auditory ossicles

1. Transmit vibrations from the eardrum to the inner ear.
2. Increase the efficiency of sound transmission.
3. Help transfer vibrations from the air-filled middle ear into the fluid-filled inner ear.

4. Eustachian tube (Auditory tube)

This tube connects the middle ear to the upper part of the throat, specifically the nasopharynx.

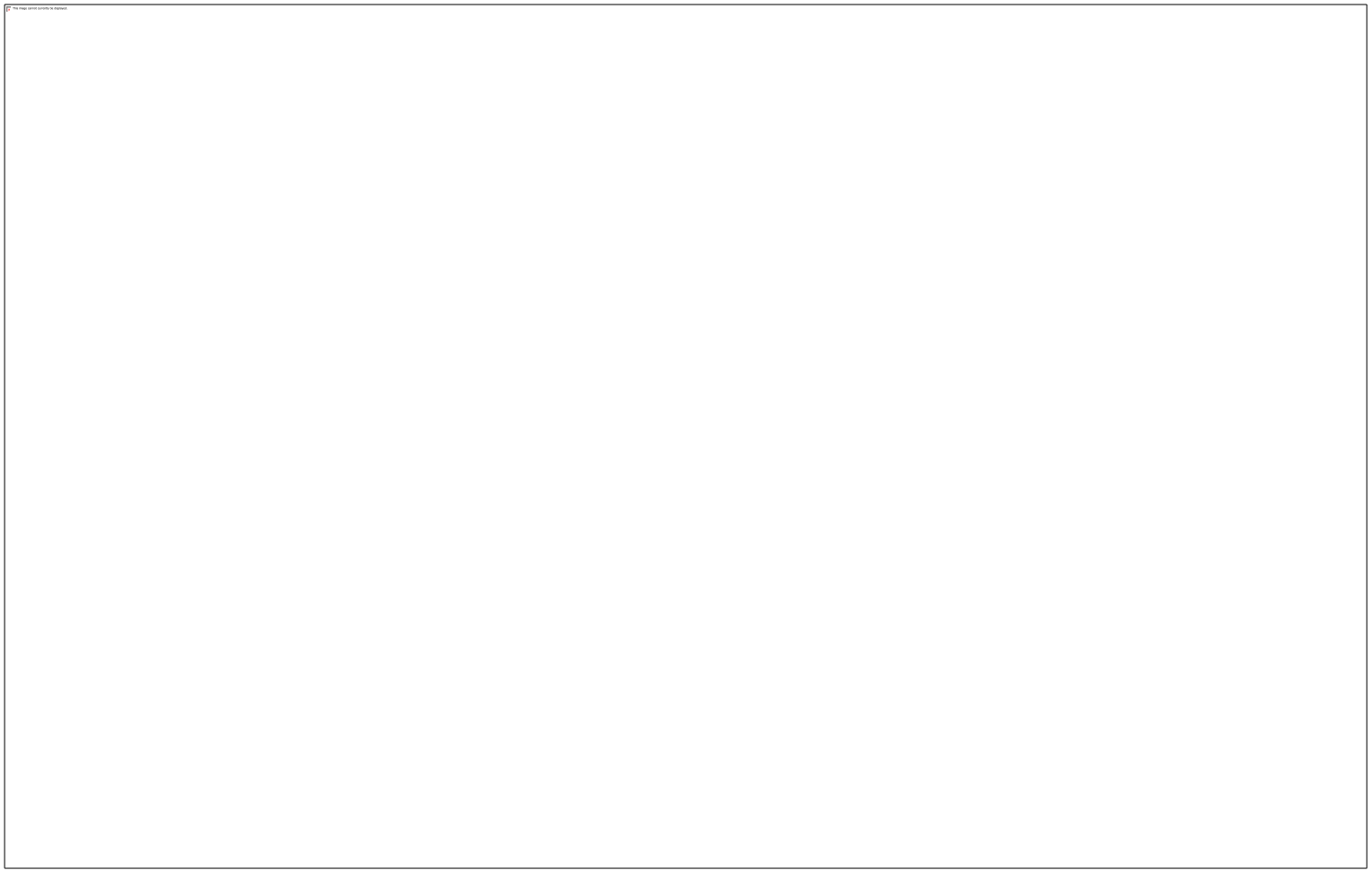
Functions:

1. Equalises air pressure on both sides of the eardrum.
2. Allows ventilation of the middle ear.
3. Helps maintain normal eardrum vibration.

Example: When travelling up a hill or flying in an aeroplane, changes in air pressure may cause a blocked feeling in the ears. Swallowing or yawning may help open the Eustachian tube and equalise pressure.

4.4 The inner ear

The inner ear contains structures responsible for hearing and balance.



1. Cochlea

The cochlea is a spiral-shaped, fluid-filled structure in the inner ear.

It contains sensory structures involved in hearing, including the organ of Corti.

Functions:

1. Converts mechanical vibrations into electrical nerve signals.
2. Enables the detection of different sound frequencies.
3. Sends hearing information towards the brain through the auditory part of the vestibulocochlear nerve.

Adaptation: It contains specialised hair cells that respond to movement of fluid and structures within the cochlea.

2. Organ of Corti

The organ of Corti is the sensory structure found inside the cochlea.

It contains specialised hair cells that respond to mechanical vibrations.

Functions:

1. Detects vibrations within the cochlea.
2. Converts mechanical movement into electrical signals.
3. Initiates nerve impulses for hearing.

3. Semicircular canals

These are three fluid-filled, curved canals arranged approximately at right angles to one another.

They detect rotational movements of the head.

Functions:

1. Detect angular or rotational movement of the head.
2. Help maintain dynamic balance.
3. Send information about head rotation to the brain.

4. Vestibule

The vestibule is the central part of the inner ear between the cochlea and semicircular canals.

It contains two important structures:

- Utricle.
- Saccule.

Functions:

1. Detects linear acceleration.
2. Helps detect the position of the head relative to gravity.
3. Contributes to static balance and posture.

5. Utricle and saccule

These structures contain sensory hair cells and small calcium carbonate crystals called otoliths.

Functions:

- The utricle is particularly sensitive to horizontal linear acceleration and head tilt.
- The saccule is particularly sensitive to vertical linear acceleration and head tilt.

6. Vestibulocochlear nerve (Auditory nerve)

This is the eighth cranial nerve, which has two main functional divisions:

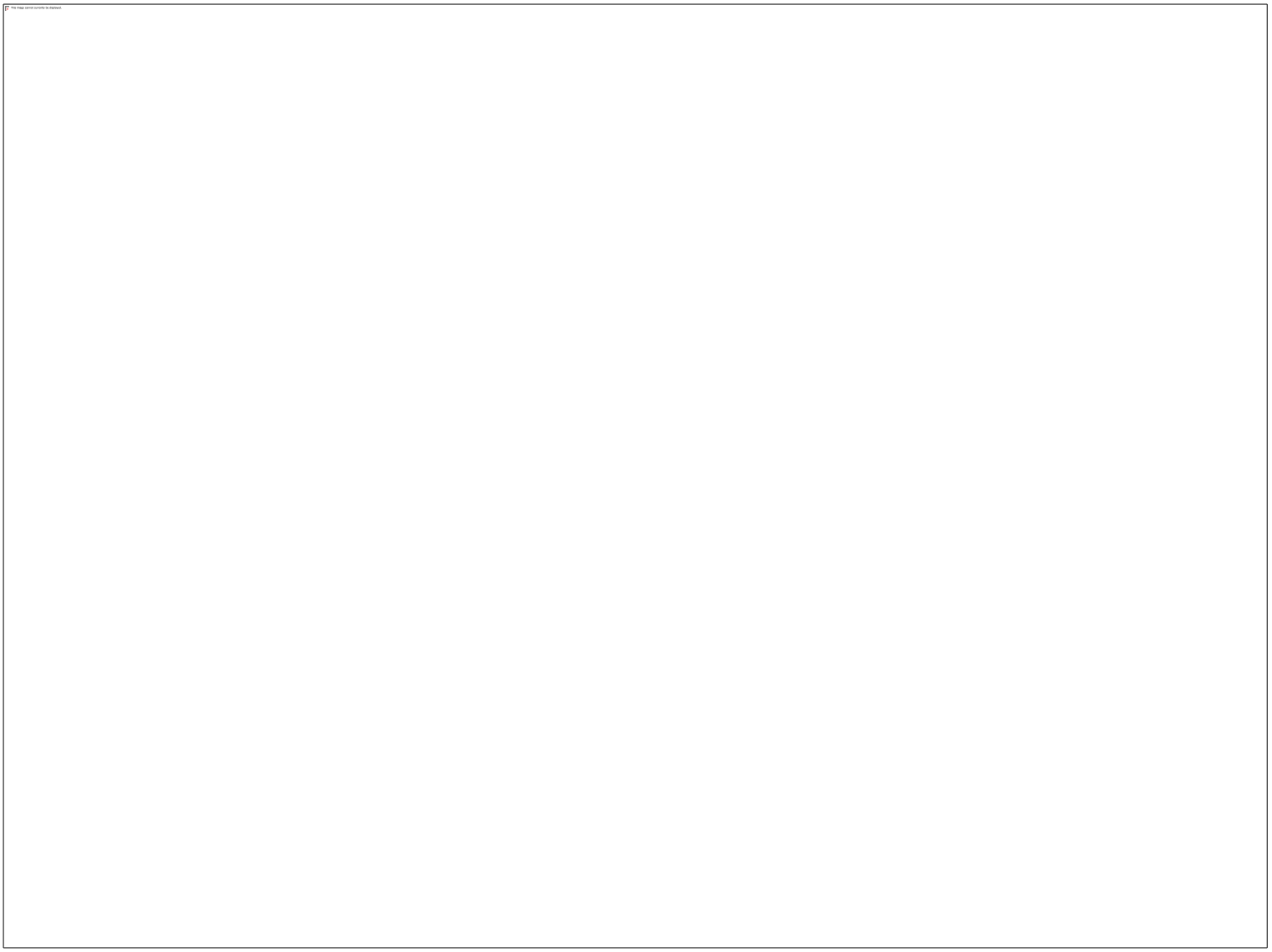
- Cochlear branch.
- Vestibular branch.

Functions:

1. Carries hearing information from the cochlea to the brain.
2. Carries balance information from the vestibular system to the brain.

4.5 The process of hearing

Hearing occurs when sound waves are collected by the outer ear and converted into electrical signals interpreted by the brain.



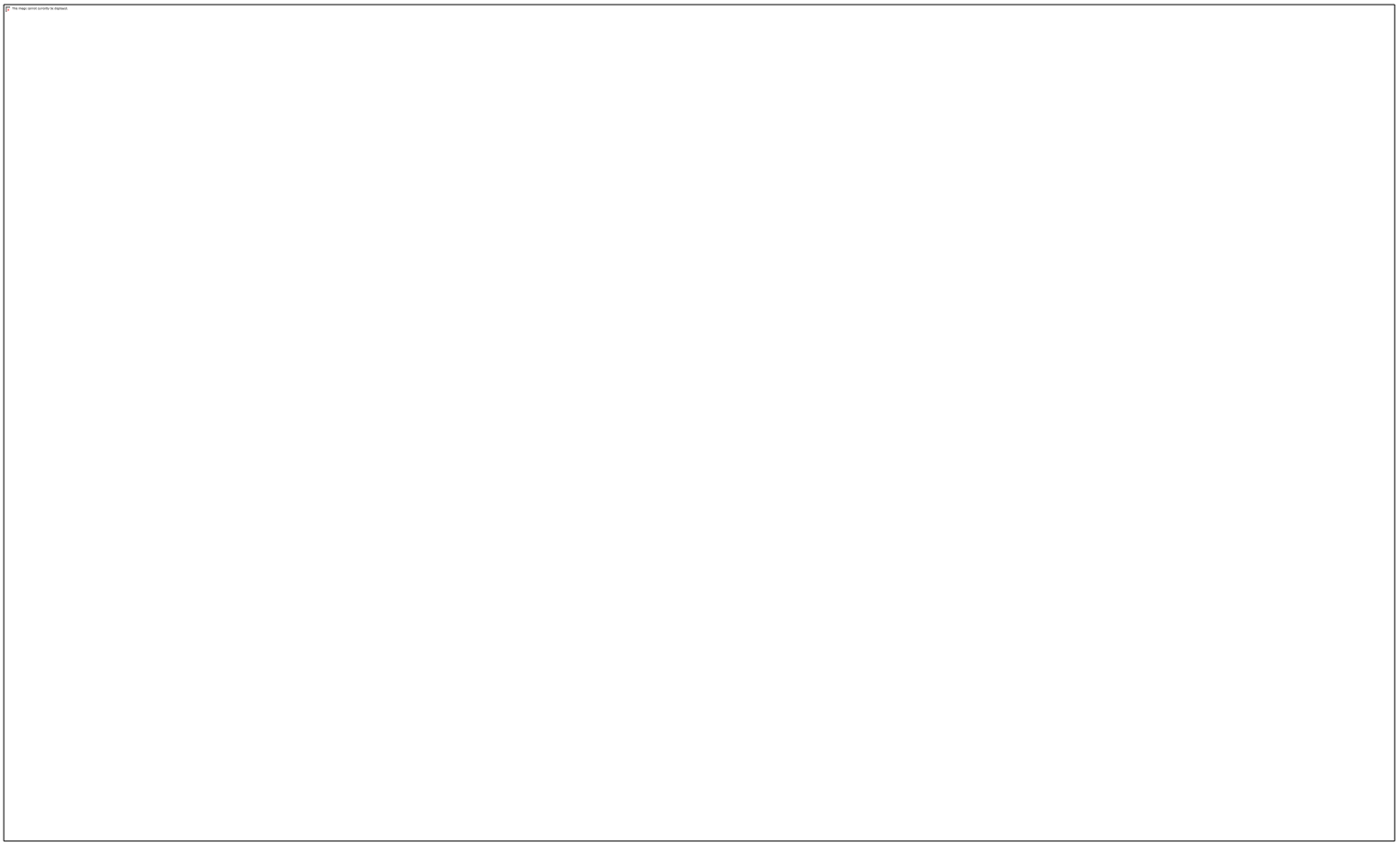
Steps involved in hearing

1. Sound waves are collected by the pinna.
2. The sound waves travel through the auditory canal.
3. The waves strike the tympanic membrane, causing it to vibrate.
4. Vibrations are transmitted to the malleus.
5. The malleus transfers vibrations to the incus.
6. The incus passes vibrations to the stapes.
7. The stapes moves against the oval window.
8. This produces pressure waves in the fluid of the cochlea.
9. Movement within the cochlea stimulates hair cells in the organ of Corti.
10. The hair cells generate electrical signals.
11. Impulses travel along the cochlear branch of the vestibulocochlear nerve.
12. The brain interprets the signals as sound.

4.6 The role of the ear in balance and posture

The ear is not only responsible for hearing. The vestibular apparatus in the inner ear helps the body maintain balance and orientation.

Balance is the ability to maintain the body's position and stability while standing, sitting or moving.



A. Role of semicircular canals

1. Detect rotational movements of the head.
2. When the head turns, fluid called endolymph moves within the semicircular canals.
3. Movement of the fluid bends sensory hair cells.
4. The hair cells produce electrical signals.
5. Signals travel to the brain through the vestibular nerve.
6. The brain uses the information to coordinate eye movements and posture.

Example: When a person turns their head to look behind while walking, the semicircular canals detect the rotation.

B. Role of the utricle and saccule

1. Detect linear acceleration and head position relative to gravity.
2. Movement of the head causes displacement of otoliths and associated structures.
3. This bends sensory hair cells.
4. Nerve signals are transmitted to the brain.
5. The brain uses this information to adjust posture and body position.

Examples:

- Detecting the movement of a vehicle when it accelerates.
- Maintaining balance when standing upright.
- Detecting a change in head position when bending forward.

C. Coordination of balance

The vestibular system works together with:

- The eyes, which provide visual information.
- Proprioceptors in muscles, tendons and joints, which detect body position and movement.
- The cerebellum and other brain regions, which coordinate posture and movement.

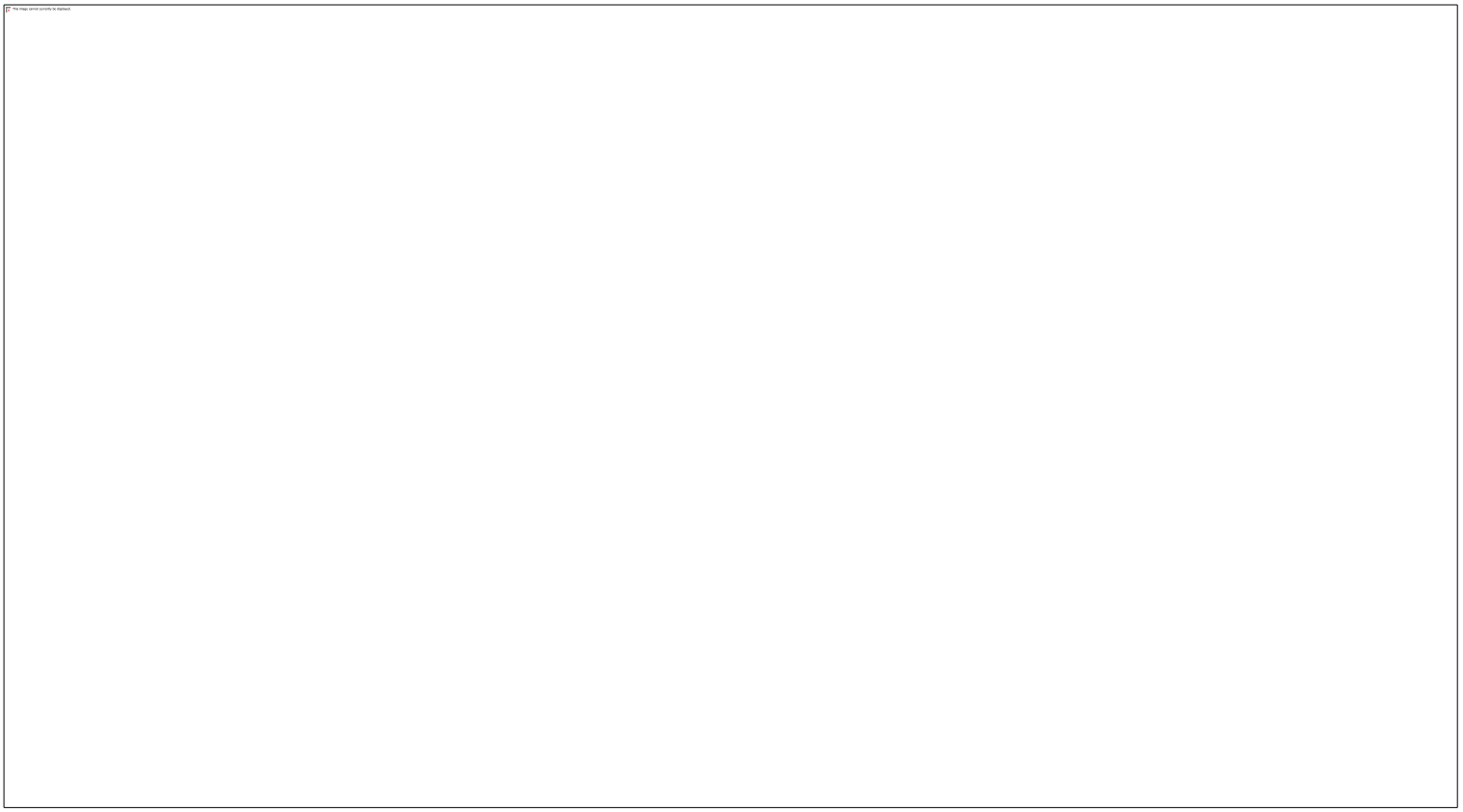
Importance of balance:

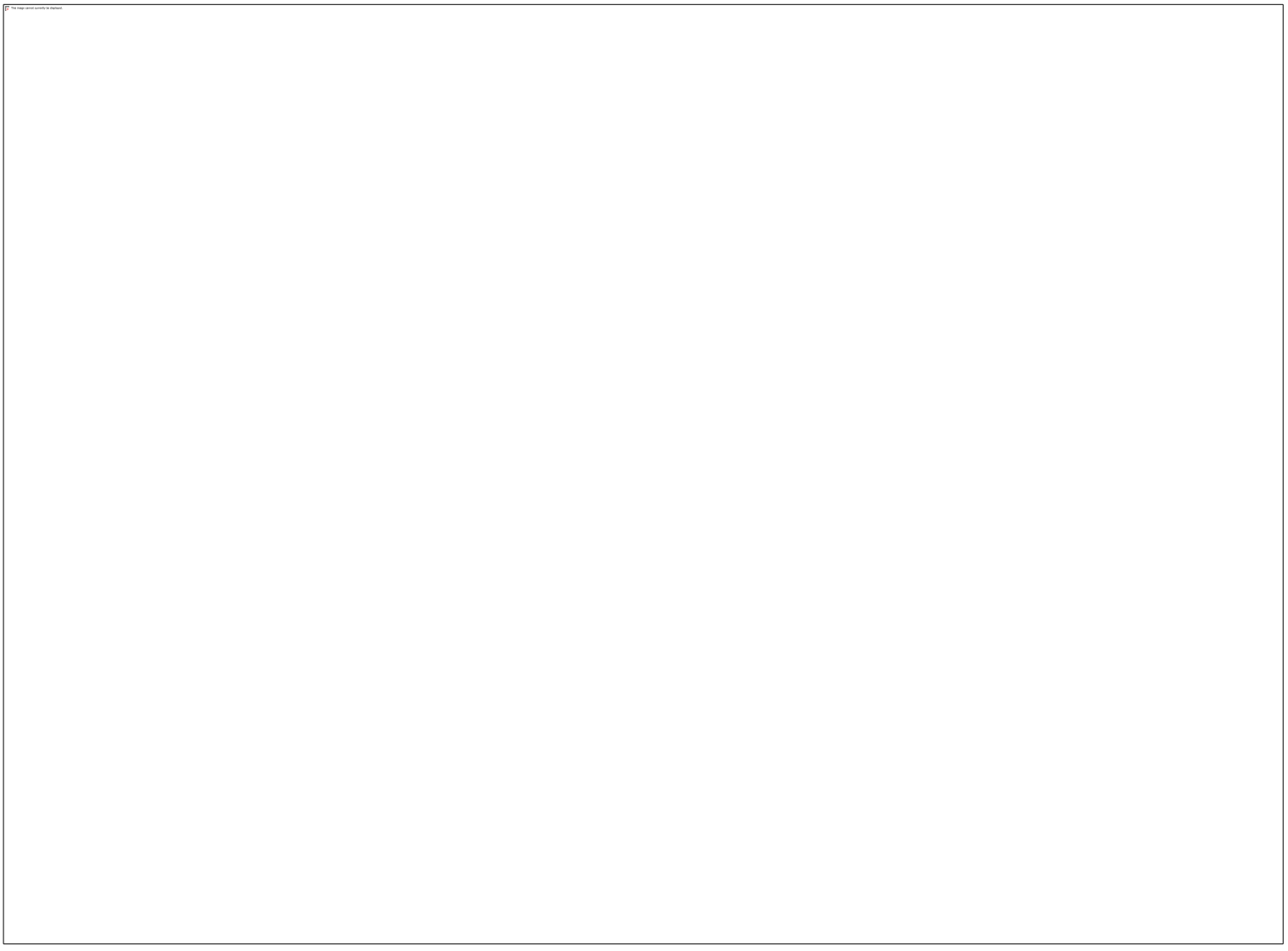
1. Enables a person to stand upright.
2. Helps prevent falls.
3. Supports walking, running and cycling.
4. Helps coordinate eye and head movements.
5. Supports participation in sports and physical activities.

4.7 Common ear disorders and their interventions

Ear disorders may affect hearing, balance or both. Some are caused by infections, injuries, excessive noise or age-related changes.







A. Otitis externa (Outer ear infection)

Otitis externa is inflammation or infection of the skin lining the external auditory canal.

It is sometimes called swimmer's ear.

Causes:

1. Bacterial or fungal infection.
2. Excessive moisture in the ear canal.
3. Scratching or injuring the ear canal.
4. Inserting objects such as cotton buds into the ear.

Signs and symptoms:

- Ear pain.
- Itching.
- Redness and swelling of the ear canal.
- Discharge from the ear.
- Temporary hearing difficulty if the canal becomes swollen.

Intervention:

1. Medical examination.
2. Prescribed ear drops where appropriate.
3. Keeping the ear dry during treatment.
4. Avoiding insertion of objects into the ear.

B. Otitis media (Middle ear infection)

Otitis media is an infection or inflammation of the middle ear, often associated with fluid accumulation behind the eardrum.

Causes:

- Bacterial infections.
- Viral infections.
- Respiratory infections that affect the Eustachian tube.

Signs and symptoms:

1. Ear pain.
2. Fever.
3. Temporary hearing difficulty.
4. Irritability, particularly in young children.
5. Fluid discharge if the eardrum ruptures.

Intervention:

- Medical examination.
- Pain relief as advised by a health professional.
- Antibiotics when a bacterial infection requires them.

- Monitoring for complications.
- Further specialist treatment for recurrent or persistent cases.

Prevention:

- Good hygiene.
- Avoiding exposure to tobacco smoke.
- Appropriate childhood vaccination.
- Early treatment of relevant infections.

C. Perforated eardrum

A perforated eardrum is a hole or tear in the tympanic membrane.

Causes:

1. Severe ear infections.
2. Inserting sharp objects into the ear.
3. Very loud explosions or sudden pressure changes.
4. Injury to the head or ear.

Signs and symptoms:

- Ear pain.
- Hearing loss.
- Ringing in the ear.
- Fluid or blood discharge.
- Dizziness in some cases.

Intervention:

1. Medical assessment.
2. Keeping the ear dry.
3. Avoiding insertion of objects into the ear.
4. Avoiding unprescribed ear drops.
5. Surgery may be required if the perforation does not heal.

Many small perforations heal naturally, but medical assessment is important.

D. Tinnitus

Tinnitus is the perception of sound, such as ringing, buzzing or humming, when no corresponding external sound is present.

Possible causes:

- Exposure to loud noise.
- Hearing loss.
- Ear infections.
- Certain medicines.
- Other ear or health conditions.

Management:

1. Identify and address the underlying cause where possible.
2. Avoid prolonged exposure to loud noise.
3. Use hearing protection in noisy environments.
4. Seek medical assessment if tinnitus is persistent or troubling.
5. Hearing therapy or sound therapy may help some individuals.

E. Hearing loss

Hearing loss is a reduced ability to detect or understand sounds.

It may be temporary or permanent and may affect one or both ears.

Types of hearing loss

1. Conductive hearing loss

This occurs when sound is not transmitted efficiently through the outer or middle ear.

Possible causes:

- Earwax blockage.
- Middle ear infections.
- Perforated eardrum.
- Damage to the ossicles.

Intervention:

- Removal of earwax by an appropriately trained health professional.
- Treatment of infections.
- Medical or surgical correction of structural problems where appropriate.
- Hearing aids in suitable cases.

2. Sensorineural hearing loss

This occurs when the cochlea's sensory cells, auditory nerve or related pathways are damaged.

Possible causes:

- Ageing.
- Prolonged exposure to loud noise.
- Certain medicines.
- Genetic factors.
- Some infections.

Intervention:

- Hearing assessment.
- Hearing aids.
- Cochlear implants for selected individuals with severe hearing loss.
- Communication support and rehabilitation.

3. Mixed hearing loss

This is a combination of conductive and sensorineural hearing loss.

F. Motion sickness

Motion sickness occurs when the brain receives conflicting information from the eyes, vestibular system and body-position receptors.

Examples:

- Feeling dizzy or nauseated when travelling by bus on a winding road.
- Feeling unwell when travelling by boat.

Symptoms:

1. Nausea.
2. Vomiting.
3. Dizziness.
4. Sweating.
5. Headache.

Management:

- Looking towards the horizon.
- Sitting where movement is less noticeable.
- Getting fresh air.
- Avoiding reading while travelling.
- Seeking medical advice for frequent or severe symptoms.

4.8 Ways of maintaining healthy ears

1. Avoid inserting cotton buds, pins or other objects into the ear canal.
2. Avoid prolonged exposure to loud music and machinery.
3. Use suitable hearing protection in noisy workplaces.
4. Keep the ears dry when prone to infections.
5. Seek medical attention for persistent ear pain or discharge.
6. Avoid using unprescribed ear drops.
7. Have hearing checked when hearing difficulties occur.
8. Avoid self-treatment of ear injuries.
9. Observe safety precautions when working with noisy machines.
10. Seek professional assistance for earwax blockage.

Application in the Kenyan environment

Learners should appreciate that hearing protection is important in:

- Workshops using power tools.
- Construction sites.
- Factories.
- Agricultural machinery operations.

- Entertainment venues with loud music.
- Transport environments with excessive noise.

Class discussion: Why should a learner avoid listening to music through earphones at very high volume for long periods?

PART B: THE ENDOCRINE SYSTEM IN HUMAN BEINGS

5.0 MEANING OF THE ENDOCRINE SYSTEM

The **endocrine system** is a system of ductless glands and hormone-producing tissues that release hormones directly into the blood to regulate and coordinate body activities.

An **endocrine gland** is a ductless gland that produces and releases hormones into the bloodstream or surrounding tissue fluid.

A **hormone** is a chemical messenger produced by specialised cells or glands and carried to target cells or organs, where it produces a specific effect.

A **target organ** is an organ or tissue whose cells have receptors for a particular hormone.

5.1 Characteristics of hormones

1. They are chemical messengers.
2. They are produced by endocrine cells or glands.
3. They are released into the blood or surrounding tissue fluid.
4. They act on specific target cells that possess suitable receptors.
5. They regulate activities such as growth, metabolism and reproduction.
6. They are effective in relatively small quantities.
7. Their effects may be slower to develop but last longer than many nervous responses.
8. Their secretion is often controlled by feedback mechanisms.

5.2 Functions of the endocrine system

The endocrine system:

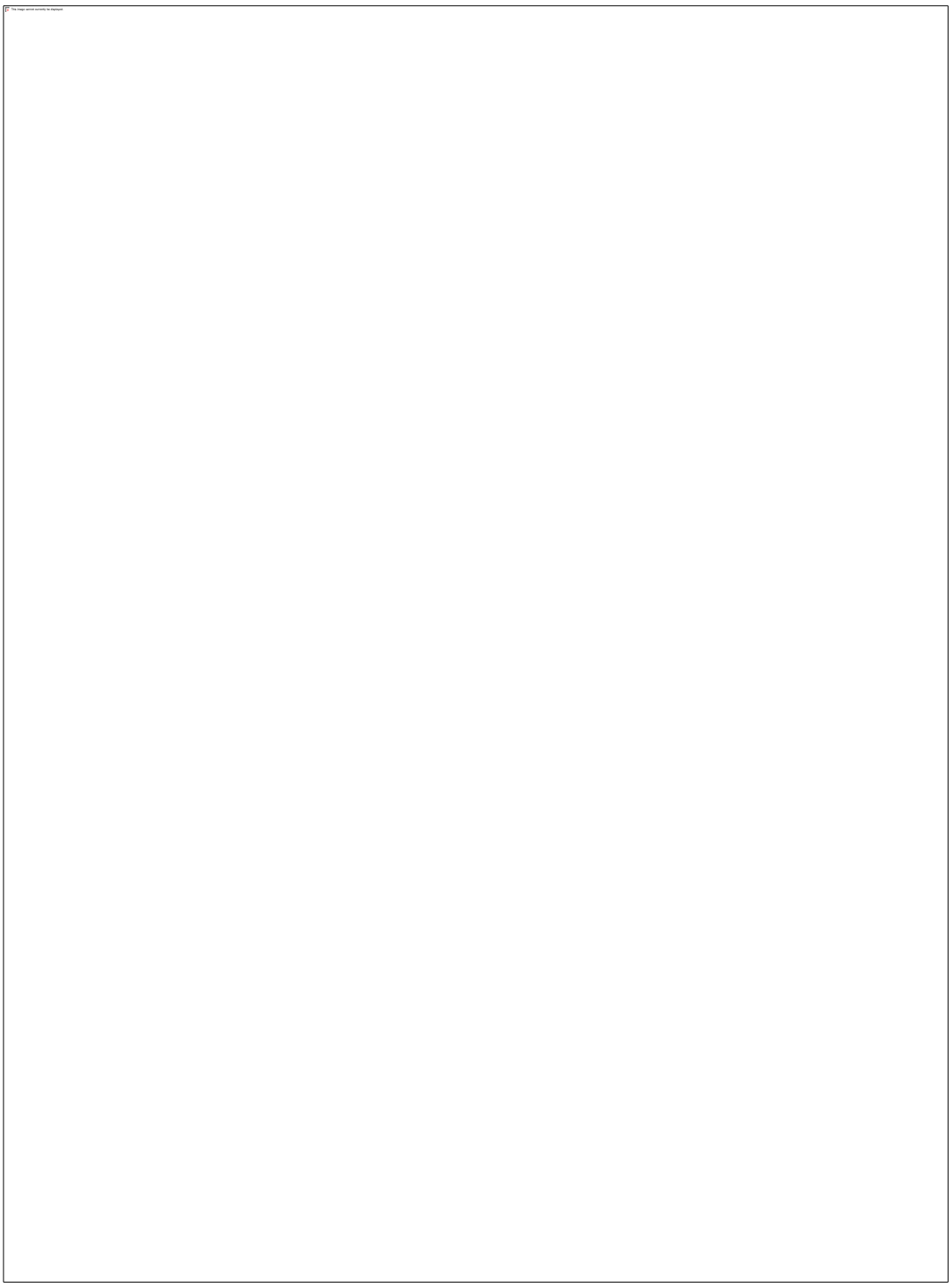
1. Regulates body growth and development.
2. Controls the rate of metabolism.
3. Regulates blood glucose levels.
4. Coordinates responses to stress and danger.
5. Regulates reproduction and sexual development.
6. Maintains water and salt balance.
7. Helps regulate blood pressure.
8. Regulates calcium levels in the blood.
9. Supports pregnancy, childbirth and milk production.
10. Helps maintain homeostasis.

Homeostasis is the maintenance of a relatively stable internal environment in the body despite changes in the external or internal environment.

6.0 COMPONENTS OF THE ENDOCRINE SYSTEM

The major glands covered in this sub-strand are:

1. Pituitary gland.
2. Thyroid gland.
3. Adrenal glands.
4. Pancreas.
5. Testes.
6. Ovaries.

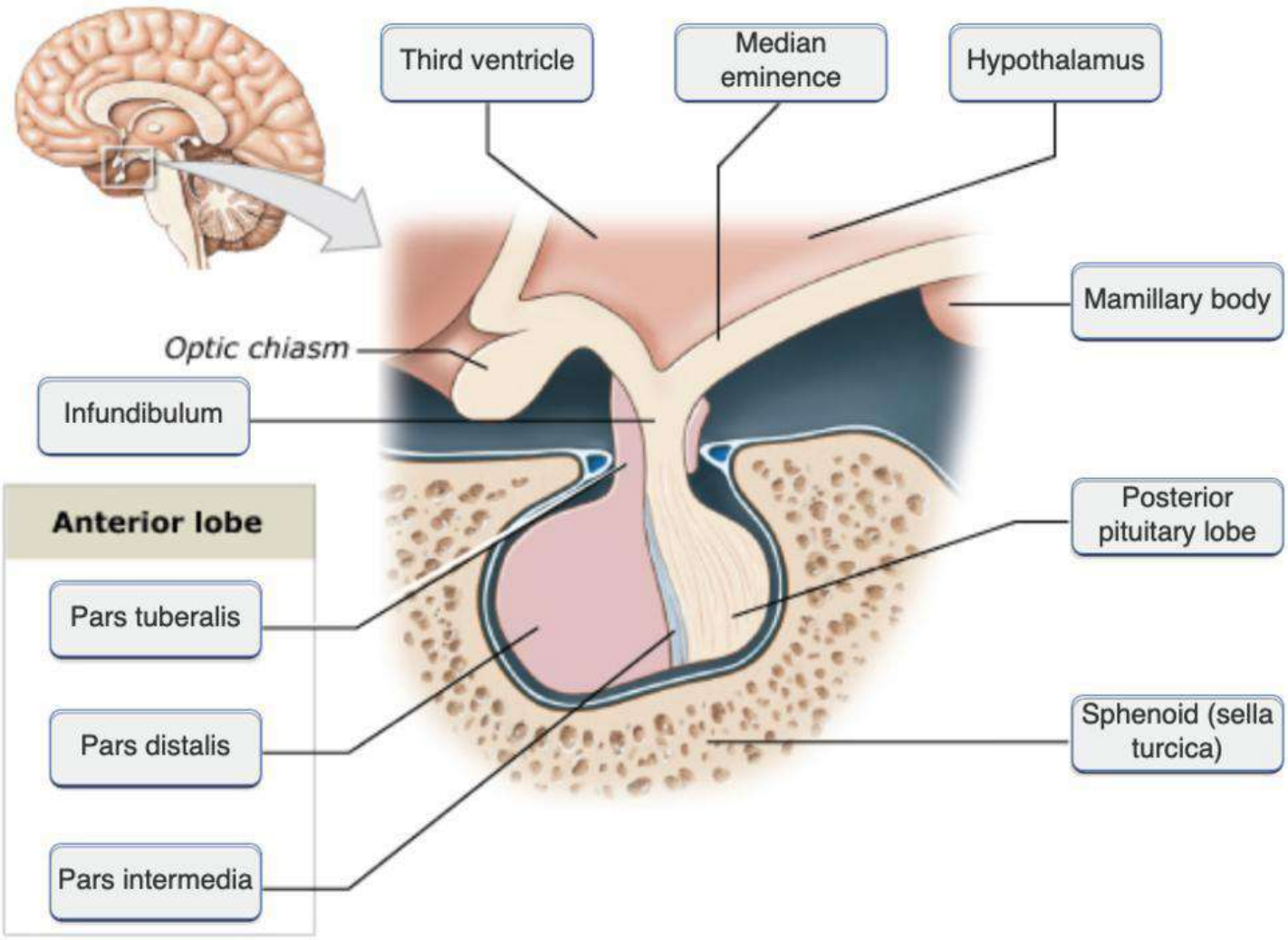


6.1 Pituitary gland

The pituitary gland is a small endocrine gland located at the base of the brain, beneath the hypothalamus.

It is sometimes called the *master gland* because several of its hormones control the activities of other endocrine glands.

However, the pituitary itself is regulated by the hypothalamus and feedback from target glands.



Hormones produced or released by the pituitary gland

The pituitary gland has two main parts:

- Anterior pituitary.
- Posterior pituitary.

Hormone	Main effect
Growth hormone (GH)	Stimulates growth of bones and body tissues.
Thyroid-stimulating hormone (TSH)	Stimulates the thyroid gland to produce thyroid hormones.
Adrenocorticotropic hormone (ACTH)	Stimulates the adrenal cortex to release glucocorticoids such as cortisol.
Follicle-stimulating hormone (FSH)	Supports development of ovarian follicles in females and sperm production in males.
Luteinising hormone (LH)	Triggers ovulation and supports sex hormone production.
Prolactin	Stimulates milk production after childbirth.
Antidiuretic hormone (ADH)	Increases water reabsorption by the kidneys.
Oxytocin	Stimulates uterine contractions during labour and milk ejection during breastfeeding.

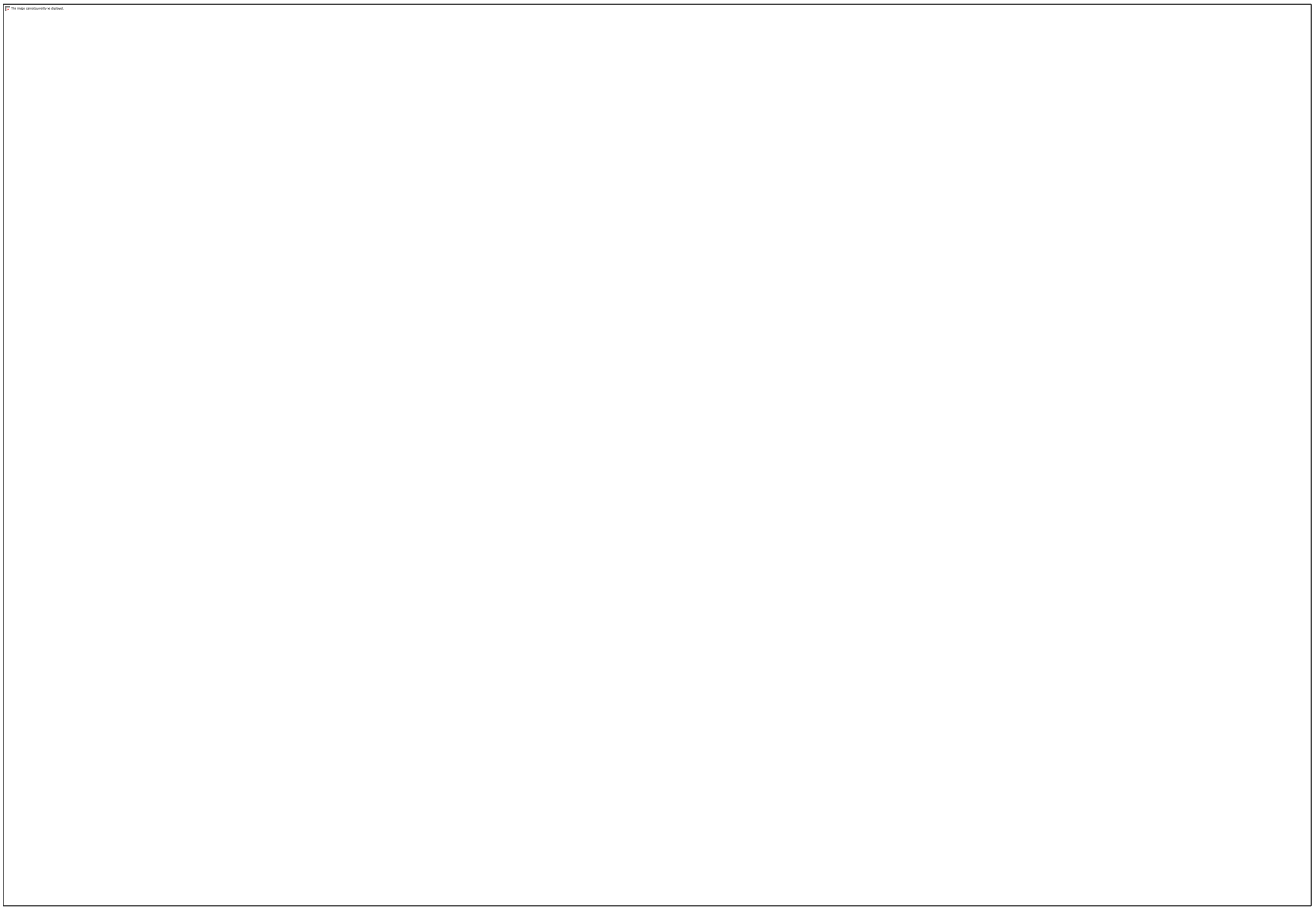
Important: ADH and oxytocin are made in the hypothalamus and stored and released by the posterior pituitary. They are not manufactured by the posterior pituitary itself.

Functions of the pituitary gland

1. Regulates growth.
2. Controls the activity of the thyroid gland.
3. Influences the activity of the adrenal cortex.
4. Regulates reproductive processes.
5. Helps control water balance.
6. Supports childbirth and breastfeeding.

6.2 Thyroid gland

The thyroid gland is a butterfly-shaped endocrine gland found at the front of the neck, below the larynx and around the upper part of the trachea.



Hormones produced by the thyroid gland

Hormone	Main effect
Thyroxine (T4)	Regulates metabolic rate, growth and development.
Triiodothyronine (T3)	Active thyroid hormone that regulates metabolism, growth and development.
Calcitonin	Helps lower blood calcium levels by reducing bone breakdown; its role in adult calcium regulation is relatively limited.

Functions of thyroxine

Thyroxine is also called T4 because it contains four iodine atoms.

Its functions include:

1. Regulating the rate at which cells use energy.
2. Supporting normal body growth.
3. Supporting brain development, especially during early life.
4. Helping regulate body temperature.
5. Influencing the rate of heart activity.
6. Supporting normal metabolism of carbohydrates, fats and proteins.

Importance of iodine: The thyroid gland requires iodine to produce T3 and T4.

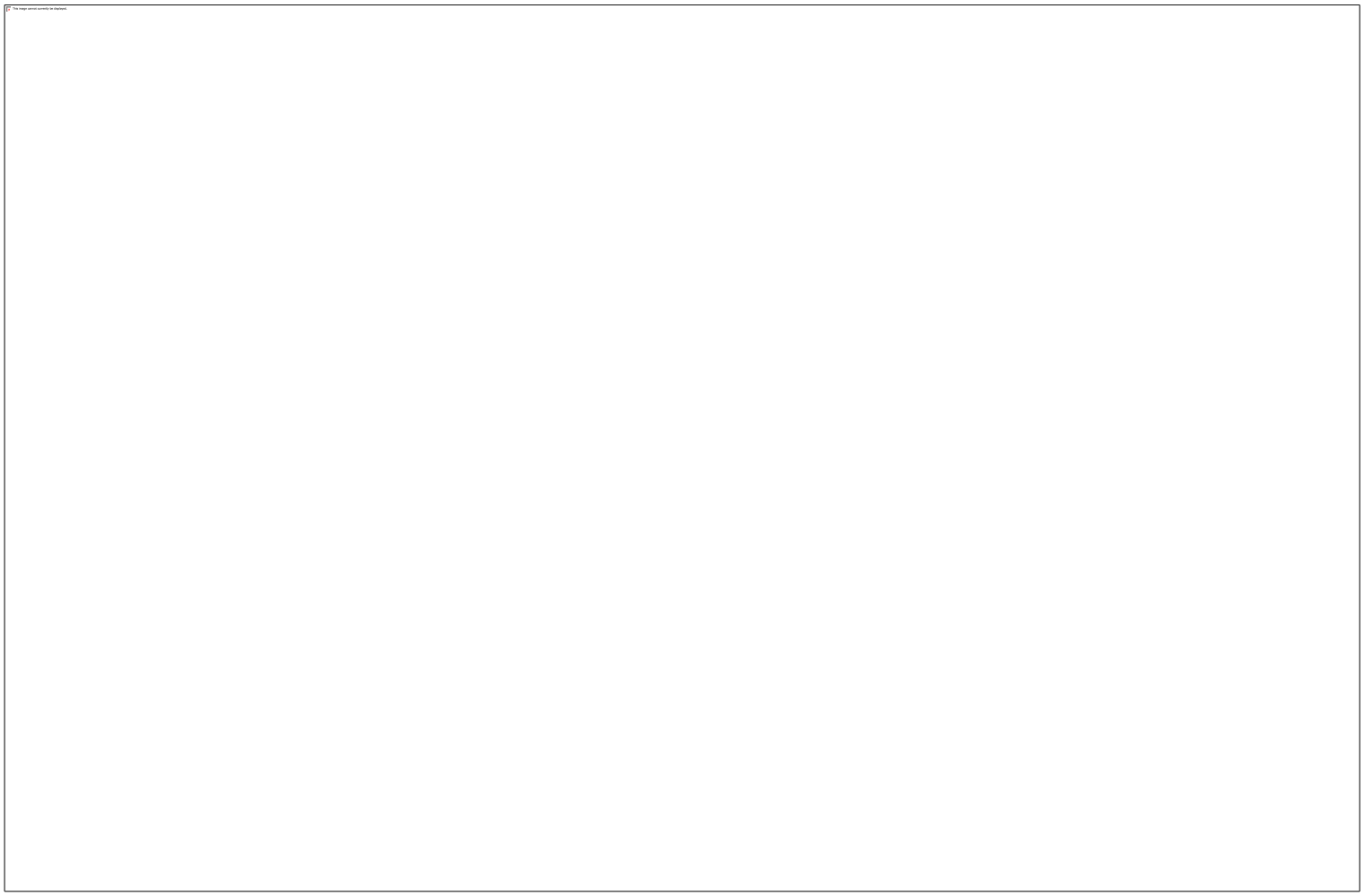
In Kenya, the use of adequately iodised salt helps reduce iodine deficiency disorders.

6.3 Adrenal glands

The adrenal glands are two small endocrine glands found above the kidneys.

Each adrenal gland consists of two main regions:

- Adrenal cortex – outer region.
- Adrenal medulla – inner region.



Hormones of the adrenal cortex

Hormone	Main effect
Cortisol	Helps regulate metabolism and the body's response to prolonged stress.
Aldosterone	Regulates sodium and potassium balance and helps control blood volume and pressure.
Adrenal androgens	Contribute to the development of some sexual characteristics and other body functions.

Hormones of the adrenal medulla

Hormone	Main effect
Adrenaline (epinephrine)	Prepares the body for rapid action during stress or danger.
Noradrenaline (norepinephrine)	Supports the stress response and helps regulate blood vessel constriction and blood pressure.

Functions of adrenaline

Adrenaline is released when a person experiences fear, excitement, danger or other stressful situations.

It prepares the body for a rapid response commonly called the **fight-or-flight response**.

Its effects include:

1. Increases heart rate.
2. Increases the force of heart contraction.
3. Dilates the bronchioles, allowing more air to enter the lungs.
4. Stimulates the breakdown of glycogen into glucose.
5. Increases blood glucose availability.
6. Redirects blood flow towards skeletal muscles.
7. Dilates the pupils.
8. Reduces some digestive activities temporarily.

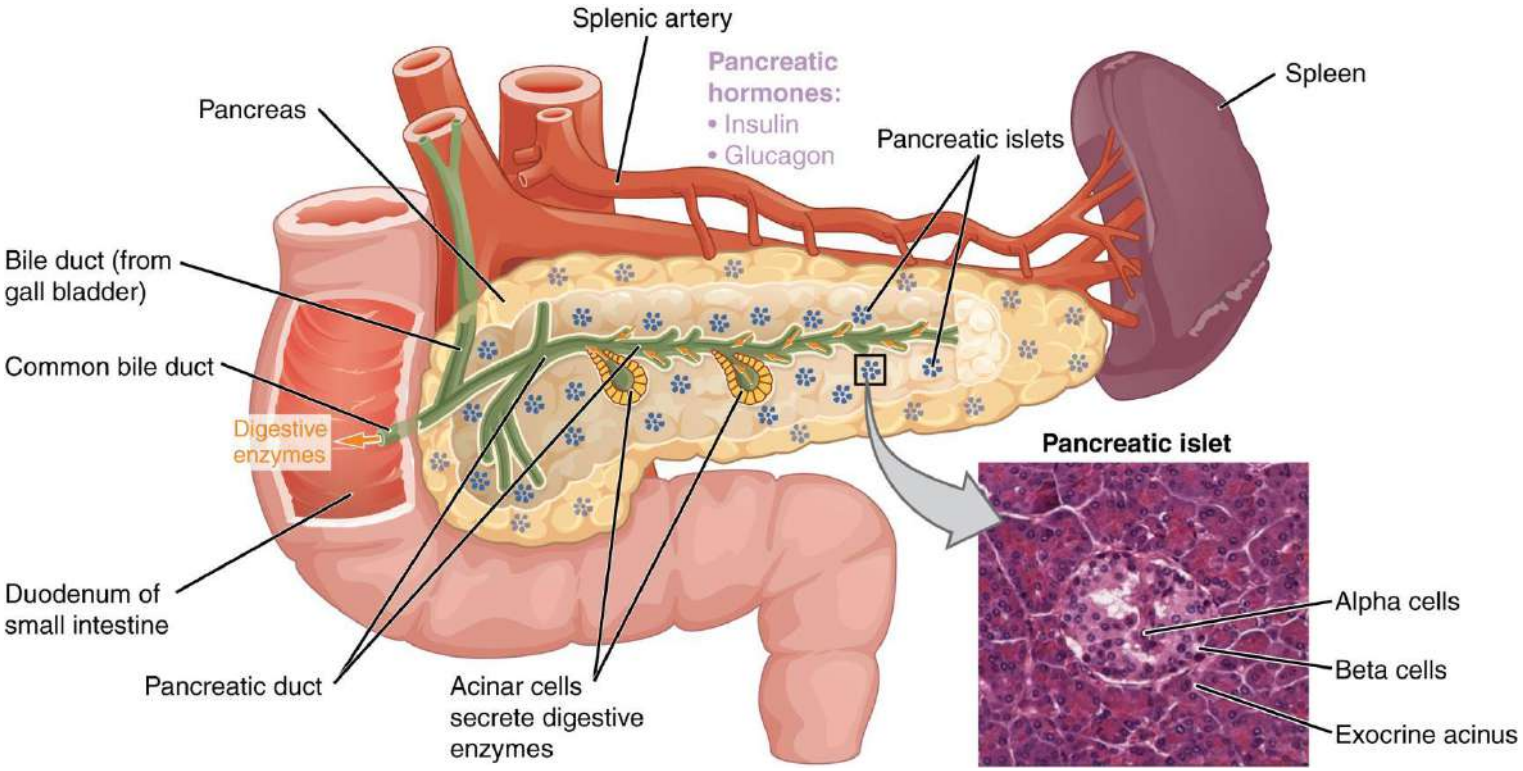
Example in the Kenyan environment: A learner who suddenly notices a speeding motorcycle approaching may experience a rapid heartbeat and increased alertness as the body prepares to respond to danger.

6.4 Pancreas

The pancreas is an elongated gland located behind the stomach.

It performs two major functions:

- Exocrine function: releases digestive enzymes into the small intestine through a duct.
- Endocrine function: releases hormones into the blood.



The endocrine part of the pancreas consists of clusters of cells called the **islets of Langerhans**.

Hormones produced by the pancreas

Hormone	Producing cells	Main effect
Insulin	Beta cells	Lowers blood glucose by promoting glucose uptake and storage.
Glucagon	Alpha cells	Raises blood glucose by stimulating the liver to release glucose.
Somatostatin	Delta cells	Helps regulate the release of insulin, glucagon and other digestive hormones.

Functions of insulin

1. Lowers blood glucose levels.
2. Promotes uptake of glucose by many body cells.
3. Stimulates conversion of glucose into glycogen in the liver and muscles.
4. Supports storage of energy in the body.

Functions of glucagon

1. Raises blood glucose levels.
2. Stimulates breakdown of glycogen in the liver.
3. Stimulates the liver to produce and release glucose.

Importance: Insulin and glucagon work together to maintain blood glucose within a suitable range.

6.5 Testes

The testes are the male reproductive glands found in the scrotum.

They perform two main functions:

1. Produce sperm cells.

2. Produce male sex hormones.

Hormones produced by the testes

Hormone	Main effect
Testosterone	Promotes development of male reproductive organs and secondary sexual characteristics and supports sperm production.
Inhibin	Helps regulate sperm production by reducing FSH secretion from the pituitary.

Functions of testosterone

1. Supports development of male reproductive organs.
2. Promotes growth of facial and body hair during puberty.
3. Deepens the voice.
4. Supports muscle and bone development.
5. Helps maintain sperm production.
6. Influences sexual development and libido.

6.6 Ovaries

The ovaries are female reproductive glands located in the pelvic cavity, one on each side of the uterus.

They produce ova and female sex hormones.

Hormones produced by the ovaries

Hormone	Main effect
Oestrogen	Promotes development of female secondary sexual characteristics and growth of the uterine lining.
Progesterone	Prepares and maintains the uterine lining for pregnancy.
Inhibin	Helps regulate the secretion of FSH.

Functions of oestrogen

1. Promotes development of breasts during puberty.
2. Supports development of female secondary sexual characteristics.
3. Helps regulate the menstrual cycle.
4. Stimulates growth of the endometrium during the first part of the menstrual cycle.
5. Supports bone health.

Functions of progesterone

1. Prepares the endometrium for implantation.
2. Helps maintain the uterine lining during pregnancy.
3. Reduces excessive uterine contractions during pregnancy.
4. Supports the normal functioning of the reproductive system.

6.7 Summary of the major endocrine glands, hormones and their principal effects

Gland	Hormone	Principal effect
Pituitary	Growth hormone	Stimulates growth of bones and body tissues.
Pituitary	TSH	Stimulates the thyroid gland.
Pituitary	ACTH	Stimulates the adrenal cortex.
Pituitary	FSH	Supports gamete production.
Pituitary	LH	Triggers ovulation and supports sex hormone production.
Pituitary	Prolactin	Stimulates milk production.
Posterior pituitary (releases)	ADH	Increases water reabsorption by kidneys.
Posterior pituitary (releases)	Oxytocin	Stimulates uterine contractions and milk ejection.
Thyroid	Thyroxine (T4)	Regulates metabolic rate, growth and development.
Thyroid	Triiodothyronine (T3)	Regulates metabolism and development.
Thyroid	Calcitonin	Helps lower blood calcium.
Adrenal cortex	Cortisol	Regulates metabolism and prolonged stress response.
Adrenal cortex	Aldosterone	Regulates salt balance and blood volume.
Adrenal medulla	Adrenaline	Prepares the body for rapid action.
Adrenal medulla	Noradrenaline	Supports stress response and blood pressure regulation.
Pancreas	Insulin	Lowers blood glucose.
Pancreas	Glucagon	Raises blood glucose.
Testes	Testosterone	Promotes male sexual development and supports sperm production.
Testes	Inhibin	Helps regulate sperm production.
Ovaries	Oestrogen	Promotes female sexual development and growth of the uterine lining.
Ovaries	Progesterone	Prepares and maintains the uterine lining.
Ovaries	Inhibin	Helps regulate FSH secretion.

7.0 VARIATIONS IN THE SECRETION OF ADRENALINE IN HUMAN BEINGS

7.1 Meaning of adrenaline secretion

Adrenaline is a hormone produced by the adrenal medulla.

It is released into the bloodstream when the body experiences stress, fear, excitement, danger or intense physical activity.

It prepares the body to respond rapidly to challenging situations.

Adrenaline secretion is normally temporary and forms part of the body's natural survival mechanism.

7.2 Normal effects of adrenaline

When adrenaline is released:

1. Heart rate increases.
2. The force of heart contraction increases.
3. Blood glucose levels rise.
4. Bronchioles widen to improve airflow.
5. Pupils dilate.
6. Blood flow is redistributed towards skeletal muscles.
7. Digestion is temporarily reduced.
8. Alertness and readiness for action increase.

7.3 Effects of excessive or prolonged adrenaline secretion

Adrenaline secretion is normally short-lived. However, repeated or prolonged activation of the stress response may affect health.

Possible effects include:

1. Rapid heartbeat or palpitations.
2. Increased blood pressure.
3. Sweating.
4. Trembling or shaking.
5. Feelings of anxiety or nervousness.
6. Difficulty sleeping.
7. Headaches.
8. Increased blood glucose.
9. Restlessness and difficulty concentrating.

Possible situations associated with increased adrenaline release:

- Fear of an accident.
- Sudden danger.
- Public speaking.
- Competitive sports.
- Emotional stress.

Important: These symptoms are not proof of excessive adrenaline secretion. Many other conditions can produce similar symptoms. Persistent symptoms require professional medical assessment.

7.4 Effects of insufficient adrenaline production

Adrenaline is not usually considered a hormone whose deficiency is diagnosed in isolation. The adrenal medulla may produce less adrenaline in some conditions affecting the adrenal glands or autonomic nervous system.

Possible effects may include:

1. A reduced adrenaline response during stress.
2. Reduced ability to increase heart rate rapidly in response to some challenges.
3. Reduced ability to mobilise glucose rapidly during stressful situations.
4. Possible dizziness or weakness in certain underlying conditions.

Important: Serious adrenal hormone deficiency often involves other adrenal hormones, particularly cortisol and sometimes aldosterone. It should not be confused with isolated low adrenaline.

7.5 Maintaining healthy stress responses

1. Get adequate sleep.
2. Participate in regular physical activity.
3. Practise relaxation techniques.
4. Maintain healthy relationships.
5. Avoid misuse of stimulants and other harmful substances.
6. Seek appropriate help when experiencing persistent anxiety or stress.
7. Maintain a balanced diet.

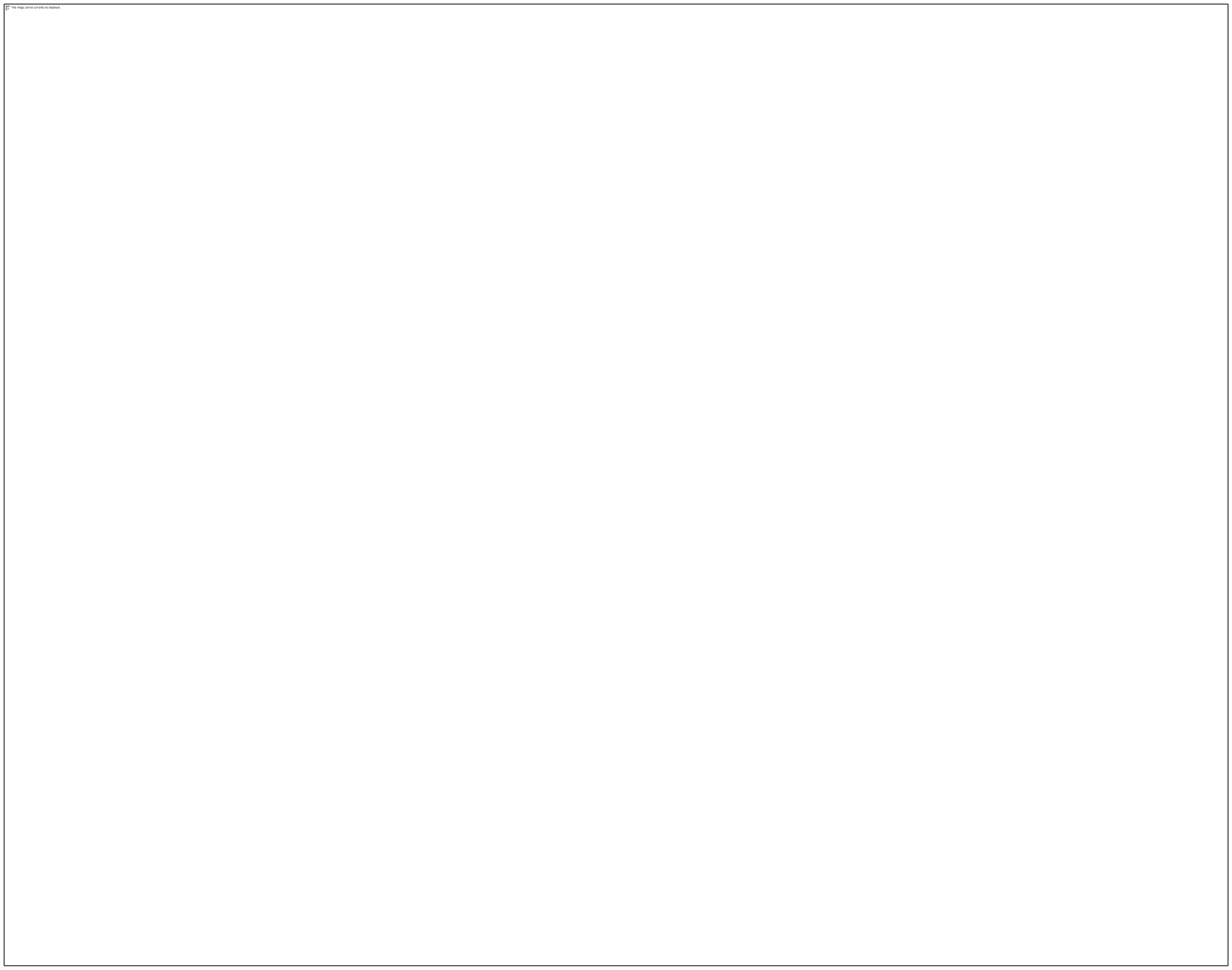
8.0 VARIATIONS IN THE SECRETION OF THYROXINE

8.1 Meaning of thyroxine

Thyroxine (T4) is a hormone produced by the thyroid gland.

It helps regulate the body's metabolic rate, growth and development.

The production of thyroid hormones is regulated through the hypothalamus-pituitary-thyroid pathway.



Regulation of thyroxine secretion

1. The hypothalamus releases thyrotropin-releasing hormone (TRH).
2. TRH stimulates the anterior pituitary gland.
3. The anterior pituitary releases thyroid-stimulating hormone (TSH).
4. TSH stimulates the thyroid gland.
5. The thyroid gland produces and releases T3 and T4.
6. Increased thyroid hormone levels inhibit further release of TRH and TSH through negative feedback.
7. When thyroid hormone levels fall, the inhibition is reduced and more TSH can be released.

This mechanism helps maintain suitable levels of thyroid hormones in the blood.

8.2 Over-secretion of thyroxine (Hyperthyroidism)

Hyperthyroidism is a condition in which the thyroid gland produces more thyroid hormones than the body requires.

Causes

1. Graves' disease, an autoimmune condition.
2. Overactive thyroid nodules.
3. Thyroid inflammation that releases stored hormones.
4. Excessive intake of thyroid hormone medication.
5. In some cases, excessive iodine intake in susceptible individuals.

Signs and symptoms

1. Increased metabolic rate.
2. Unexplained weight loss despite normal or increased appetite.
3. Rapid heartbeat.
4. Excessive sweating.
5. Heat intolerance.
6. Nervousness and irritability.
7. Trembling hands.
8. Difficulty sleeping.
9. Frequent bowel movements.

10. Muscle weakness.

Some individuals with Graves' disease may develop eye changes.

Effects on body functioning

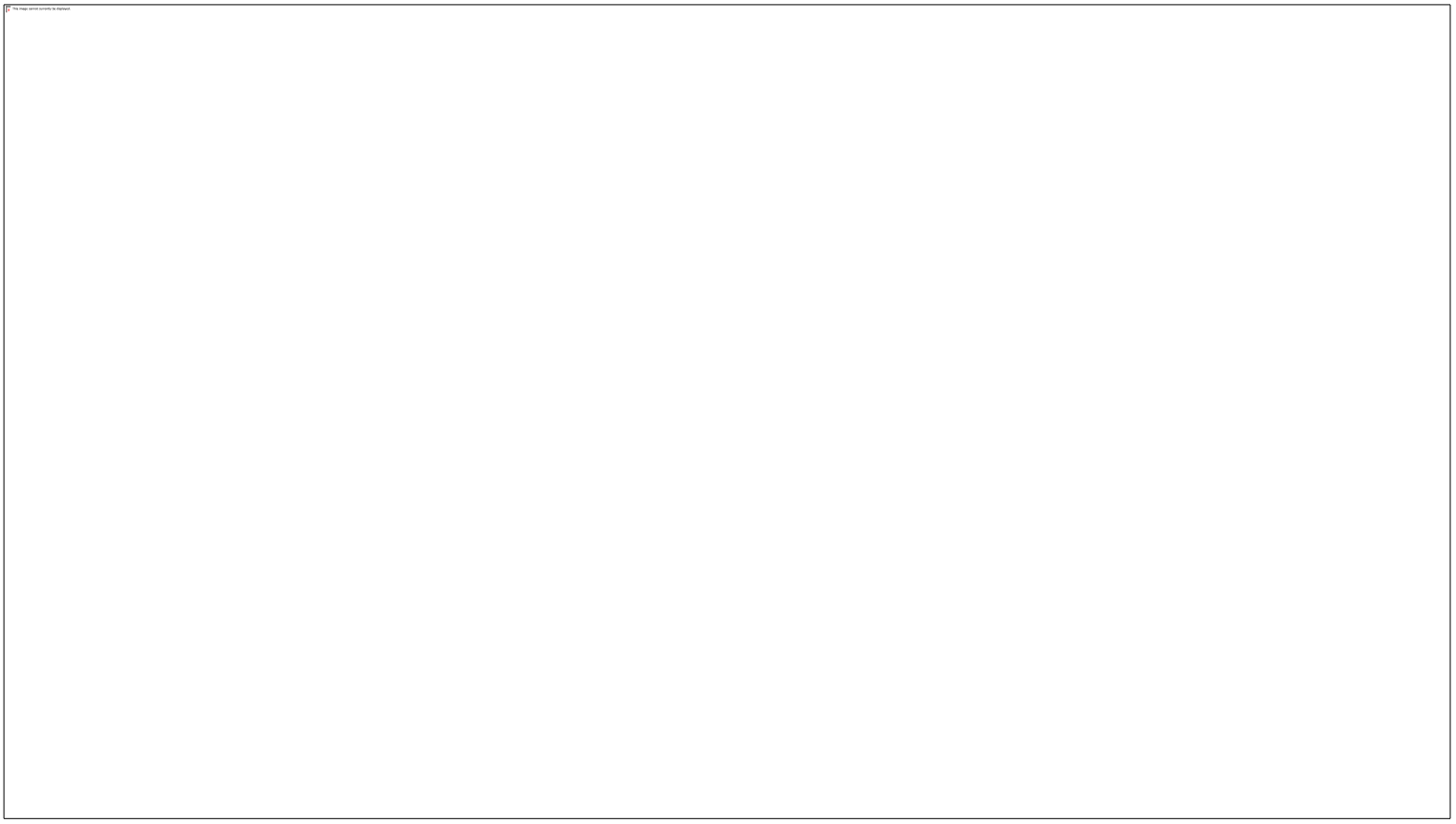
- The body uses energy more rapidly.
- The heart may beat faster than normal.
- Body temperature regulation may be affected.
- Muscle strength may decrease.
- Sleep and emotional well-being may be affected.

Intervention and management

1. Medical examination and thyroid function tests.
2. Antithyroid medicines where appropriate.
3. Radioactive iodine treatment in suitable cases.
4. Surgery in selected cases.
5. Regular medical monitoring.
6. Appropriate management of symptoms.

8.3 Under-secretion of thyroxine (Hypothyroidism)

Hypothyroidism is a condition in which the thyroid gland does not produce enough thyroid hormones to meet the body's needs.



Causes

1. Hashimoto's thyroiditis, an autoimmune condition.
2. Insufficient iodine intake.

3. Removal of the thyroid gland or damage to it.
4. Certain medicines.
5. Some congenital conditions affecting thyroid development.
6. Disorders affecting the pituitary or hypothalamus.

Signs and symptoms

1. Reduced metabolic rate.
2. Unexplained weight gain.
3. Tiredness and weakness.
4. Increased sensitivity to cold.
5. Dry skin.
6. Constipation.
7. Slower heart rate in some individuals.
8. Difficulty concentrating.
9. Hair thinning.
10. Muscle aches.

Effects on body functioning

- The body uses energy more slowly.
- The individual may feel tired.
- Body temperature regulation may be affected.
- Digestion may become slower.
- Growth and development may be affected in children.

Effects on children

Adequate thyroid hormone is essential for normal brain development and physical growth.

Severe untreated congenital hypothyroidism can cause permanent developmental problems. Early newborn screening and prompt treatment are therefore very important.

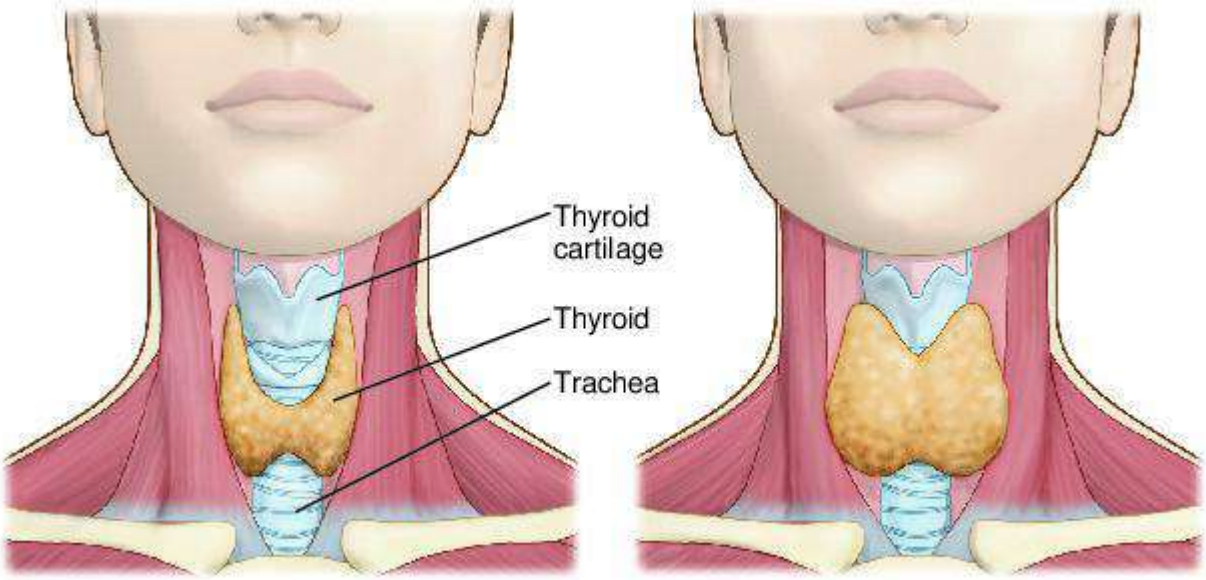
Intervention and management

1. Thyroid function tests.
2. Prescribed thyroid hormone replacement, commonly levothyroxine.
3. Regular monitoring of hormone levels.
4. Appropriate iodine intake.
5. Early diagnosis and treatment in children.

8.4 Goitre

A **goitre** is an enlargement of the thyroid gland.

It may occur with normal, increased or reduced thyroid hormone production.



Causes

- Iodine deficiency.
- Graves' disease.
- Hashimoto's thyroiditis.
- Thyroid nodules.
- Other thyroid disorders.

Signs

1. Swelling at the front of the neck.
2. Difficulty swallowing in some cases.
3. Difficulty breathing if the enlargement is severe.
4. Hoarseness in some cases.

Prevention and management

1. Use adequately iodised salt.
2. Seek medical assessment for unexplained neck swelling.
3. Treat the underlying thyroid condition.
4. Follow medical advice on iodine intake and treatment.

Kenyan context: Iodised salt is an important public health measure for preventing iodine deficiency. Excessive iodine supplementation should not be undertaken without professional advice.

8.5 Comparison between hyperthyroidism and hypothyroidism

Hyperthyroidism	Hypothyroidism
Excess production of thyroid hormones.	Insufficient production of thyroid hormones.
Increased metabolic rate.	Reduced metabolic rate.
Weight loss may occur.	Weight gain may occur.
Heat intolerance may occur.	Cold intolerance may occur.
Sweating may increase.	Skin may become dry.
Heart rate may increase.	Heart rate may decrease.

Restlessness and nervousness may occur.	Tiredness and sluggishness may occur.
Sleep difficulties may occur.	Increased sleepiness may occur.

Remember: These are common patterns, not diagnostic rules. A medical professional uses symptoms, examination and laboratory tests to diagnose thyroid disorders.

9.0 COMPARISON BETWEEN THE NERVOUS AND ENDOCRINE SYSTEMS

The nervous and endocrine systems are the two major coordination systems in human beings.

They work together to regulate body activities and maintain homeostasis.



9.1 Similarities between the nervous and endocrine systems

1. Both coordinate and regulate body activities.
2. Both help the body respond to internal and external changes.
3. Both help maintain homeostasis.
4. Both use chemical messengers at some stage of communication.
5. Both influence the functioning of target cells and organs.
6. Both work together to regulate growth, reproduction, stress responses and metabolism.

9.2 Differences between the nervous and endocrine systems

Nervous system	Endocrine system
Consists of the brain, spinal cord and nerves.	Consists of hormone-producing glands and tissues.
Uses electrical impulses along neurons.	Uses hormones transported through blood or tissue fluid.
Uses neurotransmitters at most chemical synapses.	Uses hormones as chemical messengers.
Responses are generally very rapid.	Responses are generally slower to develop.
Effects are often short-lived and localised.	Effects may be longer-lasting and widespread.
Signals travel along nerve fibres.	Hormones are transported through the bloodstream.
Can produce precise responses in particular muscles or glands.	Acts on cells that possess receptors for particular hormones.
Examples include withdrawal reflex and pupil reflex.	Examples include regulation of blood glucose and metabolic rate.

9.3 How the nervous and endocrine systems work together

The nervous and endocrine systems do not operate independently. They interact to coordinate several body activities.

Example 1: Response to danger

When a person encounters danger:

1. Sense organs detect the danger.
2. Sensory neurons carry information to the brain.
3. The brain processes the information.
4. The hypothalamus activates the sympathetic nervous system.
5. Nerve signals stimulate the adrenal medulla.
6. The adrenal medulla releases adrenaline.
7. Heart rate and breathing rate increase.
8. More blood and oxygen become available to muscles.
9. The body becomes prepared for rapid action.

Example 2: Regulation of body metabolism

1. The hypothalamus monitors the body's internal condition.
2. It releases TRH.
3. The pituitary gland releases TSH.
4. TSH stimulates the thyroid gland.
5. The thyroid releases T3 and T4.
6. Thyroid hormones regulate the metabolic activities of many body cells.
7. Increased thyroid hormone levels reduce TRH and TSH secretion through negative feedback.

Example 3: Regulation of blood glucose

1. After a meal, blood glucose rises.
2. The pancreas detects the change.
3. Beta cells release insulin.
4. Body cells take up more glucose, and the liver and muscles store glucose as glycogen.
5. Blood glucose decreases towards the normal range.
6. When blood glucose becomes too low, alpha cells release glucagon.
7. The liver releases glucose into the blood.
8. Blood glucose rises towards the normal range.

9.4 Importance of coordination in the human body

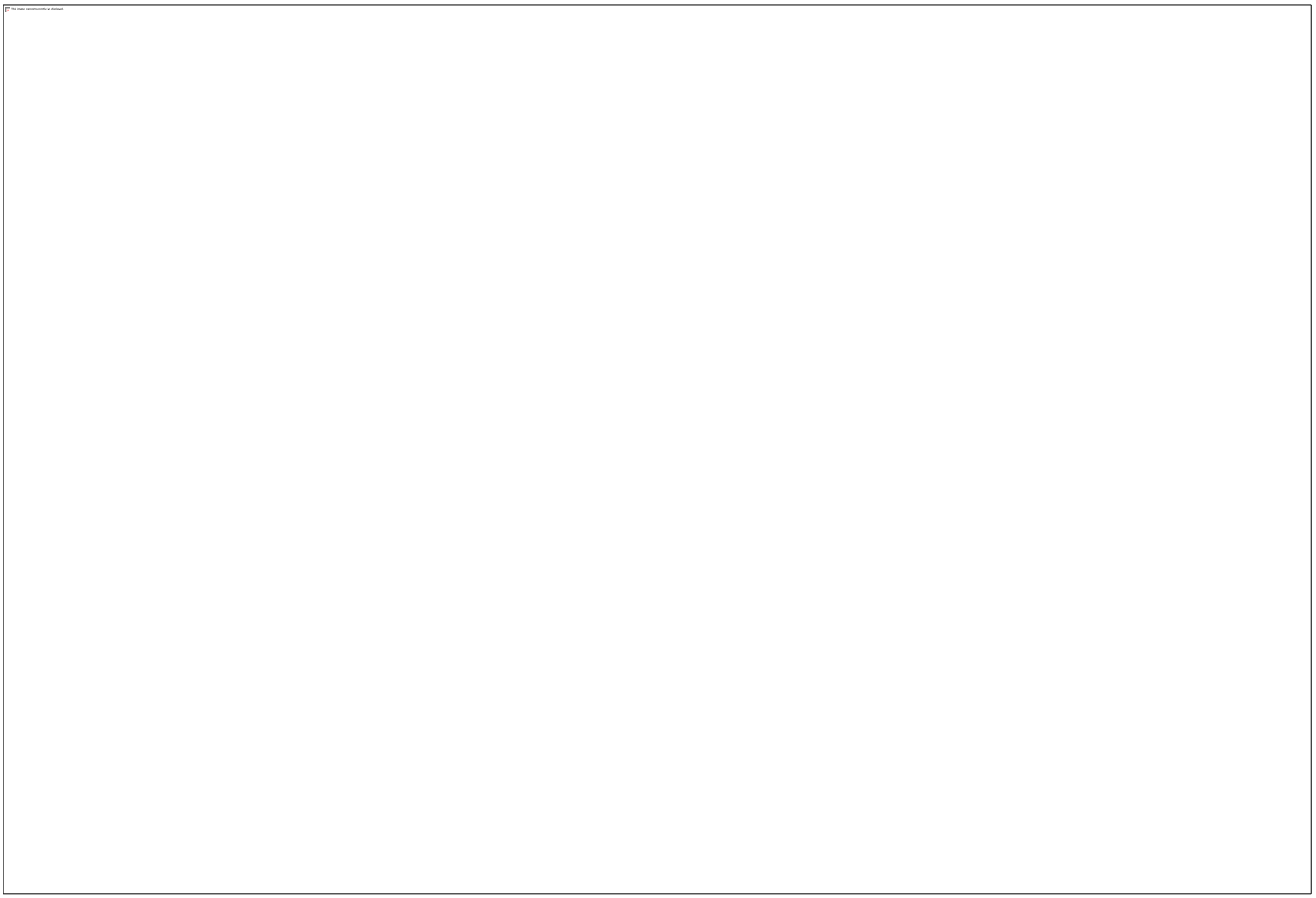
Coordination is essential because different organs and systems must work together to maintain normal functioning.

Examples include:

- The eyes and brain working together during reading.
- The ears and brain coordinating balance while walking.
- The adrenal glands helping the body respond to danger.
- The thyroid regulating metabolism.
- The pancreas regulating blood glucose.
- The reproductive glands regulating sexual development.

10.0 PRACTICAL ACTIVITIES AND INVESTIGATIONS

Activity 1: Constructing a model of the human eye



Aim: To construct a model showing the major structures of the human eye.

Materials:

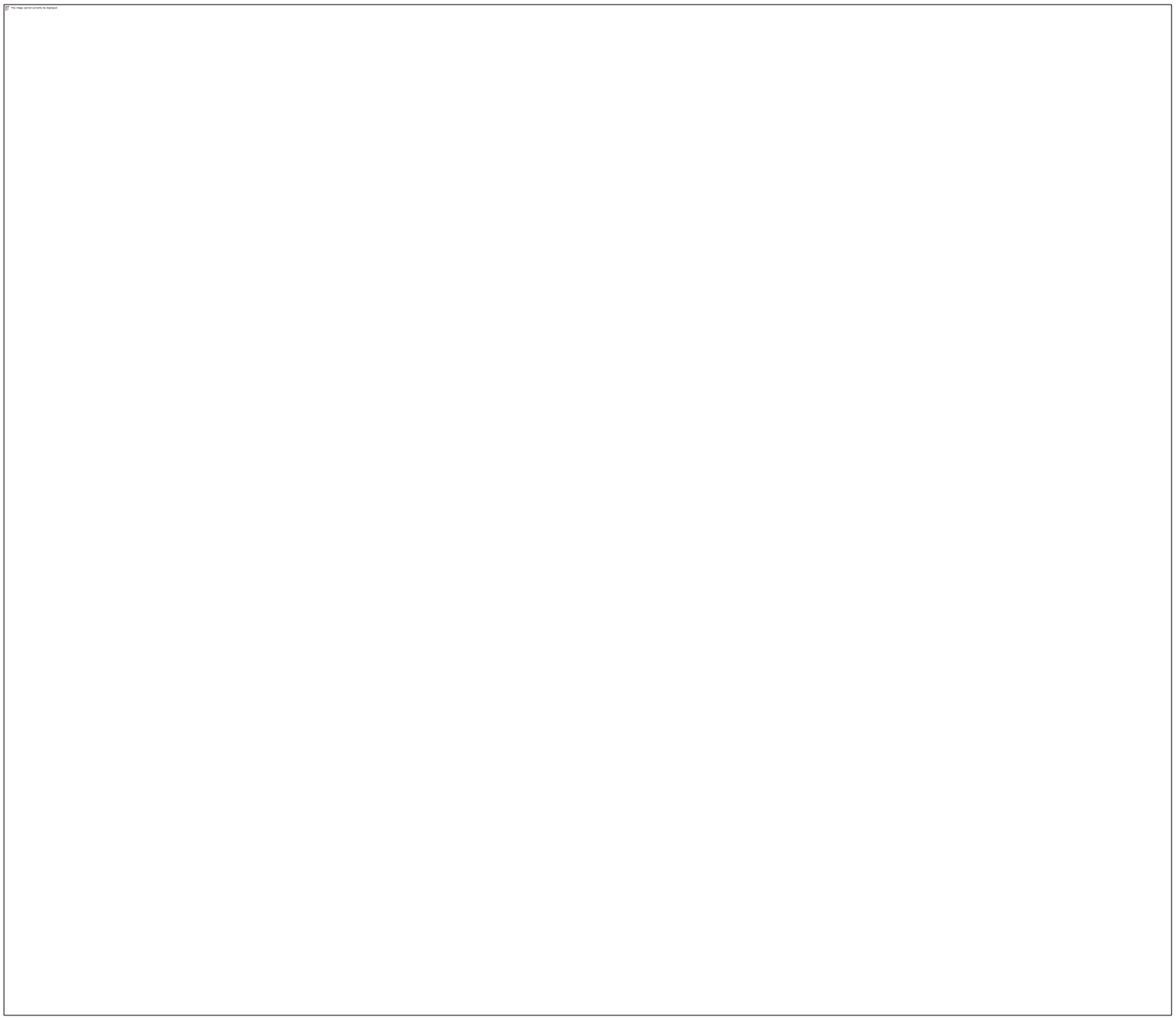
- Cardboard.
- Clay or modelling materials.
- Coloured paper.
- Glue.
- String.
- Scissors.
- Labels.

Procedure:

1. Work in groups.
2. Use locally available materials to construct an enlarged model of the eye.
3. Show the cornea, iris, pupil, lens, retina and optic nerve.
4. Label each structure.
5. Explain the function of each part to classmates.

Expected learning outcome: Learners relate the structures of the eye to their functions.

Activity 2: Constructing a model of the human ear



Aim: To model the major structures of the ear.

Materials:

- Cardboard.
- Modelling clay.
- Coloured paper.
- Recycled plastic materials.
- Glue.
- Labels.

Procedure:

1. Work in groups.
2. Construct a model showing the outer, middle and inner ear.

3. Include the pinna, auditory canal, eardrum, ossicles, cochlea and semicircular canals.
4. Label the structures.
5. Present the model and explain how hearing occurs.

Activity 3: Investigating the pupil reflex

Aim: To observe changes in pupil size under different light conditions.

Materials:

- A safe source of ordinary room light.
- A mirror, if available.
- An observation sheet.

Procedure:

1. Observe the pupil size under normal room lighting.
2. Move to a safely dimmer area.
3. Observe the pupil size again.
4. Return to normal lighting.
5. Record the observations.

Expected observations:

- The pupil becomes smaller in brighter light.
- The pupil becomes larger in dimmer light.

Conclusion: The iris regulates the amount of light entering the eye through changes in pupil size.

Safety: Never shine a bright torch or laser directly into anyone's eyes.

Activity 4: Investigating the importance of hearing

Aim: To appreciate the role of hearing in communication and safety.

Procedure:

1. Work in pairs.
2. One learner gives simple spoken instructions.
3. The other learner listens and follows the instructions.
4. Repeat in a quiet environment and a moderately noisy environment.
5. Discuss how background noise affects hearing and communication.

Discussion questions:

1. Why is hearing important during road use?
2. How does excessive noise affect communication?
3. Why should people protect their ears from loud sounds?

Activity 5: Researching endocrine glands

Aim: To identify the major endocrine glands, their hormones and their functions.

Procedure:

1. Work in groups.

2. Research the pituitary, thyroid, adrenal glands, pancreas, testes and ovaries.
3. Prepare a table showing each gland, the hormones produced and their principal effects.
4. Present findings to the class.
5. Discuss the importance of hormonal balance.

Activity 6: Demonstrating negative feedback using a model

Aim: To understand how hormone levels are regulated.

Procedure:

1. Draw a flow chart showing the hypothalamus, pituitary gland and thyroid gland.
2. Use arrows to show the release of TRH, TSH and thyroid hormones.
3. Show how increased thyroid hormone levels reduce further stimulation of the thyroid gland.
4. Explain why this is called negative feedback.

Conclusion: Negative feedback helps maintain hormone levels within suitable ranges.

REVISION EXERCISES

SECTION A: MULTIPLE-CHOICE QUESTIONS (30 MARKS)

Instructions: Answer all questions. Choose the correct answer from the alternatives A, B, C and D.

Question 1. Which of the following best describes the function of a sensory receptor?

A. Produces hormones for the body.

B. Detects stimuli and converts them into electrical signals.

C. Transports oxygen around the body.

D. Produces digestive enzymes.

Question 2. The part of the eye that controls the amount of light entering the eye is the:

A. Retina.

B. Cornea.

C. Iris.

D. Optic nerve.

Question 3. Which structure of the eye is responsible for most of the refraction of incoming light?

A. Cornea.

B. Sclera.

C. Choroid.

D. Blind spot.

Question 4. The light-sensitive layer of the eye is called the:

A. Iris.

B. Retina.

C. Sclera.

D. Lens.

Question 5. Which photoreceptor is mainly responsible for vision in dim light?

A. Cone cells.

B. Rod cells.

C. Ciliary cells.

D. Sensory neurons of the iris.

Question 6. The part of the retina responsible for the sharpest central vision is the:

A. Blind spot.

B. Choroid.

C. Fovea.

D. Optic disc.

Question 7. Which structure carries visual impulses from the retina to the brain?

A. Cornea.

B. Optic nerve.

C. Iris.

D. Suspensory ligament.

Question 8. When a person looks at a nearby object, the lens:

A. Becomes thinner.

B. Becomes thicker and more convex.

C. Becomes completely flat.

D. Stops refracting light.

Question 9. During accommodation for distant vision, the ciliary muscles:

A. Contract.

B. Relax.

C. Become permanently stretched.

D. Stop functioning.

Question 10. Which defect of vision is corrected using a concave lens?

A. Hyperopia.

B. Myopia.

C. Presbyopia.

D. Cataract.

Question 11. Cataracts are mainly associated with:

A. Clouding of the lens.

B. Damage to the auditory canal.

C. Enlargement of the pupil.

D. Inflammation of the retina only.

Question 12. Which of the following structures collects sound waves from the environment?

A. Cochlea.

B. Pinna.

C. Stapes.

D. Eustachian tube.

Question 13. The tympanic membrane is commonly known as the:

A. Cochlea.

B. Eardrum.

C. Pinna.

D. Auditory nerve.

Question 14. Which of the following is the correct sequence of the auditory ossicles?

A. Incus, stapes, malleus.

B. Malleus, incus, stapes.

C. Stapes, malleus, incus.

D. Malleus, stapes, incus.

Question 15. The main function of the Eustachian tube is to:

A. Detect sound frequencies.

B. Equalise air pressure on both sides of the eardrum.

C. Produce earwax.

D. Detect rotational movements of the head.

Question 16. Which structure of the inner ear is mainly responsible for hearing?

A. Cochlea.

B. Pinna.

C. Eustachian tube.

D. Semicircular canals.

Question 17. The semicircular canals are mainly responsible for detecting:

A. Sound intensity.

B. Rotational movement of the head.

C. Blood pressure.

D. Light intensity.

Question 18. The utricle and saccule help detect:

A. Linear acceleration and head position relative to gravity.

B. Sound waves.

C. Colour.

D. Temperature.

Question 19. Inflammation of the external auditory canal is called:

A. Otitis media.

B. Otitis externa.

C. Cataract.

D. Glaucoma.

Question 20. Which of the following is a suitable way of protecting hearing?

A. Listening to music at very high volume.

B. Inserting sharp objects into the ear.

C. Using hearing protection in noisy environments.

D. Ignoring persistent ear pain.

Question 21. The endocrine system consists mainly of:

A. Ductless hormone-producing glands and tissues.

B. Bones and joints.

C. Blood vessels only.

D. Digestive organs only.

Question 22. Which gland is commonly called the master gland?

A. Thyroid gland.

B. Pituitary gland.

C. Pancreas.

D. Adrenal gland.

Question 23. The hormone responsible for regulating metabolic rate is:

A. Insulin.

B. Thyroxine.

C. Adrenaline.

D. Testosterone.

Question 24. Which hormone prepares the body for rapid action during danger?

A. Insulin.

B. Adrenaline.

C. Progesterone.

D. Calcitonin.

Question 25. Which gland produces insulin?

A. Thyroid gland.

B. Adrenal gland.

C. Pancreas.

D. Pituitary gland.

Question 26. The main effect of insulin is to:

A. Increase blood glucose levels.

B. Lower blood glucose levels.

C. Increase body temperature directly.

D. Stimulate the production of adrenaline.

Question 27. Which hormone is produced by the testes and promotes male secondary sexual characteristics?

A. Oestrogen.

B. Progesterone.

C. Testosterone.

D. Thyroxine.

Question 28. Which hormone is mainly responsible for preparing and maintaining the uterine lining for pregnancy?

A. Progesterone.

B. Adrenaline.

C. Insulin.

D. Glucagon.

Question 29. Excessive production of thyroid hormones is known as:

A. Hypothyroidism.

B. Hyperthyroidism.

C. Diabetes mellitus.

D. Otitis media.

Question 30. Which statement correctly describes a major difference between the nervous and endocrine systems?

A. The nervous system uses only hormones.

B. The endocrine system uses electrical impulses along neurons.

C. Nervous responses are generally faster, while hormonal responses are often slower and longer-lasting.

D. Both systems operate independently and never interact.

SECTION B: STRUCTURED QUESTIONS (50 MARKS)

Instructions: Answer all questions. Write clearly and use appropriate scientific terms.

Question 31. Structure and functions of the eye (9 marks)

a) Define the term sensory receptor. (2 marks)

b) State the functions of the following structures of the eye: (4 marks)

i. Cornea.

ii. Iris.

iii. Retina.

iv. Optic nerve.

c) Explain how the eye focuses on a nearby object. (3 marks)

Question 32. Structure and functions of the ear (8 marks)

a) Name the three main divisions of the human ear. (3 marks)

b) State the functions of the following structures: (3 marks)

i. Pinna.

ii. Tympanic membrane.

iii. Cochlea.

c) Explain how the semicircular canals help maintain balance. (2 marks)

Question 33. Ear disorders and interventions (7 marks)

a) Define otitis media. (2 marks)

b) State three possible causes or risk factors of hearing loss. (3 marks)

c) Give two ways of protecting the ears from damage. (2 marks)

Question 34. The endocrine system (9 marks)

a) Define the following terms: (2 marks)

i. Endocrine gland.

ii. Hormone.

b) Name the endocrine gland that produces each of the following hormones: (3 marks)

i. Thyroxine.

ii. Insulin.

iii. Adrenaline.

c) State one principal function of each of the following hormones: (4 marks)

i. Growth hormone.

ii. Testosterone.

iii. Oestrogen.

iv. Glucagon.

Question 35. Adrenaline and thyroxine (9 marks)

a) State four effects of adrenaline secretion in the body. (4 marks)

b) Distinguish between hyperthyroidism and hypothyroidism. (2 marks)

c) State three signs or symptoms associated with hyperthyroidism. (3 marks)

Question 36. Nervous and endocrine systems (8 marks)

a) State three similarities between the nervous and endocrine systems. (3 marks)

b) Give three differences between the nervous and endocrine systems. (3 marks)

c) Explain how the nervous and endocrine systems work together when a person encounters danger. (2 marks)

TOTAL: 50 MARKS

ANSWERS AND MARKING SCHEME

SECTION A: MULTIPLE-CHOICE ANSWERS

Question	Answer	Correct response
1	B	Detects stimuli and converts them into electrical signals
2	C	Iris
3	A	Cornea
4	B	Retina
5	B	Rod cells
6	C	Fovea
7	B	Optic nerve
8	B	Becomes thicker and more convex
9	B	Relax
10	B	Myopia
11	A	Clouding of the lens
12	B	Pinna
13	B	Eardrum
14	B	Malleus, incus, stapes
15	B	Equalises air pressure
16	A	Cochlea
17	B	Rotational movement of the head
18	A	Linear acceleration and head position
19	B	Otitis externa
20	C	Using hearing protection
21	A	Ductless hormone-producing glands and tissues
22	B	Pituitary gland
23	B	Thyroxine
24	B	Adrenaline
25	C	Pancreas
26	B	Lowers blood glucose
27	C	Testosterone

28	A	Progesterone
29	B	Hyperthyroidism
30	C	Nervous responses are generally faster

SECTION B: SUGGESTED ANSWERS AND MARKING SCHEME

Question 31. Structure and functions of the eye (9 marks)

a) A sensory receptor is a specialised cell or nerve ending that detects a stimulus and converts it into an electrical signal. (2 marks)

b) Functions:

i. Cornea – Allows light to enter and refracts incoming light. (1)

ii. Iris – Controls the size of the pupil and regulates the amount of light entering the eye. (1)

iii. Retina – Contains photoreceptors that detect light and initiate electrical signals. (1)

iv. Optic nerve – Transmits visual impulses from the retina to the brain. (1)

c) Focusing on a nearby object:

1. Ciliary muscles contract. (1)
2. Suspensory ligaments loosen. (1)
3. The lens becomes thicker and more convex, increasing its refractive power to focus light on the retina. (1)

Question 32. Structure and functions of the ear (8 marks)

a) Main divisions:

1. Outer ear. (1)
2. Middle ear. (1)
3. Inner ear. (1)

b) Functions:

i. Pinna – Collects sound waves and directs them into the auditory canal. (1)

ii. Tympanic membrane – Vibrates when struck by sound waves and transmits vibrations to the ossicles. (1)

iii. Cochlea – Converts mechanical vibrations into electrical signals for hearing. (1)

c) Role of semicircular canals:

1. Detect rotational movements of the head through movement of fluid and stimulation of sensory hair cells. (1)
2. Send nerve signals to the brain, which uses the information to coordinate balance and posture. (1)

Question 33. Ear disorders and interventions (7 marks)

a) Otitis media is inflammation or infection of the middle ear, often associated with fluid accumulation behind the eardrum. (2 marks)

b) Possible causes or risk factors of hearing loss:

1. Prolonged exposure to loud noise. (1)
2. Ear infections. (1)
3. Ageing or damage to sensory hair cells. (1)

Accept genetic factors, ear injuries, certain medicines or structural abnormalities.

c) Ways of protecting the ears:

1. Avoid prolonged exposure to loud sounds and use suitable hearing protection. (1)
2. Avoid inserting sharp objects or cotton buds into the ear canal. (1)

Question 34. The endocrine system (9 marks)

a) Definitions:

i. An endocrine gland is a ductless gland that releases hormones into the blood or surrounding tissue fluid. (1)

ii. A hormone is a chemical messenger that acts on specific target cells or organs to regulate body activities. (1)

b) Endocrine glands:

i. Thyroxine – Thyroid gland. (1)

ii. Insulin – Pancreas. (1)

iii. Adrenaline – Adrenal medulla. (1)

c) Functions:

i. Growth hormone – Stimulates growth of bones and body tissues. (1)

ii. Testosterone – Promotes male sexual development and supports sperm production. (1)

iii. Oestrogen – Promotes female secondary sexual characteristics and growth of the uterine lining. (1)

iv. Glucagon – Raises blood glucose levels by stimulating glucose release from the liver. (1)

Question 35. Adrenaline and thyroxine (9 marks)

a) Effects of adrenaline:

1. Increases heart rate. (1)
2. Increases blood glucose levels. (1)
3. Dilates the bronchioles. (1)
4. Dilates the pupils or redirects blood towards skeletal muscles. (1)

b) Differences:

- Hyperthyroidism: Excess production of thyroid hormones. (1)
- Hypothyroidism: Insufficient production of thyroid hormones. (1)

c) Signs or symptoms of hyperthyroidism:

1. Unexplained weight loss. (1)
2. Rapid heartbeat. (1)
3. Heat intolerance or excessive sweating. (1)

Accept trembling, nervousness, difficulty sleeping or increased appetite.

Question 36. Nervous and endocrine systems (8 marks)

a) Similarities:

1. Both coordinate and regulate body activities. (1)
2. Both help maintain homeostasis. (1)
3. Both help the body respond to internal and external changes. (1)

b) Differences:

1. The nervous system uses electrical impulses along neurons, while the endocrine system uses hormones transported through the blood. (1)
2. Nervous responses are generally faster, while endocrine responses are generally slower. (1)
3. Nervous effects are often short-lived, while hormonal effects may last longer. (1)

c) Coordination during danger:

1. The nervous system detects and processes the danger and activates the sympathetic nervous system. (1)
2. Nerve signals stimulate the adrenal medulla to release adrenaline, preparing the body for rapid action. (1)

14.0 ADDITIONAL APPLICATION AND PROJECT WORK

Project 1: Developing a human sense organs chart

Task: Prepare a large, labelled chart showing the structures of the human eye and ear.

The chart should include:

- Names of the structures.
- Functions of the structures.
- Adaptations to their functions.
- Common disorders affecting each organ.
- Ways of protecting the organs.

Expected product: A classroom display chart made using locally available materials.

Project 2: Endocrine glands in human beings

Task: Construct a model of the human endocrine system showing the positions of the major glands.

Include:

1. Pituitary gland.
2. Thyroid gland.
3. Adrenal glands.
4. Pancreas.
5. Testes.
6. Ovaries.

For each gland, provide at least one hormone and its principal effect.

Project 3: Community health awareness

Task: Prepare a short health awareness presentation on protecting the eyes and ears.

Address:

- Safe use of earphones.
- Protection against loud noise.
- Eye protection during practical activities.
- Importance of regular eye and hearing examinations.
- Early medical attention for sensory disorders.

Suggested project assessment rubric

Assessment area	Marks
Scientific accuracy	5
Correct labelling	5
Neatness and creativity	4
Explanation of functions	4
Presentation and teamwork	2
Total	20

STRAND 2.0: MATTER AND CHEMICAL REACTIONS

SUB-STRAND 2.1: SALTS II

1.0 Introduction to salts

1.1 Meaning of salts

A **salt** is an ionic compound formed when the hydrogen ions of an acid are wholly or partially replaced by metal ions or ammonium ions.

- Salts are made up of positively charged ions called **cations** and negatively charged ions called **anions**.

- Most salts are formed through the reaction of an acid with a base, metal or carbonate.
- Salts may be soluble or insoluble in water.
- Some salts dissolve easily in water, while others dissolve only slightly or do not dissolve appreciably.

Examples of salts

Salt	Chemical formula	Common use
Sodium chloride	NaCl	Table salt and food preservation
Potassium nitrate	KNO_3	Fertilisers
Calcium carbonate	$CaCO_3$	Manufacture of cement and limestone products
Copper(II) sulphate	$CuSO_4$	Laboratory reagent and agricultural applications
Ammonium chloride	NH_4Cl	Fertilisers and dry cells
Sodium hydrogen carbonate	$NaHCO_3$	Baking and some cleaning applications

1.2 Formation of salts

Salts can be prepared through different chemical reactions.

a) Acid + metal → salt + hydrogen gas

Example:

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

Magnesium reacts with dilute hydrochloric acid to form magnesium chloride and hydrogen gas.

b) Acid + base → salt + water

Example:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

Hydrochloric acid reacts with sodium hydroxide to form sodium chloride and water.

c) Acid + carbonate → salt + water + carbon dioxide

Example:

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

Calcium carbonate reacts with hydrochloric acid to form calcium chloride, water and carbon dioxide.

d) Acid + ammonia → ammonium salt

Example:

$$NH_3 + HCl \rightarrow NH_4Cl$$

Ammonia reacts with hydrogen chloride to form ammonium chloride.

2.0 Solubility of salts in water

2.1 Meaning of solubility

Solubility is the maximum amount of a solute that can dissolve in a given amount of solvent at a specified temperature to form a saturated solution.

- A **solute** is a substance that dissolves in another substance.
- A **solvent** is the substance that dissolves the solute.
- A **solution** is a uniform mixture formed when a solute dissolves in a solvent.
- Water is a common solvent and is sometimes referred to as the universal solvent.
- Solubility is commonly expressed in grams of solute per 100 g of water.

Example:

If 36 g of sodium chloride dissolves in 100 g of water at a particular temperature to form a saturated solution, its solubility under those conditions is 36 g per 100 g of water.

2.2 Types of solutions based on solubility

a) Unsaturated solution

- Contains less dissolved solute than the maximum amount that can dissolve at a given temperature.
- More solute can dissolve in the solution.
- No undissolved solute remains when the solution is properly mixed.

b) Saturated solution

- Contains the maximum amount of solute that can dissolve at a particular temperature.
- Any additional solute remains undissolved if equilibrium conditions are maintained.
- It is in dynamic equilibrium with any undissolved solute present.

c) Supersaturated solution

- Contains more dissolved solute than a saturated solution normally holds at the same temperature.
- It is unstable.
- Disturbing the solution or adding a small crystal of the solute may cause excess solute to crystallise out.

2.3 Classification of salts according to solubility in water

Salts can be classified as:

1. Soluble salts.
2. Insoluble or sparingly soluble salts.

A. Soluble salts

These are salts that dissolve appreciably in water to form aqueous solutions.

Examples:

- Sodium chloride – NaCl.
- Potassium nitrate – KNO_3.
- Ammonium chloride – NH_4Cl.
- Copper(II) sulphate – $CuSO_4$.
- Sodium carbonate – Na_2CO_3.
- Potassium chloride – KCl.

B. Insoluble or sparingly soluble salts

These are salts that dissolve very little or do not dissolve appreciably in water.

Examples:

- Silver chloride – AgCl.
- Barium sulphate – $BaSO_4$.
- Lead(II) sulphate – $PbSO_4$.
- Calcium carbonate – $CaCO_3$.
- Copper(II) carbonate – $CuCO_3$.

2.4 General rules of solubility of salts

The following rules help learners predict whether a salt is soluble or insoluble in water.

Type of salt	General solubility rule	Examples
All nitrates	Soluble	$NaNO_3$, KNO_3, $Cu(NO_3)_2$
Sodium salts	Soluble	NaCl, Na_2SO_4
Potassium salts	Soluble	KCl, K_2CO_3
Ammonium salts	Soluble	NH_4Cl, $(NH_4)_2SO_4$
Most chlorides	Soluble	NaCl, KCl
Silver chloride	Insoluble	AgCl
Lead(II) chloride	Sparingly soluble; more soluble in hot water	$PbCl_2$
Most sulphates	Soluble	Na_2SO_4, $CuSO_4$
Barium sulphate	Insoluble	$BaSO_4$
Lead(II) sulphate	Insoluble	$PbSO_4$
Most carbonates	Insoluble except those of Group 1 metals and ammonium	$CaCO_3$, $CuCO_3$
Most hydroxides	Insoluble except Group 1 hydroxides and some others	$Cu(OH)_2$, $Fe(OH)_3$

Important points

- Solubility rules are general guidelines, and some salts are only slightly soluble.
- Calcium sulphate and lead(II) chloride are examples of salts with limited solubility.
- Sodium, potassium and ammonium salts are generally soluble.
- Nitrates are generally soluble in water.

3.0 Factors affecting the solubility of salts

The solubility of salts in water is affected mainly by temperature and the nature of the solute and solvent. Surface area affects the rate at which a salt dissolves, rather than the equilibrium solubility of a fixed salt at a fixed temperature.

3.1 Temperature

Temperature is the degree of hotness or coldness of a substance.

- Temperature affects the amount of a salt that can dissolve in water.
- For many solid salts, solubility increases as temperature increases.
- Some salts show only a small increase in solubility with temperature.
- A few salts become less soluble as temperature increases.
- When a hot saturated solution is cooled, excess dissolved salt may crystallise out.

Example:

Potassium nitrate dissolves much more readily in hot water than in cold water.

Practical activity: Investigating the effect of temperature

Materials:

- Potassium nitrate or another suitable salt.
- Water.
- Beakers.
- Measuring cylinder.
- Thermometer.
- Balance.
- Stirring rod.
- Heating apparatus.

Procedure:

1. Measure equal amounts of water into different beakers.
2. Heat the water in the beakers to different temperatures.
3. Add measured quantities of the salt gradually.
4. Stir each mixture until no more salt dissolves.
5. Record the maximum mass of salt dissolved at each temperature.
6. Compare the results.

Observation:

- For potassium nitrate, more salt dissolves as the temperature increases.

Conclusion:

- The solubility of potassium nitrate increases with temperature.

3.2 Surface area

Surface area is the total area of the exposed surface of a substance.

- Crushing a solid salt into smaller particles increases its total exposed surface area.
- A powdered salt has a larger exposed surface area than the same mass of large crystals.

- A larger surface area allows water particles to come into contact with more of the solid at the same time.
- This increases the rate at which the salt dissolves.
- Surface area does not normally change the final equilibrium solubility of the same salt at a fixed temperature.

Example:

Powdered salt dissolves faster in water than an equal mass of large salt crystals under the same conditions.

Practical activity: Investigating the effect of surface area

Materials:

- Equal masses of coarse salt and powdered salt.
- Two beakers.
- Equal volumes of water.
- Stopwatch.
- Stirring rods.

Procedure:

1. Place equal volumes of water in two beakers.
2. Put coarse salt in the first beaker.
3. Put powdered salt in the second beaker.
4. Stir both mixtures at the same rate.
5. Record the time taken for the salt to dissolve.
6. Compare the results.

Expected observation:

- Powdered salt dissolves faster than coarse salt.

Conclusion:

- Increasing surface area increases the rate of dissolving.

3.3 Nature of the solute and solvent

- Different salts have different solubilities in water.
- Some salts dissolve readily, while others dissolve only slightly.
- The attraction between the particles of the solute and solvent affects whether dissolution occurs.
- Water is a polar solvent and dissolves many ionic compounds.

Examples:

- Sodium chloride dissolves readily in water.
- Silver chloride is practically insoluble in water.
- Barium sulphate is practically insoluble in water.

3.4 Stirring

- Stirring brings fresh solvent into contact with the surface of the salt.

- It helps dissolved particles move away from the solid surface.
- It generally increases the rate of dissolving.
- Stirring does not normally increase the final equilibrium solubility at a fixed temperature.

Remember the difference:

Factor	Main effect
Temperature	Can change the equilibrium solubility
Nature of solute and solvent	Determines how readily a substance dissolves
Surface area	Increases the rate of dissolving
Stirring	Increases the rate of dissolving

4.0 Solubility curves

4.1 Meaning of a solubility curve

A **solubility curve** is a graph showing how the solubility of a substance changes with temperature.

- Temperature is normally plotted on the horizontal (x) axis.
- Solubility is plotted on the vertical (y) axis.
- Solubility is commonly expressed as grams of solute per 100 g of water.
- Each curve represents the solubility behaviour of a particular substance.

4.2 Interpretation of solubility curves

A solubility curve helps learners to:

1. Determine the solubility of a salt at a given temperature.
2. Compare the solubility of different salts.
3. Identify salts whose solubility changes greatly with temperature.
4. Determine the amount of salt that crystallises when a saturated solution is cooled.
5. Determine the amount of additional salt that can dissolve when a solution is heated.
6. Identify suitable temperatures for separating salts by fractional crystallisation.

4.3 Understanding different shapes of solubility curves

A. Upward-sloping curve

- Indicates that solubility increases as temperature increases.
- Many solid salts show this behaviour.
- Example: potassium nitrate.

B. Nearly horizontal curve

- Indicates that solubility changes only slightly with temperature.
- Example: sodium chloride has a relatively small change in solubility over a wide temperature range.

C. Downward-sloping curve

- Indicates that solubility decreases as temperature increases.
- Some salts, such as cerium(III) sulphate, show this behaviour over certain temperature ranges.

4.4 Using a solubility curve to calculate crystallisation

When a saturated solution is cooled, the amount of salt that remains dissolved decreases if the salt is less soluble at the lower temperature.

The difference between the solubility at the higher temperature and that at the lower temperature gives the mass of salt that crystallises out, provided the same mass of water is used and no water is lost.

Formula:

$$\text{Mass crystallised} = S_{\text{hot}} - S_{\text{cold}}$$

Where:

- S_{hot} = solubility at the higher temperature.
- S_{cold} = solubility at the lower temperature.

Worked example 1

The solubility of a salt is 80 g per 100 g of water at 80°C and 30 g per 100 g of water at 20°C.

Calculate the mass of salt that crystallises when a saturated solution containing 100 g of water is cooled from 80°C to 20°C.

Solution:

Solubility at 80°C = 80 g.

Solubility at 20°C = 30 g.

$$\text{Mass crystallised} = 80 - 30$$

$$= 50\ \text{g}$$

Answer: 50 g of salt crystallises out.

Worked example 2

A saturated solution contains 200 g of water. The solubility of a salt decreases from 60 g to 20 g per 100 g of water when cooled.

Calculate the mass of salt that crystallises out.

Solution:

Mass crystallised per 100 g of water:

$$60 - 20 = 40\ \text{g}$$

For 200 g of water:

$$40 \times \frac{200}{100} = 80\ \text{g}$$

Answer: 80 g of salt crystallises out.

Important: Always consider the mass of water in the solution. Do not assume the solution contains 100 g of water unless the question states so.

5.0 Fractional crystallisation

5.1 Meaning of fractional crystallisation

Fractional crystallisation is a method of separating a mixture of dissolved salts by using differences in their solubilities at different temperatures.

- It is used when two or more salts are dissolved in the same solvent.
- The mixture is concentrated by evaporating some of the solvent.
- The solution is cooled under controlled conditions.
- The salt that becomes less soluble first crystallises out.
- The crystals are separated from the remaining solution by filtration.
- Further cooling or evaporation can recover other salts.

5.2 Steps involved in fractional crystallisation

1. **Preparation of the mixture**
   - ✓ Dissolve the mixture of salts in a suitable solvent, usually water.
2. **Heating**
   - ✓ Heat the solution to increase the solubility of the salts where appropriate.
   - ✓ Evaporate some water to make the solution more concentrated.
3. **Cooling**
   - ✓ Allow the concentrated solution to cool slowly.
   - ✓ The salt whose solubility decreases sufficiently crystallises first.
4. **Filtration**
   - ✓ Filter the mixture to separate the crystals from the remaining solution.
5. **Washing**
   - ✓ Wash the crystals with a small amount of suitable cold solvent to remove impurities.
6. **Drying**
   - ✓ Dry the crystals between filter papers or in a suitable drying apparatus.
7. **Recovery of other salts**
   - ✓ Further cool or evaporate the remaining solution to obtain other salts.

5.3 Example of fractional crystallisation

A mixture containing potassium nitrate and sodium chloride can be separated using their different solubility behaviours.

- Potassium nitrate becomes much less soluble when the solution is cooled.
- Sodium chloride has a comparatively small change in solubility with temperature.
- A suitable concentrated solution can therefore be cooled to obtain potassium nitrate crystals.
- The crystals are filtered off.
- Sodium chloride remains in the solution in greater proportion and may be recovered through further evaporation and crystallisation.

Note: The exact conditions depend on the starting composition and the solubility curves of the salts.

5.4 Applications of fractional crystallisation

- Separation of salts from mixtures.
- Purification of substances in chemical industries.
- Production of potassium nitrate and other useful salts.
- Recovery of valuable minerals from natural brines.
- Processing of salts obtained from seawater.
- Production of crystals for laboratory and industrial use.

6.0 Fractional crystallisation

Kenya has important natural sources of salts and minerals. Solubility differences are useful in recovering and processing these substances.

6.1 Extraction of soda ash from Lake Magadi

- Lake Magadi is found in Kajiado County, in the southern part of Kenya.
- The lake contains highly alkaline water rich in dissolved sodium salts.
- One important mineral associated with Lake Magadi is **trona**.
- Trona is a naturally occurring sodium carbonate mineral containing water and sodium hydrogen carbonate.
- The mineral is processed to obtain soda ash, which is mainly sodium carbonate (Na_2CO_3).
- Sodium carbonate is used in glass manufacture, detergents and various industrial processes.
- Processing involves mineral recovery, purification and controlled heating; the precise industrial process is more involved than simple crystallisation alone.

Uses of soda ash

1. Manufacture of glass.
2. Manufacture of detergents.
3. Water treatment.
4. Manufacture of chemicals.
5. Some industrial cleaning processes.

6.2 Extraction of common salt from seawater

- Seawater contains dissolved salts, mainly sodium chloride.
- Seawater can be channelled into shallow evaporation ponds.
- Heat from the sun causes water to evaporate.
- The concentration of dissolved salts increases.
- Sodium chloride eventually crystallises when the solution becomes sufficiently concentrated.
- The crystals are harvested, washed where necessary and dried.
- The process is used in salt production in coastal areas, including parts of Kenya's coast.

Importance of salt production

- Provides table salt for households.

- Supports food preservation.
- Creates employment.
- Supplies raw materials for industries.
- Supports trade and economic activities.

Environmental considerations

- Salt production requires careful management of brine and waste.
- Excessive alteration of coastal wetlands can affect habitats.
- Responsible water use and environmental monitoring are important.

7.0 Qualitative analysis of salts

7.1 Meaning of qualitative analysis

Qualitative analysis is the process of identifying the substances or ions present in a sample without determining their exact quantities.

- It is used to identify cations and anions in salts.
- It involves adding suitable reagents to a sample and observing the changes.
- Common observations include colour changes, formation of precipitates and evolution of gases.
- Flame tests can also help identify certain metal ions.

7.2 Meaning of cations and anions

Cations

- Positively charged ions.
- Formed when atoms or groups of atoms lose electrons.
- Examples: Na^+, K^+, Ca^{2+}, Cu^{2+}, Fe^{2+} and NH_4^+.

Anions

- Negatively charged ions.
- Formed when atoms or groups of atoms gain electrons.
- Examples: Cl^-, SO_4^{2-}, SO_3^{2-}, CO_3^{2-} and HCO_3^-.

7.3 Reagents used in testing ions

A **reagent** is a chemical substance added to a sample to cause a reaction that helps identify the substances present.

Common reagents used in this sub-strand include:

Reagent	Formula	Main use
Dilute hydrochloric acid	HCl(aq)	Testing carbonates and hydrogen carbonates
Sodium hydroxide solution	NaOH(aq)	Testing several metal cations and ammonium ions
Aqueous ammonia	NH_3(aq)	Distinguishing some metal ions

Reagent	Formula	Main use
Barium chloride solution	$BaCl_2(aq)$	Testing sulphate and sulphite ions
Potassium iodide solution	KI(aq)	Testing lead(II) ions
Lead(II) nitrate solution	$Pb(NO_3)_2(aq)$	Testing selected anions
Silver nitrate solution	$AgNO_3(aq)$	Testing halide ions, especially chloride

Laboratory safety

- Wear safety goggles, a laboratory coat and suitable gloves.
- Use small quantities of chemicals.
- Avoid direct contact with reagents.
- Never taste chemicals or directly inhale gases.
- Lead compounds are toxic; avoid skin contact and dispose of their waste as hazardous chemical waste.
- Carry out tests that may release irritating gases in a well-ventilated laboratory or fume cupboard.
- Do not mix unknown chemicals without teacher supervision.

8.0 Tests for cations in solution

8.1 Testing for lead(II) ions (Pb^{2+})

Reagent: Aqueous potassium iodide (KI).

Procedure:

1. Place a small amount of the salt solution in a clean test tube.
2. Add a few drops of potassium iodide solution.
3. Observe the change.

Observation:

- A bright yellow precipitate forms.

Inference:

- Lead(II) ions may be present.

Ionic equation:

$$Pb^{2+}(aq) + 2I^{-}(aq) \rightarrow PbI_2(s)$$

The yellow precipitate is lead(II) iodide.

8.2 Testing for calcium ions (Ca^{2+})

Reagent: Aqueous sodium hydroxide.

Procedure:

1. Add a few drops of sodium hydroxide solution to the sample.
2. Observe the mixture.
3. Add excess sodium hydroxide and observe whether the precipitate dissolves.

Observation:

- A white precipitate forms.
- It remains insoluble in excess sodium hydroxide.

Inference:

- Calcium ions may be present.

Ionic equation:

$$Ca^{2+}(aq) + 2OH^{-}(aq) \rightarrow Ca(OH)_2(s)$$

8.3 Testing for zinc ions (Zn^{2+})

Reagent: Aqueous sodium hydroxide.

Procedure:

1. Add sodium hydroxide solution dropwise to the sample.
2. Observe the precipitate.
3. Add excess sodium hydroxide.

Observation:

- A white precipitate forms.
- The precipitate dissolves in excess sodium hydroxide to form a colourless solution.

Inference:

- Zinc ions may be present.

Ionic equation:

$$Zn^{2+}(aq) + 2OH^{-}(aq) \rightarrow Zn(OH)_2(s)$$

In excess sodium hydroxide:

$$Zn(OH)_2(s) + 2OH^{-}(aq) \rightarrow [Zn(OH)_4]^{2-}(aq)$$

8.4 Testing for copper(II) ions (Cu^{2+})

Reagent: Aqueous sodium hydroxide.

Observation:

- A light blue precipitate forms.
- It remains insoluble in excess sodium hydroxide.

Inference:

- Copper(II) ions may be present.

Ionic equation:

$$Cu^{2+}(aq) + 2OH^{-}(aq) \rightarrow Cu(OH)_2(s)$$

8.5 Testing for iron(II) ions (Fe^{2+})

Reagent: Aqueous sodium hydroxide.

Observation:

- A green precipitate forms.

- The precipitate is insoluble in excess sodium hydroxide.
- It may turn brown on standing because iron(II) hydroxide is oxidised by air.

Inference:

- Iron(II) ions may be present.

Ionic equation:

$$Fe^{2+}(aq) + 2OH^{-}(aq) \rightarrow Fe(OH)_2(s)$$

8.6 Testing for iron(III) ions (Fe^{3+})

Reagent: Aqueous sodium hydroxide.

Observation:

- A reddish-brown precipitate forms.
- It is insoluble in excess sodium hydroxide.

Inference:

- Iron(III) ions may be present.

Ionic equation:

$$Fe^{3+}(aq) + 3OH^{-}(aq) \rightarrow Fe(OH)_3(s)$$

8.7 Testing for ammonium ions (NH_4^+)

Reagent: Aqueous sodium hydroxide.

Procedure:

1. Place a small amount of the salt solution in a test tube.
2. Add sodium hydroxide solution.
3. Warm gently.
4. Test any gas produced using damp red litmus paper.

Observation:

- A colourless gas with a pungent smell is released.
- Damp red litmus paper turns blue.

Inference:

- Ammonium ions may be present.
- The gas is ammonia.

Ionic equation:

$$NH_4^+(aq) + OH^{-}(aq) \rightarrow NH_3(g) + H_2O(l)$$

Safety: Do not smell the gas directly. Use the damp litmus paper test.

8.8 Testing for potassium ions (K^+)

Method: Flame test.

Procedure:

1. Clean a nichrome or platinum wire loop.

2. Dip it into the salt sample.
3. Place it in a non-luminous Bunsen burner flame.
4. Observe the flame colour.

Observation:

- A lilac flame is produced.

Inference:

- Potassium ions may be present.

8.9 Testing for sodium ions (Na^+)

Method: Flame test.

Observation:

- A bright golden-yellow flame is produced.

Inference:

- Sodium ions may be present.

8.10 Testing for magnesium ions (Mg^{2+})

Reagent: Aqueous sodium hydroxide.

Observation:

- A white precipitate forms.
- The precipitate remains insoluble in excess sodium hydroxide.

Inference:

- Magnesium ions may be present.

Ionic equation:

$$Mg^{2+}(aq) + 2OH^{-}(aq) \rightarrow Mg(OH)_2(s)$$

8.11 Testing for barium ions (Ba^{2+})

Reagent: Aqueous sodium sulphate or another suitable source of sulphate ions.

Observation:

- A white precipitate forms.

Inference:

- Barium ions may be present.

Ionic equation:

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

Note: Aqueous sodium sulphate is used here as a confirmatory reagent. Barium salts are toxic and should be handled carefully.

9.0 Summary table for testing cations

Cation	Reagent or method	Observation

Cation	Reagent or method	Observation
Pb^{2+}	KI(aq)	Bright yellow precipitate
Ca^{2+}	NaOH(aq)	White precipitate, insoluble in excess
Zn^{2+}	NaOH(aq)	White precipitate, dissolves in excess
Cu^{2+}	NaOH(aq)	Light blue precipitate
Fe^{2+}	NaOH(aq)	Green precipitate, may turn brown
Fe^{3+}	NaOH(aq)	Reddish-brown precipitate
NH_4^+	NaOH(aq), warm gently	Ammonia gas; damp red litmus turns blue
K^+	Flame test	Lilac flame
Na^+	Flame test	Golden-yellow flame
Mg^{2+}	NaOH(aq)	White precipitate, insoluble in excess
Ba^{2+}	Sulphate solution	White precipitate

Important: A single observation may not be enough to identify an ion conclusively. Confirmatory tests and careful control of experimental conditions are important.

10.0 Flame tests for metal ions

10.1 Meaning of a flame test

A **flame test** is a chemical test used to identify certain metal ions by the characteristic colour they produce when heated in a flame.

- When some metal ions are heated, their electrons absorb energy.
- The electrons move to higher energy levels.
- When the electrons return to lower energy levels, they release energy as light.
- The light produced has characteristic colours for particular elements.
- Flame tests are useful for identifying some metal ions in salts.

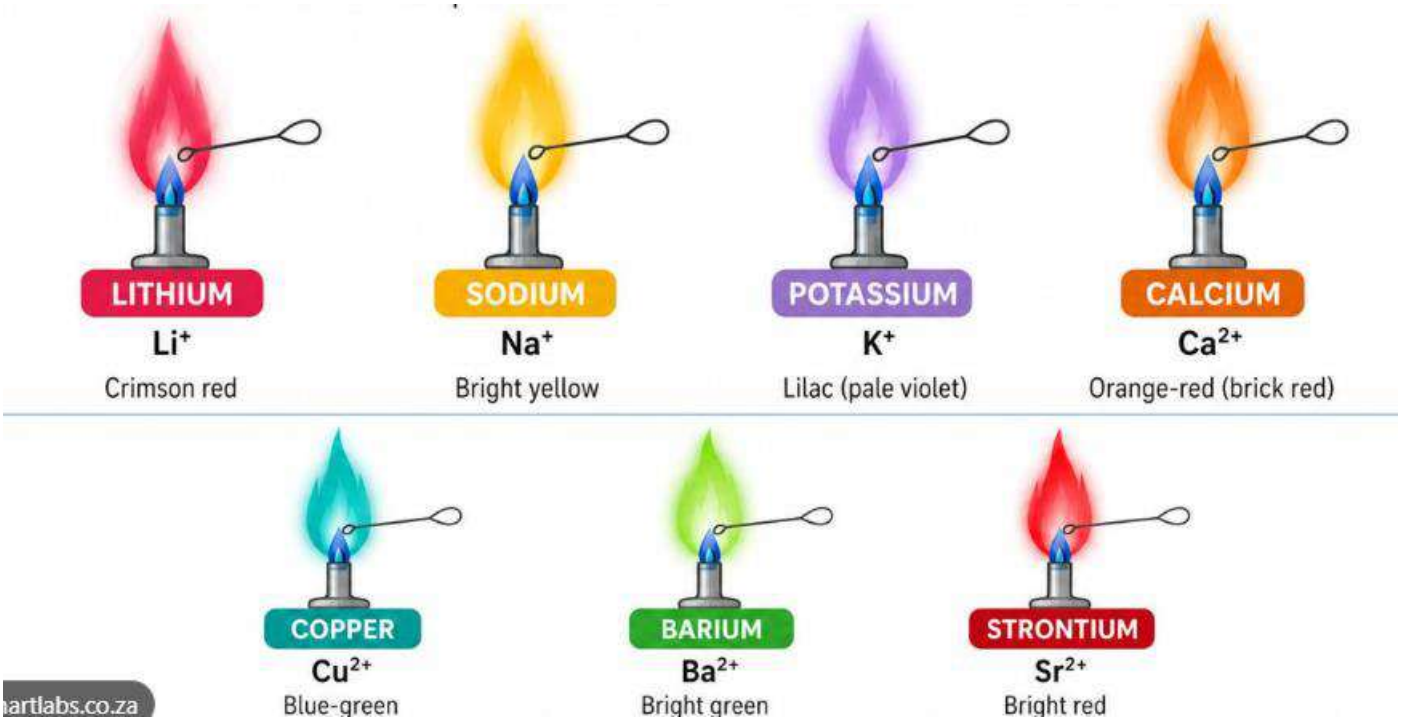
10.2 Flame test procedure

1. Clean a nichrome or platinum wire loop using a suitable cleaning procedure.
2. Moisten the clean wire loop with distilled water or a suitable acid as instructed by the teacher.
3. Dip the loop into a small quantity of the salt.
4. Place the loop in the non-luminous region of a Bunsen burner flame.
5. Observe and record the colour produced.
6. Clean the loop thoroughly before testing another salt to avoid contamination.

10.3 Flame colours of selected metal ions

Metal ion	Flame colour
Lithium (Li^+)	Crimson red

Metal ion	Flame colour
Sodium (Na^+)	Bright golden yellow
Potassium (K^+)	Lilac or pale violet
Calcium (Ca^{2+})	Brick red or orange-red
Copper (Cu^{2+})	Blue-green



Important points

- Sodium produces a very intense yellow flame and can mask the colours of other ions.
- Potassium's lilac flame may be difficult to observe when sodium contamination is present.
- A cobalt-blue glass filter may help distinguish potassium's flame colour from sodium's yellow emission.
- Flame tests are not suitable for identifying every metal ion.
- Some ions require other chemical tests for confirmation.

11.0 Tests for anions in solution

Anions are negatively charged ions. They can be identified using suitable reagents and observing the products formed.

11.1 Testing for chloride ions (Cl^-)

Reagent: Silver nitrate solution ($AgNO_3$).

Procedure:

1. Place a small quantity of the salt solution in a test tube.
2. Acidify the solution with a few drops of dilute nitric acid.
3. Add silver nitrate solution.

4. Observe the mixture.

Observation:

- A white precipitate forms.

Inference:

- Chloride ions may be present.

Ionic equation:

$$Ag^{+}(aq) + Cl^{-}(aq) \rightarrow AgCl(s)$$

The white precipitate is silver chloride.

Confirmatory test:

- The white precipitate dissolves in dilute aqueous ammonia.

Note: Nitric acid is used to acidify the sample before adding silver nitrate. Hydrochloric acid must not be used because it introduces chloride ions and may produce a false positive result.

11.2 Testing for sulphate ions (SO_4^{2-})

Reagent: Barium chloride solution ($BaCl_2$).

Procedure:

1. Place the salt solution in a test tube.
2. Acidify it with a few drops of dilute hydrochloric acid.
3. Add barium chloride solution.
4. Observe the mixture.

Observation:

- A white precipitate forms.
- The precipitate remains insoluble in dilute acid.

Inference:

- Sulphate ions may be present.

Ionic equation:

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

The white precipitate is barium sulphate.

11.3 Testing for sulphite ions (SO_3^{2-})

Reagent: Dilute hydrochloric acid.

Procedure:

1. Add dilute hydrochloric acid to the sample.
2. Observe whether a gas is released.
3. Test the gas using suitable damp indicator paper or another approved test for sulphur dioxide.

Observation:

- Effervescence occurs.

- A colourless gas with a choking smell may be produced.
- The gas is sulphur dioxide.
- Sulphur dioxide decolourises acidified potassium manganate(VII) solution.

Inference:

- Sulphite ions may be present.

Ionic equation:

$$SO_3^{2-}(aq) + 2H^+(aq) \rightarrow SO_2(g) + H_2O(l)$$

Safety: Sulphur dioxide is irritating and harmful if inhaled. The test should be carried out in a fume cupboard or under suitable teacher-controlled ventilation. Never smell the gas directly.

11.4 Testing for carbonate ions (CO_3^{2-})

Reagent: Dilute hydrochloric acid.

Procedure:

1. Add dilute hydrochloric acid to the sample.
2. Observe the reaction.
3. Pass the gas produced through limewater.

Observation:

- Effervescence occurs.
- A colourless gas is produced.
- Limewater turns milky.

Inference:

- Carbonate ions may be present.
- The gas is carbon dioxide.

Ionic equation:

$$CO_3^{2-}(aq) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l)$$

Confirmatory reaction with limewater:

$$CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(l)$$

The white calcium carbonate precipitate makes limewater appear milky.

11.5 Testing for hydrogen carbonate ions (HCO_3^-)

Reagent: Dilute hydrochloric acid.

Procedure:

1. Add dilute hydrochloric acid to the sample.
2. Observe whether effervescence occurs.
3. Pass the gas produced through limewater.

Observation:

- Effervescence occurs.

- Carbon dioxide is released.
- Limewater turns milky.

Inference:

- Hydrogen carbonate ions may be present.

Ionic equation:

$$HCO_3^- + H^+ \rightarrow CO_2 + H_2O$$

Important distinction between carbonate and hydrogen carbonate

Both carbonate and hydrogen carbonate ions release carbon dioxide when treated with dilute acids. Therefore, the acid test alone does not distinguish them reliably. A suitable additional test is needed.

For example:

- Carbonates generally produce a stronger alkaline solution than hydrogen carbonates of the same metal.
- A carefully controlled comparison of their reactions and other chemical tests may be used.
- The identity of the cation and the known composition of the sample can also help distinguish the salts.

12.0 Summary table for testing anions

Anion	Reagent	Observation
Cl^-	Dilute nitric acid followed by $AgNO_3$(aq)	White precipitate of AgCl
SO_4^{2-}	Dilute HCl followed by $BaCl_2$(aq)	White precipitate of $BaSO_4$
SO_3^{2-}	Dilute HCl	Sulphur dioxide gas released
CO_3^{2-}	Dilute HCl	Carbon dioxide gas released; limewater turns milky
HCO_3^-	Dilute HCl	Carbon dioxide gas released; limewater turns milky

12.1 Summary of important ionic equations

Test	Ionic equation
Chloride test	$Ag^+ + Cl^- \rightarrow AgCl$
Sulphate test	$Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$
Carbonate test	$CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$
Hydrogen carbonate test	$HCO_3^- + H^+ \rightarrow CO_2 + H_2O$
Sulphite test	$SO_3^{2-} + 2H^+ \rightarrow SO_2 + H_2O$
Ammonium test	$NH_4^+ + OH^- \rightarrow NH_3 + H_2O$

13.0 Significance of solubility of salts in day-to-day life

Solubility of salts is important in biological, agricultural, domestic, medical and industrial processes.

13.1 Importance in human beings

- Many body fluids contain dissolved salts.
- Sodium and potassium ions help maintain the balance of fluids in the body.
- Calcium ions are important in the formation of bones and teeth.
- Calcium ions also play a role in blood clotting and muscle contraction.
- Chloride ions help maintain fluid balance and are involved in the formation of hydrochloric acid in the stomach.
- Magnesium ions are important in the functioning of muscles and enzymes.
- Dissolved ions in body fluids help conduct electrical impulses in nerves and muscles.

Why is the human body a good conductor of electricity?

- The human body contains a large proportion of water.
- Body fluids contain dissolved ions such as sodium, potassium, calcium and chloride ions.
- These ions are free to move through body fluids.
- Moving ions carry electrical charge.
- This allows electrical impulses to travel through nerves and muscles.

Important safety point: The human body can conduct electricity, so contact with live electrical wires or faulty electrical equipment can cause serious injury or death.

13.2 Importance in agriculture

- Soluble salts are used in the manufacture of fertilisers.
- Potassium salts supply potassium needed for plant growth.
- Nitrate salts supply nitrogen for the formation of proteins and other plant materials.
- Phosphate salts supply phosphorus needed for root development and energy transfer.
- Magnesium salts provide magnesium needed for chlorophyll formation.
- The solubility of fertilisers affects how quickly plants can absorb nutrients through their roots.

Examples of fertiliser salts

Salt	Nutrient supplied
Potassium nitrate (KNO_3)	Potassium and nitrogen
Ammonium sulphate ($(NH_4)_2SO_4$)	Nitrogen and sulphur
Ammonium nitrate (NH_4NO_3)	Nitrogen
Potassium chloride (KCl)	Potassium
Magnesium sulphate ($MgSO_4$)	Magnesium and sulphur

13.3 Importance in medicine and health

- Sodium chloride is used in the preparation of normal saline solutions.

- Oral rehydration salts help replace water and important electrolytes lost through diarrhoea and vomiting.
- Calcium salts are used in some supplements and medical preparations.
- Magnesium salts are used in certain medicines.
- The solubility of a medicinal salt affects how it dissolves and becomes available for absorption.

13.4 Importance in food preparation and preservation

- Sodium chloride is used to preserve meat and fish.
- Salt helps reduce the availability of water for the growth of some microorganisms.
- Sodium hydrogen carbonate is used in baking.
- Some soluble salts are used in food processing.
- Salt improves the taste of many foods.

13.5 Importance in water treatment

- Certain salts are used in water treatment processes.
- Aluminium sulphate is used as a coagulant in some water treatment systems.
- Calcium and magnesium salts affect water hardness.
- Solubility affects the formation of scale in water pipes and heating equipment.
- Understanding dissolved salts helps in the treatment of drinking water.

13.6 Importance in industries

- Sodium carbonate is used in glass manufacture.
- Sodium chloride is used in the chemical industry.
- Calcium carbonate is used in cement and lime production.
- Copper(II) sulphate has agricultural and laboratory applications.
- Potassium nitrate is used in fertiliser manufacture.
- Solubility differences are used in the purification and separation of industrial salts.

13.7 Importance in the environment

- Dissolved salts influence the quality of freshwater and seawater.
- Excessive salt accumulation in soil can affect plant growth.
- Salinity can reduce agricultural productivity.
- Salt concentration affects aquatic organisms.
- Solubility influences how minerals move through soil and water.
- The management of industrial salt waste helps prevent environmental pollution.

14.0 Practical investigations and learner activities

Activity 1: Investigating solubility at different temperatures

Aim: To determine how temperature affects the solubility of a salt.

Materials: Salt, water, beakers, thermometer, balance, measuring cylinder, stirring rod and heating apparatus.

Procedure:

1. Measure equal amounts of water into several beakers.
2. Heat the water to different temperatures.
3. Add the same salt gradually to each beaker.
4. Stir until no more salt dissolves.
5. Record the amount dissolved at each temperature.
6. Present the results in a table.

Expected outcome: Learners observe how the solubility of the selected salt changes with temperature.

Activity 2: Investigating the effect of surface area on dissolving

Aim: To compare the rate of dissolving of coarse and powdered salt.

Procedure:

1. Measure equal masses of coarse and powdered salt.
2. Put equal volumes of water into two beakers.
3. Add the coarse salt to the first beaker.
4. Add the powdered salt to the second beaker.
5. Stir both mixtures at the same rate.
6. Record the time taken for each sample to dissolve.

Expected outcome: Powdered salt generally dissolves faster because it has a larger exposed surface area.

Activity 3: Preparing crystals

Aim: To prepare crystals from a saturated salt solution.

Procedure:

1. Dissolve a suitable soluble salt in warm water.
2. Add the salt until the solution becomes saturated.
3. Filter the solution if it contains insoluble impurities.
4. Allow the solution to cool slowly or evaporate some water.
5. Observe the formation of crystals.
6. Separate and dry the crystals.

Expected outcome: Crystals of the salt form as the solution becomes saturated or supersaturated.

Activity 4: Testing ions in salt solutions

Aim: To identify selected cations and anions.

Procedure:

1. Obtain labelled salt solutions supplied by the teacher.
2. Place small quantities in separate test tubes.

3. Add suitable reagents as instructed.
4. Record the colour changes, precipitates and gases produced.
5. Compare observations with the standard tests.
6. Write conclusions based on the evidence.

Expected outcome: Learners identify selected ions using chemical tests.

Activity 5: Investigating flame colours

Aim: To observe the characteristic flame colours of selected metal salts.

Procedure:

1. Clean the wire loop.
2. Place a small amount of the salt on the loop.
3. Introduce it into the flame.
4. Record the colour observed.
5. Repeat with other salts, cleaning the loop between tests.

Expected outcome: Learners identify selected metal ions using their characteristic flame colours.

REVISION EXERCISES

SECTION A: MULTIPLE-CHOICE QUESTIONS

30 MARKS • Answer all questions. Each question carries 1 mark.

Question 1. What is meant by the solubility of a salt?

A. The speed at which a salt dissolves in water.
B. The maximum amount of salt that dissolves in a given amount of solvent at a specified temperature.
C. The mass of water in a salt solution.
D. The amount of salt that remains undissolved.

Question 2. Which one of the following salts is soluble in water?

A. Silver chloride
B. Barium sulphate
C. Sodium nitrate
D. Calcium carbonate

Question 3. Which of the following salts is generally insoluble in water?

A. Potassium chloride
B. Ammonium nitrate
C. Sodium sulphate
D. Lead(II) sulphate

Question 4. Which factor increases the rate at which a solid salt dissolves without normally changing its equilibrium solubility?

A. Surface area
B. Chemical formula
C. Type of cation
D. Mass of the container

Question 5. Which of the following salts generally becomes much more soluble as temperature increases?

A. Potassium nitrate
B. Silver chloride
C. Barium sulphate
D. Lead(II) sulphate

Question 6. A saturated solution is one that:

A. Contains no dissolved solute.
B. Contains the maximum amount of dissolved solute at a given temperature.
C. Contains more solute than it can normally dissolve at a given temperature.
D. Contains only water.

Question 7. What does a solubility curve show?

A. The relationship between pressure and volume.
B. The relationship between temperature and solubility.
C. The relationship between mass and density.
D. The relationship between time and reaction rate.

Question 8. The solubility of a salt is 70 g per 100 g of water at 80°C and 25 g per 100 g of water at 20°C. How much salt crystallises when a saturated solution containing 100 g of water is cooled?

A. 25 g
B. 45 g
C. 70 g
D. 95 g

Question 9. Which method is used to separate salts based on differences in their solubilities at different temperatures?

A. Distillation
B. Fractional crystallisation
C. Chromatography
D. Sublimation

Question 10. Which mineral is associated with the production of soda ash at Lake Magadi?

A. Trona
B. Haematite
C. Bauxite
D. Limestone

Question 11. What is the chemical formula of sodium chloride?

A. Na_2CO_3
B. NaCl

C. NaOH
D. $NaNO_3$

Question 12. Which of the following is a cation?

A. Cl^-
B. SO_4^{2-}
C. Na^+
D. CO_3^{2-}

Question 13. Which reagent is commonly used to test for chloride ions after acidification with dilute nitric acid?

A. Silver nitrate
B. Sodium hydroxide
C. Potassium iodide
D. Barium chloride

Question 14. What is the observation when silver nitrate reacts with chloride ions?

A. Blue precipitate
B. White precipitate
C. Green precipitate
D. Brown precipitate

Question 15. Which reagent is used to test for sulphate ions?

A. Sodium hydroxide
B. Barium chloride
C. Potassium iodide
D. Silver nitrate only

Question 16. What is the colour of the precipitate formed when barium ions react with sulphate ions?

A. Yellow
B. Blue
C. White
D. Green

Question 17. Which gas is released when a carbonate reacts with dilute hydrochloric acid?

A. Hydrogen
B. Oxygen
C. Carbon dioxide
D. Ammonia

Question 18. Which gas turns damp red litmus paper blue?

A. Carbon dioxide
B. Ammonia
C. Sulphur dioxide
D. Hydrogen

Question 19. What is observed when sodium hydroxide is added to a solution containing copper(II) ions?

A. Green precipitate
B. Light blue precipitate
C. Reddish-brown precipitate
D. Yellow precipitate

Question 20. Which precipitate is formed when sodium hydroxide is added to a solution containing iron(III) ions?

A. White
B. Blue

C. Reddish-brown
D. Green

Question 21. Which ion produces a lilac flame?

A. Na^+
B. K^+
C. Ca^{2+}
D. Cu^{2+}

Question 22. Which ion produces a golden-yellow flame?

A. Sodium
B. Potassium
C. Calcium
D. Lithium

Question 23. Which ion produces a brick-red flame?

A. Copper
B. Calcium
C. Sodium
D. Potassium

Question 24. Which ion produces a blue-green flame?

A. Lithium
B. Sodium
C. Copper
D. Calcium

Question 25. Which gas is produced when ammonium ions react with hydroxide ions on warming?

A. Carbon dioxide
B. Ammonia
C. Hydrogen
D. Sulphur dioxide

Question 26. Which of the following is the correct ionic equation for the formation of silver chloride?

A. $Ag^+ + Cl^- \rightarrow AgCl$
B. $Ag^+ + NO_3^- \rightarrow AgNO_3$
C. $Na^+ + Cl^- \rightarrow NaCl$
D. $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$

Question 27. Why are dissolved salts important in the human body?

A. They prevent all diseases.
B. They help conduct electrical impulses and maintain fluid balance.
C. They stop the movement of water.
D. They replace all proteins in the body.

Question 28. Which salt is commonly used in the manufacture of glass?

A. Sodium carbonate
B. Silver chloride
C. Lead(II) sulphate
D. Calcium hydroxide

Question 29. What is the main reason powdered salt dissolves faster than large salt crystals?

A. It has a lower mass.
B. It has a larger exposed surface area.

C. It has a different chemical composition.
D. It produces a different solvent.

Question 30. Which of the following is an important environmental effect of excessive salt accumulation in agricultural soil?

A. Increased soil fertility in all cases.
B. Improved growth of every crop.
C. Reduced ability of plants to absorb water.
D. Complete removal of soil minerals.

SECTION B: STRUCTURED QUESTIONS

50 MARKS • Answer all questions.

Question 1: Solubility of salts (8 marks)

a) Define the term solubility. (2 marks)

b) Distinguish between a saturated solution and an unsaturated solution. (2 marks)

c) Classify the following salts as soluble or insoluble in water. (4 marks)

i. Sodium chloride

ii. Silver chloride

iii. Potassium nitrate

iv. Barium sulphate

Question 2: Factors affecting solubility (8 marks)

a) State two factors that affect the solubility or rate of dissolving of salts in water. (2 marks)

b) Explain how temperature affects the solubility of most solid salts. (2 marks)

c) Explain why powdered salt dissolves faster than large salt crystals. (2 marks)

d) State why stirring increases the rate of dissolving but does not normally change the final equilibrium solubility. (2 marks)

Question 3: Solubility curves and crystallisation (8 marks)

A salt has a solubility of 90 g per 100 g of water at 80°C and 30 g per 100 g of water at 20°C.

a) Define a solubility curve. (2 marks)

b) Calculate the mass of salt that crystallises when a saturated solution containing 100 g of water is cooled from 80°C to 20°C. (2 marks)

c) Calculate the mass of salt that crystallises if the saturated solution contains 250 g of water. (2 marks)

d) State two uses of fractional crystallisation. (2 marks)

Question 4: Tests for cations (8 marks)

a) Name the reagent used to test for the following ions. (3 marks)

i. Pb^{2+}

ii. NH_4^+

iii. Cu^{2+}

b) State the observation when sodium hydroxide is added to a solution containing: (3 marks)

i. Fe^{2+}

ii. Fe^{3+}

iii. Zn^{2+}, followed by excess sodium hydroxide.

c) State the flame colours of: (2 marks)

i. Sodium ions.

ii. Potassium ions.

Question 5: Tests for anions (8 marks)

a) Describe how chloride ions are tested in a salt solution. (2 marks)

b) State the observation when barium chloride solution is added to an acidified solution containing sulphate ions. (2 marks)

c) Describe the test for carbonate ions using dilute hydrochloric acid and limewater. (2 marks)

d) Write the ionic equation for the reaction between sulphate ions and barium ions. (2 marks)

Question 6: Applications of salts (10 marks)

a) State three uses of salts in day-to-day life. (3 marks)

b) Explain two ways in which dissolved salts are important in the human body. (4 marks)

c) Explain how common salt can be obtained from seawater. (2 marks)

d) Name the mineral associated with soda ash production at Lake Magadi. (1 mark)

ANSWERS AND MARKING SCHEME

Section A: Multiple-choice answer key

Question	Answer	Question	Answer	Question	Answer
1	B	11	B	21	B
2	C	12	C	22	A
3	D	13	A	23	B
4	A	14	B	24	C
5	A	15	B	25	B
6	B	16	C	26	A

Question	Answer	Question	Answer	Question	Answer
7	B	17	C	27	B
8	B	18	B	28	A
9	B	19	B	29	B
10	A	20	C	30	C

Section B: Suggested marking scheme

Question 1 (8 marks)

a) Solubility is the maximum amount of a solute that dissolves in a given amount of solvent at a specified temperature to form a saturated solution. (2)

- Saturated solution: contains the maximum amount of dissolved solute at a given temperature. (1)
- Unsaturated solution: contains less than the maximum amount and can dissolve more solute. (1)
- Sodium chloride – Soluble. (1)
- Silver chloride – Insoluble. (1)
- Potassium nitrate – Soluble. (1)
- Barium sulphate – Insoluble. (1)

Question 2 (8 marks)

a) Any two:

- Temperature. (1)
- Nature of the solute and solvent. (1)
- Surface area or stirring, where the question concerns the rate of dissolving. (1 each, maximum 2)
- Increasing temperature increases the solubility of most solid salts. (1)
- More salt can dissolve in a given amount of water at higher temperatures. (1)
- Powdered salt has a larger exposed surface area. (1)
- More of the salt comes into contact with water at the same time, increasing the rate of dissolving. (1)
- Stirring brings fresh solvent into contact with the salt and helps dissolved particles move away from its surface. (1)
- It affects the rate of dissolving, not the final equilibrium solubility at a fixed temperature. (1)

Question 3 (8 marks)

a) A solubility curve is a graph showing how the solubility of a substance changes with temperature. (2)

$$90 - 30 = 60\ \text{g}$$

Answer: **60 g**. (2)

Mass crystallised for 100 g water = 60 g.

$$60 \times \frac{250}{100} = 150\ \text{g}$$

Answer: **150 g**. (2)

d) Any two:

- Separating mixtures of salts. (1)
- Purifying salts. (1)
- Recovering salts from natural brines. (1)
- Producing useful industrial crystals. (1)

Question 4 (8 marks)

- Pb^{2+} – Potassium iodide solution. (1)
- NH_4^+ – Sodium hydroxide solution, followed by gentle warming. (1)
- Cu^{2+} – Sodium hydroxide solution. (1)
- Fe^{2+} – Green precipitate. (1)
- Fe^{3+} – Reddish-brown precipitate. (1)
- Zn^{2+} – White precipitate dissolves in excess sodium hydroxide to form a colourless solution. (1)
- Sodium – Golden-yellow flame. (1)
- Potassium – Lilac flame. (1)

Question 5 (8 marks)

- Acidify the salt solution with dilute nitric acid and add silver nitrate solution. (1)
- A white precipitate of silver chloride forms. (1)
- A white precipitate forms. (1)
- The precipitate is barium sulphate and remains insoluble in dilute acid. (1)
- Add dilute hydrochloric acid to the sample; effervescence occurs as carbon dioxide is released. (1)
- Pass the gas through limewater; it turns milky. (1)

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

Correct equation with state symbols. (2)

Question 6 (10 marks)

a) Any three:

- Food preservation. (1)
- Manufacture of fertilisers. (1)
- Water treatment. (1)
- Manufacture of glass. (1)
- Preparation of medicines. (1)
- Food preparation. (1)

b) Any two well-explained points:

- Sodium and potassium ions help maintain fluid balance in the body. (2)
- Dissolved ions carry electrical charges and help transmit nerve impulses. (2)
- Calcium ions are important in bone formation and muscle contraction. (2)

- Chloride ions contribute to the formation of hydrochloric acid in the stomach. (2)

Award 2 marks for each well-explained point, maximum 4.

- Seawater is channelled into shallow evaporation ponds and exposed to the sun. (1)
- Water evaporates, the solution becomes concentrated and sodium chloride crystallises for harvesting. (1)

d) Trona. (1)

SUMMARY NOTES ON SALTS

Competency-Based Education (CBE) teaching and learning notes, practical activities, revision exercises and marking scheme.

INTRODUCTION TO SALTS

1.(a) A salt is an ionic compound formed when the cation from a base combine with the anion derived from an acid.

A salt is therefore formed when the hydrogen ions in an acid are replaced wholly/fully or partially/partly ,directly or indirectly by a metal or ammonium radical.

(b) The number of ionizable/replaceable hydrogen in an acid is called **basicity** of an acid.

Some acids are therefore:

(i) M**ono**basic acids generally denoted HX e.g.

HCl, HNO_3, HCOOH,CH_3COOH.

(ii) D**i**basic acids ; generally denoted H_2X e.g.

H_2SO_4, H_2SO_3, H_2CO_3, HOOCOOH.

(iii) T**ri**basic acids ; generally denoted H_3X e.g.

H_3PO_4.

(c) Some salts are **normal** salts while other are **acid** salts.

1. A normal salt is formed when all the ionizable /replaceable hydrogen in an acid is replaced by a metal or metallic /ammonium radical.
2. An acid salt is formed when part/portion the ionizable/replaceable hydrogen in an acid is replaced by a metal or metallic/ammonium radical.

(d) Some salts undergo **hygroscopy**, **deliquescence** and **efflorescence**.

1. Hygroscopic salts /compounds are those that absorb water from the atmosphere but do not form a solution. Some salts which are hygroscopic include anhydrous copper(II)sulphate(VI), anhydrous cobalt(II)chloride, potassium nitrate(V) common table salt.
2. Deliquescent salts /compounds are those that absorb water from the atmosphere and form a solution. Some salts which are deliquescent include: Sodium nitrate(V),Calcium chloride, Sodium hydroxide, Iron(II)chloride, Magnesium chloride.
3. Efflorescent salts/compounds are those that lose their water of crystallization to the atmosphere. Some salts which effloresces include: sodium carbonate decahydrate, Iron(II)sulphate(VI)heptahydrate, sodium sulphate (VI)decahydrate.

(e)Some salts contain water of crystallization.They are hydrated.Others do not contain water of crystallization. They are anhydrous

Some salts exist as two salts in one. They are called **double salts**.

Table of some double salts

Name of double salts	Chemical formula
Trona(sodium sesquicarbonate)	$Na_2CO_3\ NaHCO_3.2H_2O$
Ammonium iron(II)sulphate(VI)	$FeSO_4(NH_4)_2SO_4.2H_2O$
Ammonium aluminium(III)sulphate(VI)	$Al_2(SO_4)_3(NH_4)_2SO_4.H_2O$

Solubility of salts;

All potassium, sodium and ammonium salts are soluble in water.

1. All nitrates are soluble.
2. All sulphates are soluble except those of barium and lead. Calcium sulphate is slightly soluble.
3. All chlorides are soluble except lead (II) chloride and silver chloride. Lead (II) chloride is insoluble in cold water but soluble when hot.
4. All carbonates are insoluble except those of Group I metals and ammonium.

Carbonates of aluminium and iron do not exist.

The oxides of calcium and magnesium are slightly soluble. The solution formed is alkaline and turns red litmus paper blue.

Potassium and sodium oxides are also soluble. The oxides of zinc, aluminium, lead, iron and copper are insoluble in water. Ammonium oxide does not exist.

Potassium and sodium hydroxides are soluble in water. The hydroxides of calcium and magnesium are slightly soluble. The resulting solutions are; alkaline and turn red litmus blue.

The hydroxides of zinc, aluminium, iron, lead and copper are insoluble in water.

Ammonia is a base and dissolves in water to form aqueous ammonia

Preparation of Soluble salts

Direct displacement/reaction of a metal with an acid.

By reacting a metal higher in the reactivity series than hydrogen with a dilute acid, a salt is formed and hydrogen gas is evolved.

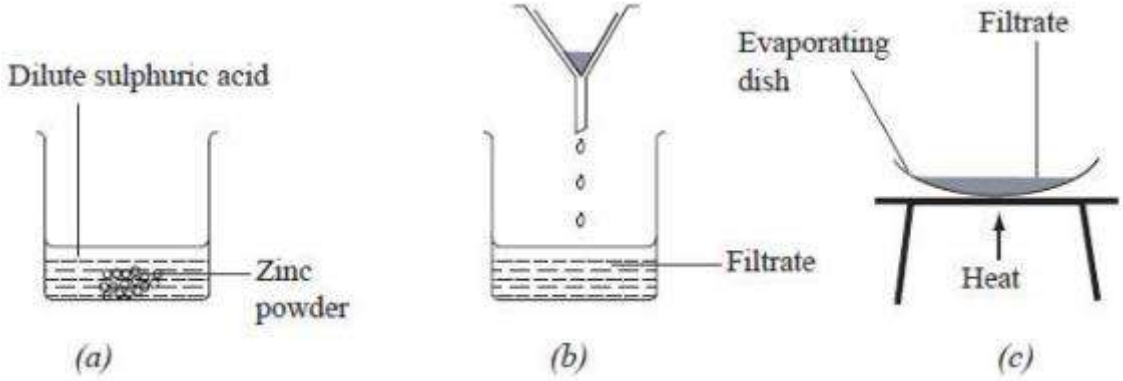
Excess of the metal must be used to ensure all the acid has reacted.

When effervescence/bubbling /fizzing has stopped, excess metal is filtered.

The filtrate is heated to concentrate then allowed to crystallize.

Washing with distilled water then drying between filter papers produces a sample crystal of the salt.

How is zinc sulphate prepared?



Zinc reacts with dilute sulphuric (VI) acid to produce zinc sulphate and hydrogen gas.

Effervescence stops when all the sulphuric acid has completely reacted with zinc powder.

Excess zinc is used to ensure all the acid reacts completely. The unreacted zinc is removed by filtration.

Zinc + Sulphuric (VI) acid

Zinc sulphate + Hydrogen gas

$Zn(s) + H_2SO_4(aq)$

$ZnSO_4(aq) + H_2(g)$

The saturated salt solution is allowed to cool for zinc sulphate crystals to form. The process of obtaining salt crystals from a saturated solution by cooling is called **crystallisation**. Other salts that can be prepared by the same method are magnesium nitrate, zinc chloride and calcium chloride.

Reaction of an insoluble base with an acid

By adding an insoluble base (oxide/hydroxide)to a dilute acid until **no more dissolves**, in the acid,a salt and water are formed. Excess of the base is filtered off.

The filtrate is heated to concentrate ,allowed to crystallize then washed with distilled water before drying between filter papers e.g.

$PbO(s) + 2HNO_3(aq) \rightarrow Pb(NO_3)_2(aq) + H_2O(l)$

$Pb(OH)_2(s) + 2HNO_3(aq) \rightarrow Pb(NO_3)_2(aq) + 2H_2O(l)$

$CaO(s) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + H_2O(l)$

$MgO(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2O(l)$

$MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$

$ZnO(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2O(l)$

$Zn(OH)_2(s) + 2HNO_3(aq) \rightarrow Zn(NO_3)_2(aq) + 2H_2O(l)$

$CuO(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l)$

$CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$

$Ag_2O(s) + 2HNO_3(aq) \rightarrow 2AgNO_3(aq) + H_2O(l)$

$Na_2O(s) + 2HNO_3(aq) \rightarrow 2NaNO_3(aq) + H_2O(l)$

Reaction of insoluble /soluble carbonate /hydrogen carbonate with an acid.

By adding an excess of a soluble /insoluble carbonate or hydrogen carbonate to a dilute acid, effervescence /fizzing/bubbling out of carbon (IV) oxide gas shows the reaction is taking place.

When effervescence /fizzing/bubbling out of the gas is over, excess of the insoluble carbonate is filtered off. The filtrate is heated to concentrate, allowed to crystallize then washed with distilled water before drying between filter paper papers e.g.

$PbCO_3(s) + 2HNO_3(aq) \rightarrow Pb(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

$ZnCO_3(s) + 2HNO_3(aq) \rightarrow Zn(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

$CaCO_3(s) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

$MgCO_3(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l) + CO_2(g)$

$Cu CO_3(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l) + CO_2(g)$

$Ag_2CO_3(s) + 2HNO_3(aq) \rightarrow 2AgNO_3(aq) + H_2O(l) + CO_2(g)$

$Na_2CO_3(s) + 2HNO_3(aq) \rightarrow 2NaNO_3(aq) + H_2O(l) + CO_2(g)$

$K_2CO_3(s) + 2HCl(aq) \rightarrow 2KCl(aq) + H_2O(l) + CO_2(g)$

$NaHCO_3(s) + HNO_3(aq) \rightarrow NaNO_3(aq) + H_2O(l) + CO_2(g)$

$KHCO_3(s) + HCl(aq) \rightarrow KCl(aq) + H_2O(l) + CO_2(g)$

Neutralization/reaction of soluble base/alkali with dilute acid

By adding an acid to a burette into a known volume of an alkali with 2-3 drops of an indicator, the colour of the indicator changes when the acid has completely reacted with an alkali at the end point. The procedure is then repeated without the indicator .The solution mixture is then heated to concentrate , allowed to crystallize ,washed with distilled water before drying with filter papers. e.g.

$NaOH(aq) + HNO_3(aq) \rightarrow NaNO_3(aq) + H_2O(l)$

$KOH(aq) + HNO_3(aq) \rightarrow KNO_3(aq) + H_2O(l)$

$KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$

$2KOH(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$

$2 NH_4OH(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq) + 2H_2O(l)$

$NH_4OH(aq) + HNO_3(aq) \rightarrow NH_4NO_3(aq) + H_2O(l)$

Direct synthesis/combination.

When a metal **burn** in a gas jar containing a non metal , the two directly combine to form a salt. e.g.

$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$

$2K(s) + Cl_2(g) \rightarrow 2KCl(s)$

$Mg(s) + Cl_2(g) \rightarrow Mg\,Cl_2\,(s)$

$Ca(s) + Cl_2(g) \rightarrow Ca\,Cl_2\,(s)$

Preparation of Soluble Salts Part 2 - Video Lesson and PDF Notes

Preparation of insoluble salts

How is lead (II) sulphate prepared?

Procedure;

- Put 10cm³ of lead (II) nitrate in a beaker. To the same beaker, add excess magnesium sulphate solution. Stir the solution using a glass rod. Let the solid settle then decant the liquid. Wash the solid with distilled water. Filter and dry the solid between filter papers.
- When lead (II) nitrate and magnesium sulphate solutions are mixed, a white solid is formed.
- The ions present in the reactants are lead (Pb^{2+}), and nitrate (NO_3^-) ions from lead (II) nitrate; magnesium (Mg^{2+}) and sulphate ($SO4^{2-}$) ions from magnesium sulphate.
- When the two salt solutions react, lead sulphate and magnesium nitrate salts are formed.
- In this reaction, the metal ions of the salts simply exchange their anions. Lead sulphate is formed as a white solid (precipitate). This type of reaction is called double decomposition.

- Lead (II) nitrate + Magnesium sulphate → Lead (II) sulphate + Magnesium nitrate
- $Pb(NO_3)_2(aq) + MgSO_4(aq) \rightarrow PbSO_4(s) + Mg(NO_3)_2(aq)$
- $Pb^{2+}(aq) + 2NO^-_3(aq) + Mg^{2+}(aq) + SO^{2-}_4(aq) \rightarrow PbSO_4(s) + Mg^{2+}(aq) + 2NO^-_3(aq)$

- The ions in the salt solutions that react to form lead sulphate are lead ions (Pb^{2+}) and sulphate ions (SO_4^{2-}). These ions are in aqueous state in the beginning of the reaction and end up in the solid state at the end of the reaction. The ions undergo a change in their physical state as shown by the equation below.

$Pb^{2+}(aq) + SO^{2-}_4(aq) \rightarrow PbSO_4(s)$

The equation obtained by writing only those ions that undergo change during a chemical reaction is called an **ionic equation.**

- Magnesium ions (Mg^{2+}) and nitrate ions (NO^-_3) are in aqueous state in the beginning and at the end of the reaction, they remain unchanged throughout the reaction. The ions that remain unchanged during a chemical reaction are called **spectator ions** and are omitted when writing ionic equations.
- Reactions in which solids are formed from aqueous solutions are called **precipitation reactions.** The solids formed are referred to as **precipitates.** Precipitation reactions are suitable for preparing insoluble salts.

Other examples of precipitation reactions are:

- Barium nitrate + Zinc sulphate → Barium sulphate + Zinc nitrate
- $Ba(NO_3)_2(Aq) + ZnSO_4(aq) \rightarrow BaSO_4(s) + Zn(NO_3)_2(aq)$
- $Ba^{2+}(aq) + 2NO^-_3(aq) + Zn^{2+}(aq) + SO^{2-}_4 \rightarrow BaSO_4(s) + Zn^{2+}(aq) + 2NO^-_3(g)$
- ***Ionic equation:*** $Ba^{2+}(aq) + SO^{2-}_4\,(aq) \rightarrow BaSO_4\,(s)$
- Lead nitrate + Potassium iodide → Lead iodide + Potassium nitrate.
- $Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$

- $Pb^{2+}(aq) + 2NO^{-}_{3}(aq) + 2K^{+}(aq) + 2I^{-}(aq) \rightarrow PbI_2(s) + 2K^{+}(aq) + 2NO^{-}_{3}(aq)$
- ***Ionic equation:*** $Pb^{2+}(aq) + 2I^{-}(aq) \rightarrow PbI_2(s)$
- Silver nitrate + Sodium chloride → Silver chloride + Sodium nitrat
- $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$
- $Ag^{+}(aq) + NO^{-}_{3}(aq) + Na^{+} + Cl^{-}(aq) \rightarrow AgCl(s) + Na^{+}(aq) + NO^{-}_{3}(aq)$
- ***Ionic equation:*** $Ag^{+}(aq) + Cl^{-}(aq) \rightarrow AgCl(s)$

In a precipitation reaction, the two reactants must be soluble salts and one of the products must be insoluble.

Effect of Heat on Salts

Action of Heat on Carbonates

Pure carbonates of sodium and potassium are not affected by heat. Carbonates of these metals are stable because of the high position of the metals in the reactivity series.

If hydrated, the salts only lose their water of crystallization. The water vapour condenses on the sides of the test tube as a colourless liquid. The residue is a white solid.

$$\text{Sodium carbonate decahydrate} \xrightarrow{heat} \text{Sodium carbonate + Water of crystallisation}$$

$$Na_2CO_3.10H_2O(s) \xrightarrow{heat} Na_2CO_3(s) + 10H_2O(l)$$

The other metal carbonates decompose on heating to give off a colourless gas and the corresponding metal oxide. On testing the gas with calcium hydroxide, a white precipitate is formed confirming the gas to be carbon (IV) oxide.

$$\text{Calcium carbonate} \xrightarrow{heat} \text{Calcium oxide + Carbon (IV) oxide}$$

$$CaCO_3(s) \xrightarrow{heat} CaO(s) + CO_2(g)$$

$$\text{Zinc Carbonate} \xrightarrow{heat} \text{Zinc oxide + Carbon (IV) oxide}$$

$$ZnCO_3(s) \xrightarrow{heat} ZnO(s) + CO_2(g)$$

$$\text{Lead (II) carbonate} \xrightarrow{heat} \text{Lead (II) oxide + Carbon (IV) oxide}$$

$$PbCO_3(s) \xrightarrow{heat} PbO(s) + CO_2(g)$$

$$\text{Copper (II) carbonate} \xrightarrow{heat} \text{Copper (II) oxide + Carbon (IV) oxide}$$

$$CuCO_3(s) \xrightarrow{heat} CuO(s) + CO_2(g)$$

Ammonium carbonate decomposes to form ammonia gas, carbon (IV) oxide and steam.

Presence of ammonia is confirmed by the turning of moist red litmus paper to blue.

$$\text{Ammonium carbonate} \xrightarrow{heat} \text{Ammonia + Carbon (VI) oxide + Steam}$$

$$(NH_4)_2CO_3(s) \xrightarrow{heat} 2NH_3(g) + CO_2(g) + H_2O(g)$$

Hydrogen carbonates of metals high in the reactivity series decompose on heating to produce the corresponding metal carbonates, carbon (IV) oxide and water.

Sodium hydrogen carbonate $\xrightarrow{heat}$ Sodium carbonate + water + Carbon (IV) oxide

$2NaHCO_3(s) \xrightarrow{heat} Na_2CO_3(s) + H_2O(l) + CO_2(g)$

Potassium hydrogen carbonate $\xrightarrow{heat}$ Potassium carbonate + Water + Carbon (IV) oxide

$2KHCO_3(s) \xrightarrow{heat} K_2CO_3(s) + H_2O(g) + CO_2(g)$

The hydrogen carbonates of calcium and magnesium exist only in solution whereas hydrogen carbonates of aluminium and iron do not exist.

Action of Heat on Nitrates

Potassium nitrate and sodium nitrate decompose to form oxygen and a white residue which is potassium nitrite and sodium nitrite respectively.

Potassium nitrate $\xrightarrow{heat}$ Potassium nitrite + Oxygen

$2KNO_3(s) \xrightarrow{heat} 2KNO_2 + O_2(g)$

Sodium nitrate $\xrightarrow{heat}$ Sodium nitrite + Oxygen

$2NaNO_3(s) \xrightarrow{heat} 2NaNO_2(s) + O_2(g)$

The nitrates of calcium, zinc, lead and copper decompose on heating to form the metal oxide, nitrogen (IV) oxide and oxygen gas.

Calcium nitrate $\xrightarrow{heat}$ Calcium oxide + Nitrogen (IV) oxide + Oxygen

$2Ca(NO_3)_2(s) \xrightarrow{heat} 2CaO(s) + 4NO_2(g) + O_2(g)$

(white) *(white)* *(brown gas)*

Zinc nitrate $\xrightarrow{heat}$ Zinc oxide + Nitrogen (IV) oxide + Oxygen

$2Zn(NO_3)_2(s) \xrightarrow{heat} 2ZnO(s) + 4NO_2(g) + O_2(g)$

(white) *(yellow when hot)* *(white when cold)* *(brown)*

Lead (II) nitrate $\xrightarrow{heat}$ Lead (II) oxide + Nitrogen (IV) oxide + Oxygen

$2Pb(NO_3)_2(s) \xrightarrow{heat} 2PbO(s) + 4NO_2(g) + O_2(g)$

(white) *(orange when hot)* *(yellow when cold)*

Copper Nitrate $\xrightarrow{heat}$ Copper (II) oxide + Nitrogen (IV) oxide + Oxygen

$2Cu(NO_3)_2(s) \xrightarrow{heat} 2CuO(s) + 4NO_2(s) + O_2(g)$

(blue) *(black)* *(brown)*

The nitrates of silver and mercury decompose to give nitrogen (IV) oxide, oxygen and the corresponding metal.

$$\text{Silver nitrate} \xrightarrow{heat} \text{Silver} + \text{Nitrogen (IV) Oxide} + \text{Oxygen}$$

$$2AgNO_3(s) \xrightarrow{heat} 2Ag(s) + 2NO_2(g) + O_2(g)$$

$$\text{Mercury (II) Nitrate} \xrightarrow{heat} \text{Mercury} + \text{Nitrogen(IV) Oxide} + \text{Oxygen}$$

$$Hg(NO_3)_2(s) \xrightarrow{heat} Hg(s) + 2NO_2(g) + O_2(g)$$

Ammonium nitrate decomposes to give steam and nitrogen (I) oxide

$$\text{Ammonium nitrate} \xrightarrow{heat} \text{Nitrogen (I) oxide} + \text{water}$$

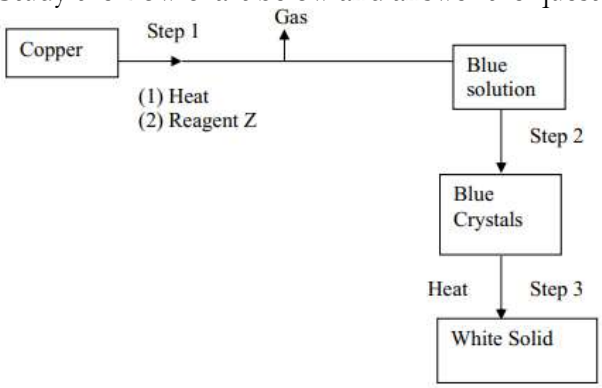
$$NH_4NO_3(s) \xrightarrow{heat} N_2O(g) + 2H_2O(l)$$

REVISION QUESTIONS — SALTS

Competency-Based Education (CBE) teaching and learning notes, practical activities, revision exercises and marking scheme.

Questions

1. Study the flow chart below and answer the questions that follow:



   a. Name reagent Z.

   b. Describe the process which takes place in step 2.

   c. Identify the white solid.

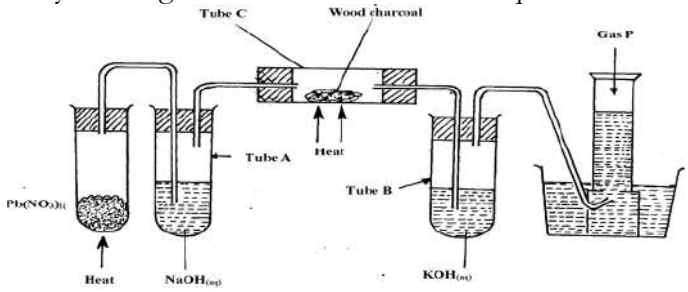
2.

   a. Starting from solid magnesium oxide, describe how a solid sample of magnesium hydroxide can be prepared.

   b. Give one use of magnesium hydroxide.

3. Starting with lead (II) oxide, describe how you would prepare a solid sample of lead (II) Carbonate

4. Study the diagram below and answer the questions that follow:



   a. Name the two salts formed in tube A

   b. State the observations made in tube C

   c. Name gas P

5. Study the information in the table below and answer the questions that follow:-

PARTICLE	MASS NUMBER	NUMBER OF PROTONS	NUMBER OF NEUTRONS	NUMBER OF ELECTRONS
E	37	17	(i)	18
F	32	(ii)	16	16
G	(iii)	19	20	18
H	40	20	(iv)	18

6.

   a. Complete the table by filling in the blank spaces (i) , (ii) (iii), and (iv)

   b. Identify the particles which are electrically charged

7. Sodium Carbonate Decahydrate crystals were left exposed on a watch glass for two days.

   a. State the observations made on the crystals after two days.

   b. Name the property of salts investigated in the above experiment

8. Starting with sodium oxide, describe how a sample of crystals of sodium hydrogen carbonate may be prepared

9. In an experiment, ammonium chloride was heated in test-tube. A moist red litmus paper placed at the mouth of test first changed blue then red. Explain these observations:-

10. Using dots (•) and cross (x), show the structure of ammonium ion

11.

   a. Give the name of each of the processes described below which takes place when salts are exposed to air for sometime

      i. Anhydrous copper sulphate becomes wet

      ii. Magnesium chloride forms an aqueous solution

      iii. Fresh crystals of sodium carbonate, $Na_2CO_3.10H_2O$ become covered with white powder of formula $Na_2CO_3.H_2O$

   b. Write the formula of the complex ion formed in each of the following reactions described below;

      i. Zinc metal dissolves in hot alkaline solution

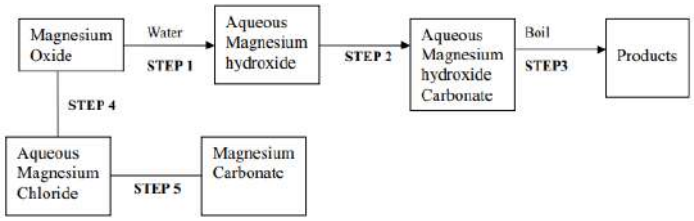
      ii. Copper hydroxide dissolves excess ammonia solution

12. Write an equation to show the effect of heat on the nitrate of:-

    a. Potassium

    b. Silver

13. The scheme below shows some reactions starting with magnesium oxide. Study it and answer the questions that follow:-



    a. Name the reagents used in steps 2 and 4

    b. Write an equation for the reaction in step 3

    c. Describe how a solid sample of anhydrous magnesium carbonate is obtained in step 5

14. In the preparation of magnesium carbonate, magnesium was burnt in air and the product collected. Dilute sulphuric acid was then added and the mixture filtered and cooled. Sodium carbonate was added to the filtrate and the contents filtered. The residue was then washed and dried to give a white powder.

    a. Give the name of the product

    b. Write the chemical equation for the formation of the product

    c.

        i. Name the filtrate collected after sodium carbonate was added.

        ii. Write down the chemical formula of the white powder

    d. Write a chemical equation for the reaction between product in (a) and the acid

    e. Write an ionic equation to show the formation of the white powder.

    f. Write an equation to show what happens when the white powder is strongly heated.

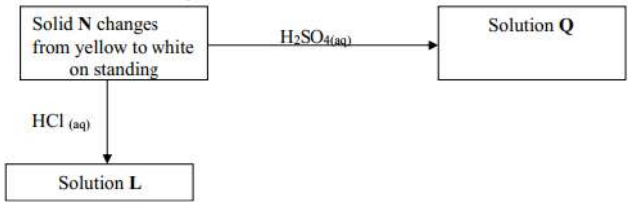
    g. Identify the ions present in the filtrate after addition of sodium carbonate.

    h. What is the name given to the reaction that takes place when sodium carbonate was added to the filtrate?

    i. Explain the observations made when crystals of sodium carbonate decahydrate are left exposed to the atmosphere for two days

15. You are provided with the following:- solid lead (II) nitrate, magnesium oxide powder, dilute sulphuric (VI)acid and distilled water. Describe how you can prepare a dry sample of lead (II) sulphate

16. Use the scheme to answer the questions that follow:



    a. Identify solid N …….

    b. Write a balanced equation for the formation of Q

    c. Write the formula of the complex ion formed when sodium hydroxide is added to solution L in excess

17. When exposed to air, crystals of hydrated sodium carbonate loses water of crystallizations;-

    a. Name this process

    b. Write the formula of hydrated sodium carbonate

18. A student poured sodium iodide solution into a small portion of solution Q, a yellow precipitate was formed.

    a. Which ion was most likely in solution Q?

    b. Write an ionic equation leading to the formation of the yellow precipitate

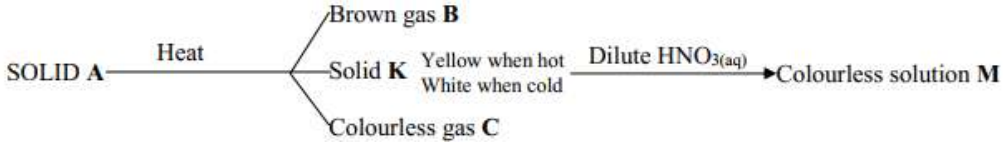
19. Calcium oxide can be used as a solid drying agent for some laboratory gases. Explain

20. A piece of marble chips was strongly heated in air for about 30 minutes. Some drops of water were added drop by drop to the product when it was still warm. Using equation, explain:

    a. What happens when the piece of marble chips is heated?

    b. The reaction that takes place when water is added to the final warm product.

21. Study the flow chart below and answer the questions that follow



Identify ;

    a. gases C and B

    b. Ions likely to be presented in solid A

22. Potassium nitrate crystals in a test-tube were heated strongly for some time. State the observation made:

    a. When a glowing splint is introduced into the test-tube during the heating

    b. At the end of the heating

23. Name the process which takes place when:

    a. Anhydrous iron (III) chloride absorb water vapour from the air to form solution

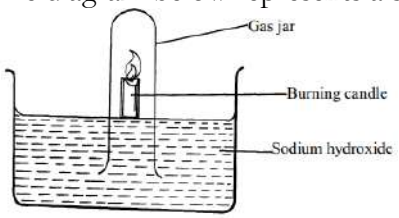
    b. Zinc chloride vapour changes directly to zinc chloride solid

24.

    a. Starting form solid magnesium oxide, describe how a solid sample of magnesium hydroxide can be prepared

    b. Give one use of magnesium hydroxide

25. The diagram below represents a set-up that was used to show that part of air used during burning.



State two sources of errors in this experiment

26. In an experiment the following solids were provided to form three students; $Ca(NO_3)_2(s)$, $NaH_2PO^4(s)$; $Mg(OH)Cl(s)$ and $Fe(NH_4)_2(SO_4)_2.6H_2O$. They were then told to dissolve the given solids in differently in 20ml of water.

    a. Classify the given salts accordingly

b.

i. Explain the process which takes place when $FeCl_3$ is dissolved in water

ii. A student placed a moist litmus paper on the product in (i) above. State and explain the

Answers

1.

a. Conc. H_2SO_4 /$H_2SO_{4(l)}$

b. Heat the solution to concentrate it.
Allow for crystals to form✓½ Filter ✓½

c. Anhydrous Copper(II) sulphate/$CUSO_{4(s)}$

2.

a. To MgO, add excess HNO_3,✓½ HCl or H_2SO_4. Add NaOH or KOH or NH_4OH to the mixture, ✓½ Filter ✓½ and dry ✓½ the residue.

b. – Anti-acid (Treatment of acid indigestion)
- Making tooth past ✓1

3. Add excess lead (II) Oxide to dilute nitric (v) acid and filter to get lead (II) nitrate solution.
Add sodium carbonate solution to lead (II) nitrate to precipitate lead (II) carbonate and wash with distilled water.

4.

a. Sodium nitrate/ sodium nitrite

b. Black charcoal glows red
Grey ash formed

c. carbon (II) oxide

5.

a.

Particle	Mass number	Number of protons	Number of neutrons	Number of electrons
E	37	17	**(i) 20**	18

F	32	**(ii) 16**	16	16
G	**(iii) 39**	19	20	18
H	40	20	**(iv)20**	18

b. E,G and H

6.

a. They became a white powder

b. Efflorescency

7. Add water to sodium oxide to form sodium hydroxide solution. Bubble excess carbon (IV) oxide in sodium hydroxide solution to form sodium hydrogen carbonate. Heat sodium hydrogen carbonate solution to evaporate water.

8. NH_4Cl decomposes on heating to produce NH_3 and $HCl_{(g)}$.$NH_{3(g)}$ is lighter than $HCl_{(g)}$ hence diffuses faster and turns red-litmus to blue HCl is denser hence diffuses at a slower rate: changes blue litmus to red

9.

10.

a.

i. Hydroscopy// hygroscopic

ii. Deliquescence// Deliquescent

iii. Efflorescence// Efflorescent

b.

i. $Zn(OH)_4^{2-}$

ii. $Cu(NH3)_4^{2+}$

11.

a. $2KNO_{3(s)} \rightarrow 2KNO_{2(s)} + O_{2(g)}$- ½mk for wrong states

b. $2AgNO_{3(s)} \rightarrow 2Ag_{(s)} + 2NO_{2\,(g)} + O_{2\,(g)}$

12.

a. Carbon (IV) Oxide
Dilute hydrochloric acid

b. $Mg(HCO_3)_{2(aq)} \rightarrow MgCO_{3(s)} + H_2O_{(l)} + CO_{2(g)}$

c. Add sodium carbonate/any soluble carbonate (named) solution;
Filter
Dry the residue between two filter papers

13.

a. magnesium Oxide

b. $2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$

c.

i. Sodium sulphate

ii. $MgCO_3$

d. $MgO_{(s)} + H_2SO_{4(aq)} \rightarrow MgSO_{4(aq)}) + H_2O_{(l)}$

e. $Mg^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow MgCO_{3(s)}$

f. $MgCO_{3(g)} \rightarrow MgO_{(g)} + CO_{2(g)}$

g. Na+ ions and SO_4^{2-} ions

h. Precipitation/ double decomposition

i. Crystals turn to a white powder. The salt is efflorescent hence it looses its water of crystallization forming a powder

14. - Dissolve lead (ii) nitrate crystal in a given amount of distilled water in a beaker
- To dilute sulphuric√ ½ (vi) acid in a beaker add magnesium√ ½ oxide powder
- React the two solutions obtained
- Filter the mixture
- Dry the residue between filter papers to obtain a dry sample of lead (ii) sulphate

15.

a. Zinc oxide √1 ZnO (1 mk)

b. $ZnO(s) + H_2SO_{4(aq)}$ √1 $\rightarrow ZnSO_{4(aq)} + H_2O$ (1 mk)

c. $[Zn(OH)]^{2-}$ √1 (1 mk)

16.

a. Efflorescence

b. $Na_2CO_3.10H_2O$ (If letters are joined – no mark)

17.

a. Pb^{2+}

b. White precipitate formed soluble in excess

18. Calcium oxide hygroscopic atmospheric water vapour ad becomes wet
Some laboratory gases are acidic
While calcium oxide is basic
Therefore calcium oxide reacts with the gas//calcium oxide would absorb the gas

19.

a. It decomposes to give Calcium oxide/Lime and Carbon (IV) oxide
$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$

b. Alot of heat is evolved which makes the piece of lime swell hence the name quick lime and Calcium hydroxide(slaked lime) is formed. ✓ ½
$CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)}$ ✓1

20.

a.

i. Gas C - $O_{2(g)}$ ✓ ½ Gas B - NO_2 ✓ ½

ii. Zn^{2+} and NO_3^+✓ ½

b. $ZnO_{(g)} + 2HNO_{3\,(aq)} \rightarrow Zn(NO_3)_{2(aq)} + H_2O_{(l)}$
Balanced
State symbols
Chemical symbols

21.

a. Glowing splint is relighted/rekindles

b. Pale yellow solid

22.

a. Deliquescence√1

b. Deposition √1

23.

a. - To MgO add excess HNO_3 √ ½ (Or HCl or H_2SO_4)
- Add NaOH or KOH or NH_4 OH to the mixture √ ½
- Filter and dry the residue√1

b. Uses as
- Anti – acid or tooth paste √

24. - Dil NaOH may not absorb all the carbon (IV) oxide gas produced
- Candle may go off before all the oxygen is used due to build up carbon (IV) oxide

25.

a. Acid salts $NaH_2PO_{4(s)}$ √1
Basic salts – Mg(OH) Cl(s) √1
Normal salts – $Ca(NO_3)_{2(s)}$ √1
Double salt – $Fe(NH4)_2(SO_4)_2.6H_2O$√1

b.

i. Hydrolysis – Reaction of water with a compound to form at least two products √1

ii. Moist litmus paper turns red due to the HCL gas produced √1
Or accept equation for the explanation
$FeCl_{3(s)} + 3H_2O_{(l)} \rightarrow Fe(OH)_{3(s)} + 3HCl_{(g)}$

STRAND 2.0: MATTER AND CHEMICAL REACTIONS

SUB-STRAND 2.2: THE MOLE

1.0 Introduction to the mole

1.1 Meaning of the mole

The **mole** is the SI unit for measuring the amount of a substance. One mole contains exactly $6.02214076 \times 10^{23}$ elementary particles.

These particles may be:

- Atoms.
- Molecules.
- Ions.
- Electrons.
- Formula units of ionic compounds.

The number $6.02214076 \times 10^{23}$ is called the **Avogadro constant**.

It is commonly written as:

$$N_A = 6.022 \times 10^{23}\ mol^{-1}$$

Examples

- 1 mole of carbon atoms contains 6.022×10^{23} carbon atoms.
- 1 mole of water contains 6.022×10^{23} water molecules.
- 1 mole of sodium chloride contains 6.022×10^{23} formula units of sodium chloride.
- 1 mole of sodium ions contains 6.022×10^{23} sodium ions.

1.2 Why chemists use the mole

Atoms, molecules and ions are extremely small. It is not practical to count them individually during chemical experiments.

The mole provides a convenient way of counting particles by measuring their masses.

For example:

- A chemist can weigh 12 g of carbon to obtain approximately one mole of carbon atoms.
- A learner can weigh a known mass of sodium chloride to calculate the number of formula units present.
- Chemical equations can be interpreted in terms of the number of moles of reactants and products.

1.3 Relationship between the mole and a dozen

A dozen means 12 items.

Similarly, a mole means 6.022×10^{23} particles.

Counting unit	Number of particles
One pair	2
One dozen	12
One gross	144
One mole	6.022×10^{23}

Example:

- One dozen eggs contains 12 eggs.
- One mole of oxygen molecules contains 6.022×10^{23} oxygen molecules.

The mole is therefore a counting unit used in chemistry.

2.0 Relative atomic mass (RAM)

2.1 Meaning of relative atomic mass

Relative atomic mass (RAM) is the weighted average mass of the atoms of an element compared with one-twelfth of the mass of one carbon-12 atom.

It is represented by A_r.

$$A_r = \frac{\text{Average mass of one atom of an element}}{\frac{1}{12} \text{ mass of one carbon-12 atom}}$$

- RAM compares the masses of atoms.
- It takes into account the different naturally occurring isotopes of an element.
- It is a relative quantity and has no unit.
- RAM values are usually obtained from periodic tables.

2.2 Meaning of isotopes

Isotopes are atoms of the same element that have the same number of protons but different numbers of neutrons.

- Isotopes have the same atomic number.
- They have different mass numbers.
- They have similar chemical properties because they have the same electronic arrangement in neutral atoms.
- Their masses contribute to the relative atomic mass of the element.

Example: Isotopes of chlorine

Chlorine has two common isotopes:

- Chlorine-35, which has a mass number of 35.
- Chlorine-37, which has a mass number of 37.

The relative atomic mass of chlorine is approximately 35.5 because it is a weighted average of the masses of its naturally occurring isotopes.

2.3 Calculating relative atomic mass from isotopic abundance

The relative atomic mass of an element can be calculated using the following formula:

$$A_r = \frac{\sum(\text{isotopic mass} \times \text{percentage abundance})}{100}$$

Worked example 1

An element has two isotopes:

- Isotope X-10 has an abundance of 80%.
- Isotope X-11 has an abundance of 20%.

Calculate the relative atomic mass of the element.

Solution:

$$A_r = \frac{(10 \times 80) + (11 \times 20)}{100}$$

$$= \frac{800 + 220}{100}$$

$$= \frac{1020}{100}$$

$$\boxed{A_r = 10.2}$$

Worked example 2

Chlorine consists of two isotopes, chlorine-35 and chlorine-37, with approximate abundances of 75% and 25%, respectively.

Calculate its relative atomic mass.

Solution:

$$A_r = \frac{(35 \times 75) + (37 \times 25)}{100}$$

$$= \frac{2625 + 925}{100}$$

$$= \frac{3550}{100}$$

$$\boxed{A_r = 35.5}$$

2.4 Relative atomic masses of selected elements

The following are commonly used approximate values. Learners should use the values supplied in a question or the periodic table where they differ.

Element	Symbol	Relative atomic mass

Element	Symbol	Relative atomic mass
Hydrogen	H	1
Carbon	C	12
Nitrogen	N	14
Oxygen	O	16
Sodium	Na	23
Magnesium	Mg	24
Aluminium	Al	27
Sulphur	S	32
Chlorine	Cl	35.5
Potassium	K	39
Calcium	Ca	40
Iron	Fe	56
Copper	Cu	63.5
Zinc	Zn	65
Silver	Ag	108
Barium	Ba	137
Lead	Pb	207

Important points

- RAM is a relative value and has no unit.
- The mass number of an individual isotope is a whole number.
- RAM may be a decimal because it is a weighted average of isotopic masses.

3.0 Relationship between relative atomic mass and the mole

The mass of one mole of atoms, expressed in grams, is numerically equal to the relative atomic mass of the element.

For example:

- RAM of carbon = 12.
- One mole of carbon atoms has a mass of approximately 12 g.
- RAM of magnesium = 24.
- One mole of magnesium atoms has a mass of approximately 24 g.
- RAM of calcium = 40.
- One mole of calcium atoms has a mass of approximately 40 g.

3.1 Molar mass

Molar mass is the mass of one mole of a substance.

- It is represented by M.
- Its SI unit is kilograms per mole, but in school-level chemistry it is commonly expressed in grams per mole (g mol^{-1}).
- The numerical value of the molar mass of an element is the same as its RAM, expressed in grams per mole.

Examples

Element	RAM	Molar mass
Carbon	12	12 g mol^{-1}
Oxygen	16	16 g mol^{-1}
Sodium	23	23 g mol^{-1}
Calcium	40	40 g mol^{-1}
Iron	56	56 g mol^{-1}

3.2 Difference between RAM and molar mass

Relative atomic mass (RAM)	Molar mass
Compares the average mass of an atom with one-twelfth of carbon-12.	Gives the mass of one mole of a substance.
Has no unit.	Commonly expressed in g mol^{-1}.
Applies to atoms of elements.	Applies to elements, molecules and compounds.
Example: RAM of carbon = 12.	Example: molar mass of carbon = 12 g mol^{-1}.

4.0 Relative formula mass (RFM)

4.1 Meaning of relative formula mass

Relative formula mass (RFM) is the sum of the relative atomic masses of all the atoms represented in the formula of a substance.

It is represented by M_r.

- It is calculated by adding the RAM values of all atoms in a chemical formula.
- It has no unit.
- It is used for ionic compounds and substances represented by formula units.
- For molecular substances, the corresponding term is often called relative molecular mass.

4.2 Calculating relative formula mass

Formula:

$$M_r = \sum(\text{RAM of each atom} \times \text{number of atoms})$$

Worked example 1: Sodium chloride (NaCl)

Given:

- Na = 23

- Cl = 35.5

$$M_r = 23 + 35.5$$

$$\boxed{M_r = 58.5}$$

Worked example 2: Water (H_2O)

Given:

- H = 1
- O = 16

$$M_r = (2 \times 1) + 16$$

$$= 2 + 16$$

$$\boxed{M_r = 18}$$

Worked example 3: Calcium carbonate ($CaCO_3$)

Given:

- Ca = 40
- C = 12
- O = 16

$$M_r = 40 + 12 + (3 \times 16)$$

$$= 40 + 12 + 48$$

$$\boxed{M_r = 100}$$

Worked example 4: Aluminium sulphate [$Al_2(SO_4)_3$]

Given:

- Al = 27
- S = 32
- O = 16

$$M_r = (2 \times 27) + [3 \times 32] + [12 \times 16]$$

$$= 54 + 96 + 192$$

$$\boxed{M_r = 342}$$

Important: The number outside a bracket multiplies every atom inside the bracket.

5.0 Conversions involving mass and moles

5.1 Relationship between mass, moles and molar mass

The mass of a substance can be used to calculate the number of moles present.

The relationship is:

$$\boxed{n = \frac{m}{M}}$$

Where:

- n = number of moles (mol).
- m = mass of the substance (g).
- M = molar mass (g mol^{-1}).

The formula can also be rearranged:

$$\boxed{m = n \times M}$$

$$\boxed{M = \frac{m}{n}}$$

5.2 Calculating the number of moles from mass

Worked example 1

Calculate the number of moles in 24 g of magnesium.

Given:

- Mass = 24 g.
- Molar mass of magnesium = 24 g mol^{-1}.

Formula:

$$n = \frac{m}{M}$$

Substitution:

$$n = \frac{24}{24}$$

$$\boxed{n = 1\ mol}$$

Answer: 1 mole of magnesium.

Worked example 2

Calculate the number of moles in 36 g of water.

Given:

- Mass = 36 g.
- Molar mass of water = 18 g mol^{-1}.

$$n = \frac{36}{18}$$

$$\boxed{n = 2\ mol}$$

Answer: 2 moles of water.

5.3 Calculating mass from the number of moles

Worked example 3

Calculate the mass of 3 moles of sodium chloride.

Given:

- Number of moles = 3 mol.
- Molar mass of NaCl = 58.5 g mol^{-1}.

Formula:

$$m = n \times M$$

Substitution:

$$m = 3 \times 58.5$$

$$\boxed{m = 175.5\ g}$$

Answer: 175.5 g.

Worked example 4

Calculate the mass of 0.5 moles of calcium carbonate.

Given:

- $n = 0.5\ mol.$
- M_r of $CaCO_3$ = 100.

$$m = 0.5 \times 100$$

$$\boxed{m = 50\ g}$$

5.4 Calculating molar mass from mass and moles

Worked example 5

A sample of a substance has a mass of 80 g and contains 2 moles. Calculate its molar mass.

$$M = \frac{m}{n}$$

$$M = \frac{80}{2}$$

$$\boxed{M = 40\ g\ mol^{-1}}$$

5.5 Converting between number of particles and moles

The mole is also related to the number of particles through the Avogadro constant.

$$\boxed{n = \frac{N}{N_A}}$$

Where:

- n = number of moles.
- N = number of particles.
- N_A = Avogadro constant.

$$N_A = 6.022 \times 10^{23}\ mol^{-1}$$

To calculate the number of particles:

$$\boxed{N = n \times N_A}$$

Worked example 6

Calculate the number of atoms in 2 moles of sodium.

$$N = n \times N_A$$

$$= 2 \times 6.022 \times 10^{23}$$

$$\boxed{N = 1.2044 \times 10^{24}\ atoms}$$

Worked example 7

Calculate the number of moles represented by 3.011×10^{23} molecules of water.

$$n = \frac{N}{N_A}$$

$$= \frac{3.011 \times 10^{23}}{6.022 \times 10^{23}}$$

$$\boxed{n = 0.5\ mol}$$

5.6 Calculating the number of atoms in a compound

One mole of a compound contains Avogadro's number of molecules or formula units. The number of atoms of each element depends on the chemical formula.

Example: Water (H_2O)

One molecule of water contains:

- 2 hydrogen atoms.
- 1 oxygen atom.
- 3 atoms altogether.

Therefore, one mole of water contains:

- $2 \times 6.022 \times 10^{23}$ hydrogen atoms.
- $1 \times 6.022 \times 10^{23}$ oxygen atoms.

Example: Carbon dioxide (CO_2)

One molecule contains:

- 1 carbon atom.
- 2 oxygen atoms.

One mole of carbon dioxide therefore contains one mole of carbon atoms and two moles of oxygen atoms.

6.0 Chemical formulae of compounds

6.1 Meaning of a chemical formula

A **chemical formula** is a representation showing the elements present in a substance and the number or simplest ratio of their atoms or ions.

Examples:

- H_2O represents water.
- CO_2 represents carbon dioxide.
- NaCl represents sodium chloride.
- $CaCO_3$ represents calcium carbonate.
- H_2SO_4 represents sulphuric acid.

6.2 Types of chemical formulae

A. Empirical formula

An empirical formula shows the simplest whole-number ratio of atoms of each element in a compound.

Examples:

Molecular formula	Empirical formula
H_2O_2	HO
$C_6H_{12}O_6$	CH_2O
C_2H_4	CH_2
C_6H_6	CH
CO_2	CO_2

B. Molecular formula

A molecular formula shows the actual number of atoms of each element in one molecule of a substance.

Examples:

- H_2O represents two hydrogen atoms and one oxygen atom.
- $C_6H_{12}O_6$ represents six carbon atoms, twelve hydrogen atoms and six oxygen atoms.
- C_2H_6 represents two carbon atoms and six hydrogen atoms.

6.3 Difference between empirical and molecular formulae

Empirical formula	Molecular formula
Shows the simplest whole-number ratio of atoms.	Shows the actual number of atoms in a molecule.
May be the same as the molecular formula.	May be a whole-number multiple of the empirical formula.
Example: CH_2O.	Example: $C_6H_{12}O_6$.

6.4 Determining empirical formula from experimental data

The empirical formula can be determined using the masses or percentage composition of the elements in a compound.

Steps followed

6. Write down the mass or percentage of each element.
7. Divide each mass or percentage by the relative atomic mass of the element.
8. Obtain the mole ratio.
9. Divide all the mole values by the smallest value.
10. Convert the resulting ratios into the simplest whole numbers.
11. Write the empirical formula using the calculated ratios.

6.5 Worked example: Determining empirical formula from masses

A compound contains 12 g of carbon and 4 g of hydrogen. Determine its empirical formula.

Given:

- RAM of carbon = 12.
- RAM of hydrogen = 1.

Step 1: Calculate the number of moles of each element.

Element	Mass (g)	RAM	Moles
Carbon	12	12	$12 \div 12 = 1$
Hydrogen	4	1	$4 \div 1 = 4$

Step 2: Divide by the smallest mole value.

- Carbon: $1 \div 1 = 1$.
- Hydrogen: $4 \div 1 = 4$.

Step 3: Write the simplest ratio.

C : H = 1 : 4.

Therefore, the empirical formula is:

$$\boxed{CH_4}$$

6.6 Worked example: Determining empirical formula from percentage composition

A compound contains:

- 40% carbon.
- 6.67% hydrogen.
- 53.33% oxygen.

Determine its empirical formula.

Given:

- C = 12.
- H = 1.
- O = 16.

Step 1: Assume the compound has a mass of 100 g.

Therefore:

- Carbon = 40 g.
- Hydrogen = 6.67 g.
- Oxygen = 53.33 g.

Step 2: Divide each mass by its RAM.

Element	Mass	RAM	Moles
C	40	12	3.33
H	6.67	1	6.67
O	53.33	16	3.33

Step 3: Divide by the smallest mole value.

- C: $3.33 \div 3.33 = 1$.
- H: $6.67 \div 3.33 = 2$.
- O: $3.33 \div 3.33 = 1$.

Step 4: Write the empirical formula.

$$\boxed{CH_2O}$$

6.7 Determining empirical formula from experimental results

In the laboratory, an empirical formula may be obtained by reacting a known mass of a compound or element and measuring the masses of the products formed.

For example, a metal oxide can be reduced to the metal, allowing the mass of oxygen in the original compound to be determined.

The steps include:

12. Weigh a clean, dry crucible.
13. Add a known mass of the metal oxide.
14. Heat it under suitable reducing conditions.
15. Allow the crucible to cool safely.
16. Reweigh the crucible and its contents.
17. Determine the mass of oxygen removed.
18. Calculate the mole ratio of metal to oxygen.
19. Deduce the empirical formula.

The exact procedure depends on the metal oxide and the reducing agent used.

6.8 Determining molecular formula from empirical formula

The molecular formula is a whole-number multiple of the empirical formula.

The relationship is:

$$\boxed{n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}}}$$

Where n is a whole number.

The molecular formula is obtained by multiplying every subscript in the empirical formula by n.

Worked example

A compound has an empirical formula of CH_2O and a molecular mass of 180. Determine its molecular formula.

Given:

- C = 12.
- H = 1.
- O = 16.

Step 1: Calculate the empirical formula mass.

$$(12) + (2 \times 1) + (16) = 30$$

Step 2: Calculate the multiplying factor.

$$n = \frac{180}{30} = 6$$

Step 3: Multiply all subscripts by 6.

$$(CH_2O) \times 6$$

$$\boxed{C_6H_{12}O_6}$$

Answer: $C_6H_{12}O_6$.

7.0 Percentage composition of substances in a compound

7.1 Meaning of percentage composition

Percentage composition is the percentage by mass of each element present in a compound.

It shows the proportion of the total mass of a compound contributed by each element.

Percentage composition is useful in:

- Identifying unknown compounds.
- Determining empirical formulae.
- Checking the purity of substances.
- Comparing the composition of chemical substances.
- Analysing fertilisers and other industrial materials.

7.2 Formula for percentage composition

$$\boxed{\%\text{ of an element} = \frac{\text{Mass of the element in one mole of compound}}{\text{Molar mass of compound}} \times 100}$$

7.3 Worked example 1: Percentage composition of water

Determine the percentage composition of water (H_2O).

Given:

- H = 1.
- O = 16.

Step 1: Calculate the molar mass of water.

$$M_r = (2 \times 1) + 16$$

$$= 18$$

Step 2: Calculate the percentage of hydrogen.

$$\%H = \frac{2}{18} \times 100$$

$$\boxed{\%H = 11.11\%}$$

Step 3: Calculate the percentage of oxygen.

$$\%O = \frac{16}{18} \times 100$$

$$\boxed{\%O = 88.89\%}$$

Check:

$$11.11 + 88.89 = 100\%$$

7.4 Worked example 2: Percentage composition of calcium carbonate

Determine the percentage composition of calcium carbonate ($CaCO_3$).

Given:

- Ca = 40.
- C = 12.
- O = 16.

Step 1: Calculate RFM.

$$M_r = 40 + 12 + (3 \times 16)$$

$$= 100$$

Step 2: Percentage of calcium.

$$\%Ca = \frac{40}{100} \times 100$$

$$\boxed{40\%}$$

Step 3: Percentage of carbon.

$$\%C = \frac{12}{100} \times 100$$

$$\boxed{12\%}$$

Step 4: Percentage of oxygen.

$$\%O = \frac{48}{100} \times 100$$

$$\boxed{48\%}$$

Check:

$$40 + 12 + 48 = 100\%$$

7.5 Worked example 3: Percentage composition of sodium sulphate

Determine the percentage composition of Na_2SO_4.

Given:

- Na = 23.
- S = 32.
- O = 16.

Step 1: Calculate RFM.

$$M_r = (2 \times 23) + 32 + (4 \times 16)$$

$$= 46 + 32 + 64 = 142$$

Step 2: Percentage of sodium.

$$\%Na = \frac{46}{142} \times 100$$

$$= 32.39\%$$

Step 3: Percentage of sulphur.

$$\%S = \frac{32}{142} \times 100$$

$$= 22.54\%$$

Step 4: Percentage of oxygen.

$$\%O = \frac{64}{142} \times 100$$

$$= 45.07\%$$

7.6 Importance of percentage composition in Kenya

- It helps in checking the nutrient content of fertilisers sold to farmers.
- It is useful in determining the purity of industrial chemicals.
- It helps in analysing minerals obtained from natural deposits.
- It is useful in quality control in food-processing industries.
- It helps laboratories determine the composition of chemical products.

8.0 Concentration of solutions

8.1 Meaning of concentration

Concentration is the amount of solute dissolved in a given volume or mass of solvent or solution.

- A concentrated solution contains a relatively large amount of solute in a given volume of solution.
- A dilute solution contains a relatively small amount of solute in a given volume of solution.
- Concentration can be expressed in different units.
- In this sub-strand, concentration is mainly expressed in moles per litre.

8.2 Meaning of molarity

Molarity is the number of moles of solute dissolved in one litre of solution.

It is represented by C or M.

$$\boxed{C = \frac{n}{V}}$$

Where:

- C = concentration in mol L^{-1}.
- n = number of moles of solute.
- V = volume of solution in litres.

Since:

$$n = \frac{m}{M_r}$$

Then:

$$\boxed{C = \frac{m}{M_r \times V}}$$

Here, M_r is used numerically for the molar mass in g mol^{-1}, m is in grams and V is in litres.

Important: The volume used in molarity calculations must be the volume of the final solution, not simply the volume of water initially added.

8.3 Units of concentration

Common units include:

- mol L^{-1}.
- mol dm^{-3}.
- mol m^{-3}.

In school chemistry:

$$1\ L = 1\ dm^3$$

Therefore:

8.4 Converting volume units

$$1000\ mL = 1\ L$$

$$1000\ cm^3 = 1\ dm^3$$

$$1\ mL = 1\ cm^3$$

Examples:

- 250 mL = 0.250 L.
- 500 mL = 0.500 L.
- 750 mL = 0.750 L.
- 100 cm^3 = 0.100 dm^3.

8.5 Calculating concentration from moles and volume

Worked example 1

Calculate the concentration of a solution containing 0.5 moles of sodium chloride in 2 litres of solution.

Given:

- $n = 0.5\ mol$.
- $V = 2\ L$.

$$C = \frac{n}{V}$$

$$C = \frac{0.5}{2}$$

8.6 Calculating concentration from mass and volume

Worked example 2

Calculate the concentration in mol L^{-1} of a solution prepared by dissolving 5.85 g of sodium chloride in sufficient water to make 500 mL of solution.

Given:

- Mass = 5.85 g.
- Molar mass of NaCl = 58.5 g mol^{-1}.

- Volume = 500 mL = 0.5 L.

Step 1: Calculate the number of moles.

$$n = \frac{5.85}{58.5}$$

$$n = 0.1\ mol$$

Step 2: Calculate the concentration.

$$C = \frac{0.1}{0.5}$$

8.7 Calculating the mass required to prepare a solution

Worked example 3

Calculate the mass of sodium hydroxide required to prepare 250 mL of a 0.2 mol L^{-1} solution.

Given:

- .
- $V = 250\ mL = 0.25\ L$.
- Molar mass of NaOH = 40 g mol^{-1}.

Step 1: Calculate moles.

$$n = C \times V$$

$$n = 0.2 \times 0.25$$

$$n = 0.05\ mol$$

Step 2: Calculate mass.

$$m = n \times M$$

$$m = 0.05 \times 40$$

$$\boxed{m = 2.0\ g}$$

Answer: 2.0 g of sodium hydroxide.

9.0 Preparation of molar solutions

9.1 Meaning of a molar solution

A **molar solution** is a solution whose concentration is expressed in moles of solute per litre of solution.

Examples:

- 1.0 mol L^{-1} sodium chloride solution contains 1 mole of sodium chloride in each litre of solution.
- 0.5 mol L^{-1} sodium hydroxide solution contains 0.5 moles of sodium hydroxide in each litre of solution.
- 0.1 mol L^{-1} hydrochloric acid contains 0.1 moles of hydrogen chloride per litre of solution.

9.2 Apparatus used to prepare a molar solution

The apparatus includes:

- Electronic balance.

- Weighing boat or watch glass.
- Spatula.
- Beaker.
- Glass stirring rod.
- Funnel.
- Volumetric flask.
- Wash bottle containing distilled water.
- Stopper.

9.3 Procedure for preparing a solution from a solid solute

Example: Preparation of 250 mL of 0.1 mol L^{-1} sodium chloride solution.

Step 1: Calculate the required mass.

Given:

- Concentration = 0.1 mol L^{-1}.
- Volume = 250 mL = 0.25 L.
- Molar mass of NaCl = 58.5 g mol^{-1}.

$$n = C \times V$$

$$= 0.1 \times 0.25$$

$$= 0.025\ mol$$

Calculate mass:

$$m = n \times M$$

$$= 0.025 \times 58.5$$

$$\boxed{m = 1.4625\ g}$$

Step 2: Weigh the solute.

- Place a clean weighing boat on the balance.
- Weigh 1.4625 g of sodium chloride, or the closest achievable mass.

Step 3: Dissolve the solute.

- Transfer the sodium chloride into a beaker.
- Add a small amount of distilled water.
- Stir until all the salt dissolves.

Step 4: Transfer the solution.

- Transfer the solution into a 250 mL volumetric flask using a funnel.
- Rinse the beaker, glass rod and funnel with distilled water.
- Add the rinsings to the volumetric flask to ensure quantitative transfer.

Step 5: Make up to the mark.

- Add distilled water until the bottom of the meniscus reaches the calibration mark.
- Read the mark at eye level.

Step 6: Mix thoroughly.

- Stopper the flask.
- Invert it several times to ensure uniform mixing.
- Label the solution with its name, concentration and date.

9.4 Precautions when preparing molar solutions

- Use clean apparatus.
- Use distilled or deionised water where appropriate.
- Ensure the solute dissolves completely before making up to the mark.
- Transfer all the solution and rinsings into the volumetric flask.
- Read the meniscus at eye level.
- Avoid adding excess water beyond the calibration mark.
- Mix the solution thoroughly.
- Label the prepared solution correctly.

9.5 Standard solutions

A **standard solution** is a solution whose concentration is accurately known.

- It is prepared by dissolving a known amount of a suitable substance in a measured final volume.
- It is used in titrations and other quantitative chemical analyses.
- A primary standard should be pure, stable and suitable for accurate weighing.
- Sodium carbonate is a common primary standard used in acid-base analysis.
- Sodium hydroxide is not a primary standard because it absorbs moisture and carbon dioxide from the air.

10.0 Dilution of solutions

10.1 Meaning of dilution

Dilution is the process of reducing the concentration of a solution by adding more solvent.

- The amount of solute remains unchanged during simple dilution.
- The total volume of the solution increases.
- The concentration decreases.
- Water is commonly used as the solvent in aqueous solutions.

Example:

Adding distilled water to concentrated hydrochloric acid produces a more dilute hydrochloric acid solution.

10.2 Dilution formula

The relationship used in dilution calculations is:

$$\boxed{C_1V_1 = C_2V_2}$$

Where:

- C_1 = initial concentration.
- V_1 = initial volume taken.
- C_2 = final concentration.
- V_2 = final total volume.

The formula assumes that the amount of solute remains unchanged.

10.3 Worked example 1: Calculating the volume of concentrated solution required

Calculate the volume of 2.0 mol L^{-1} hydrochloric acid needed to prepare 250 mL of 0.5 mol L^{-1} hydrochloric acid.

Given:

- .
- .
- $V_2 = 250\ mL.$
- $V_1 =?$

Using:

$$C_1V_1 = C_2V_2$$

$$2.0 \times V_1 = 0.5 \times 250$$

$$V_1 = \frac{0.5 \times 250}{2.0}$$

$$\boxed{V_1 = 62.5\ mL}$$

Answer: Measure 62.5 mL of the concentrated acid and dilute it to a final volume of 250 mL.

10.4 Worked example 2: Calculating final concentration

50 mL of a 1.0 mol L^{-1} solution is diluted to 200 mL. Calculate the final concentration.

Given:

- .
- $V_1 = 50\ mL.$
- $V_2 = 200\ mL.$

$$C_1V_1 = C_2V_2$$

$$1.0 \times 50 = C_2 \times 200$$

$$C_2 = \frac{50}{200}$$

10.5 Procedure for preparing a dilute solution from a concentrated solution

20. Calculate the volume of concentrated solution required using the dilution formula.
21. Use a pipette to measure the calculated volume accurately.
22. Transfer it into a suitable volumetric flask that already contains some distilled water.

23. Add more distilled water until the solution approaches the calibration mark.
24. Add water dropwise until the bottom of the meniscus reaches the mark.
25. Stopper the flask.
26. Invert the flask several times to mix thoroughly.
27. Label the final solution.

Important laboratory safety rule

When diluting concentrated acids, always add acid slowly to water, never water to concentrated acid. The process releases heat and may cause dangerous splashing.

11.0 Acid-base titration

11.1 Meaning of acid-base titration

Acid-base titration is a laboratory technique used to determine the concentration of an acid or base by reacting it with a solution of accurately known concentration.

- It involves the controlled addition of one solution to another.
- It is based on the neutralisation reaction between an acid and a base.
- An indicator is commonly used to show when the reaction has reached its end point.
- The volume of solution delivered from a burette is measured.
- The results are used to calculate an unknown concentration.

11.2 Meaning of important titration terms

A. Titrant

- The solution placed in the burette.
- Its concentration is usually known in a standard titration.

B. Analyte

- The solution being analysed.
- It is usually placed in the conical flask.
- Its concentration may be unknown.

C. Indicator

- A substance that changes colour over a particular pH range.
- It is used to indicate the end point of a titration.

D. End point

- The stage at which the indicator changes colour.
- It is the experimentally observed point at which the titration is stopped.

E. Equivalence point

- The point at which the acid and base have reacted in the exact mole ratio given by the balanced chemical equation.
- The end point should be close to the equivalence point when a suitable indicator is used.

F. Titre

- The volume of solution delivered from the burette during a titration.

G. Concordant titres

- Two or more titre values that are very close to one another.
- They indicate that the titration has been repeated consistently.

11.3 Apparatus used in acid-base titration

The apparatus includes:

28. **Burette:** Measures and delivers accurately controlled volumes of solution.
29. **Pipette:** Measures a fixed accurate volume of a solution.
30. **Conical flask:** Holds the solution being analysed.
31. **Retort stand and clamp:** Support the burette vertically.
32. **White tile:** Makes the indicator colour change easier to observe.
33. **Funnel:** Helps fill the burette; it must be removed before taking readings.
34. **Wash bottle:** Contains distilled water for rinsing.
35. **Volumetric flask:** Used to prepare solutions of accurate concentration.
36. **Indicator:** Shows the end point through a colour change.

11.4 Common acid-base indicators

An indicator changes colour depending on the acidity or alkalinity of the solution.

Indicator	In acidic solution	In alkaline solution
Litmus	Red	Blue
Methyl orange	Red	Yellow
Phenolphthalein	Colourless	Pink
Bromothymol blue	Yellow	Blue

Choosing an appropriate indicator

- A suitable indicator changes colour sharply near the equivalence point.
- Phenolphthalein is commonly used for a strong acid–strong base titration.
- Methyl orange can also be used for a strong acid–strong base titration.
- For a weak acid–strong base titration, phenolphthalein is generally suitable.
- For a strong acid–weak base titration, methyl orange is generally suitable.
- An indicator must be selected according to the pH change around the equivalence point.

11.5 General procedure for acid-base titration

Step 1: Prepare the burette

- Rinse the burette with distilled water.
- Rinse it with a small amount of the solution that will be placed in it.

- Fill the burette with the titrant.
- Ensure there are no air bubbles in the jet.
- Remove the funnel.
- Record the initial burette reading at eye level.

Step 2: Prepare the pipette

- Rinse the pipette with distilled water.
- Rinse it with a small quantity of the solution to be measured.
- Use the pipette to transfer a fixed volume, for example 25.0 mL, into a clean conical flask.

Step 3: Add the indicator

- Add two or three drops of a suitable indicator to the conical flask.
- Place the flask on a white tile.

Step 4: Carry out the titration

- Slowly open the burette tap.
- Allow the titrant to flow into the conical flask.
- Swirl the flask continuously.
- As the end point approaches, add the titrant drop by drop.
- Stop when a permanent colour change is observed.

Step 5: Record the final reading

- Read the final burette reading at eye level.
- Record the volume used.

Step 6: Repeat the titration

- Carry out another titration.
- Repeat until concordant titres are obtained.
- Calculate the mean titre using the concordant results.

11.6 Titration readings

The volume delivered from a burette is calculated using:

$$\boxed{\text{Titre} = \text{Final reading} - \text{Initial reading}}$$

Example:

Reading	Volume
Initial burette reading	0.00 mL
Final burette reading	24.80 mL
Titre	24.80 mL

$$24.80 - 0.00 = 24.80\ mL$$

Example of repeated titration results

Titration	Initial reading (mL)	Final reading (mL)	Titre (mL)
Rough	0.00	25.10	25.10
1	0.00	24.80	24.80
2	0.00	24.85	24.85
3	0.00	24.80	24.80

The concordant titres are 24.80 mL, 24.85 mL and 24.80 mL.

Mean titre:

$$= \frac{24.80 + 24.85 + 24.80}{3}$$

$$= \frac{74.45}{3}$$

$$\boxed{24.82\ mL}$$

11.7 Neutralisation reaction

Neutralisation occurs when an acid reacts with a base to form salt and water.

General equation:

$$\text{Acid} + \text{Base} \rightarrow \text{Salt} + \text{Water}$$

Example:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

Hydrochloric acid reacts with sodium hydroxide to form sodium chloride and water.

Net ionic equation:

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

11.8 Calculations involving acid-base titration

Titration calculations are based on:

37. The balanced chemical equation.
38. The concentration of the known solution.
39. The measured volume of the known solution.
40. The volume of the unknown solution.
41. The mole ratio of the reacting substances.

Worked example 1: A 1:1 acid-base reaction

25.0 mL of sodium hydroxide solution is neutralised by 20.0 mL of 0.10 mol L^{-1} hydrochloric acid. Calculate the concentration of the sodium hydroxide solution.

Step 1: Write the balanced chemical equation.

$$HCl + NaOH \rightarrow NaCl + H_2O$$

Mole ratio:

$$HCl : NaOH = 1:1$$

Step 2: Convert the volume of hydrochloric acid into litres.

$$20.0\ mL = \frac{20.0}{1000} = 0.0200\ L$$

Step 3: Calculate the moles of hydrochloric acid.

$$n = C \times V$$

$$n = 0.10 \times 0.0200$$

$$n = 0.0020\ mol$$

Step 4: Determine the moles of sodium hydroxide.

From the 1:1 mole ratio:

$$n(NaOH) = 0.0020\ mol$$

Step 5: Convert the sodium hydroxide volume into litres.

$$25.0\ mL = 0.0250\ L$$

Step 6: Calculate the concentration of sodium hydroxide.

$$C = \frac{n}{V}$$

$$C = \frac{0.0020}{0.0250}$$

Answer: 0.080 mol L^{-1}.

11.9 Worked example 2: A 1:2 mole ratio

25.0 mL of sulphuric acid is neutralised by 20.0 mL of 0.20 mol L^{-1} sodium hydroxide. Calculate the concentration of the sulphuric acid.

Step 1: Write the balanced equation.

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

Mole ratio:

$$H_2SO_4 : NaOH = 1:2$$

Step 2: Convert the sodium hydroxide volume into litres.

$$20.0\ mL = 0.0200\ L$$

Step 3: Calculate the moles of sodium hydroxide.

$$n = C \times V$$

$$= 0.20 \times 0.0200$$

$$= 0.0040\ mol$$

Step 4: Calculate the moles of sulphuric acid.

From the 1:2 ratio:

$$n(H_2SO_4) = \frac{0.0040}{2}$$

$$= 0.0020\ mol$$

Step 5: Convert the acid volume into litres.

$$25.0\ mL = 0.0250\ L$$

Step 6: Calculate the acid concentration.

$$C = \frac{0.0020}{0.0250}$$

Answer: 0.080 mol L^{-1}.

11.10 Precautions during titration

- Ensure the burette is vertical.
- Remove air bubbles from the burette jet.
- Remove the funnel before taking readings.
- Read the meniscus at eye level.
- Use a suitable indicator.
- Add the titrant slowly near the end point.
- Swirl the conical flask continuously.
- Use a white tile to observe colour changes clearly.
- Rinse the apparatus with the appropriate solutions before use.
- Repeat the titration to obtain concordant titres.
- Do not return unused chemicals to their original stock bottles.

12.0 Laboratory safety during chemical calculations and experiments

The preparation of solutions and titrations involves chemicals and glassware that must be handled carefully.

12.1 General laboratory safety rules

42. Wear a laboratory coat, safety goggles and suitable footwear.
43. Use gloves when handling corrosive or hazardous reagents.
44. Never taste laboratory chemicals.
45. Never pipette by mouth; use a pipette filler.
46. Avoid inhaling chemical vapours.
47. Use small quantities of reagents.
48. Keep chemical containers properly labelled.
49. Report spills and breakages to the teacher immediately.
50. Dispose of chemical waste according to laboratory instructions.
51. Wash hands after completing experiments.

12.2 Safety when handling acids

- Concentrated acids can cause severe burns.
- Always add acid slowly to water during dilution.
- Use a suitable pipette filler when measuring acids.

- If acid spills on the skin, rinse immediately with plenty of running water and inform the teacher.
- Do not attempt to neutralise acid on the skin using another chemical.

12.3 Safety when handling alkalis

- Strong alkalis such as sodium hydroxide can cause serious skin and eye injuries.
- Avoid contact with the skin and eyes.
- Handle solutions carefully.
- Rinse affected areas immediately with plenty of running water.
- Seek appropriate assistance if a chemical enters the eyes.

13.0 Applications of the mole in everyday life and Kenya

The mole is important in understanding chemical quantities and controlling chemical processes.

13.1 Agriculture

- Fertiliser manufacturers use chemical calculations to determine nutrient content.
- Farmers benefit from knowing the concentration of fertiliser solutions.
- Chemical calculations help in preparing solutions used in agricultural research.
- The mole helps chemists determine the exact amounts of nutrients in fertilisers.

Example: Potassium nitrate contains potassium and nitrogen. Its chemical formula can be used to calculate the percentage composition of each element.

13.2 Water treatment

- Chemical calculations help determine the quantities of treatment chemicals required.
- Accurate concentrations are important in water quality testing.
- Titration can be used in the analysis of water samples.
- The concentration of dissolved substances can affect the suitability of water for domestic and industrial use.

13.3 Food processing

- Chemical concentrations are important in food preservation.
- Acids and bases are used in some food-processing operations.
- The mole helps in calculating quantities of ingredients used in chemical processes.
- Titration can be used to determine the acidity of some food products.

13.4 Medical and health applications

- Correct concentrations are essential in preparing medical solutions.
- Electrolyte solutions contain carefully controlled quantities of dissolved ions.
- Chemical analysis helps determine the composition of some medical preparations.
- Accurate measurement reduces errors in laboratory testing.

13.5 Industrial applications

- Chemical manufacturers use mole calculations to determine the quantities of reactants needed.
- Molar solutions are used in quality control laboratories.
- Percentage composition helps establish the purity of industrial products.
- Titration is used to analyse acids, bases and other chemical products.

14.0 Summary of important formulae

Concept	Formula
Number of moles from mass	$n = \frac{m}{M}$
Mass from moles	$m = nM$
Molar mass	$M = \frac{m}{n}$
Number of particles	$N = nN_A$
Moles from particles	$n = \frac{N}{N_A}$
Relative formula mass	$M_r = \sum(A_r \times \text{number of atoms})$
Molecular formula factor	$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}}$
Percentage composition	$\frac{\text{Mass of element in one mole}}{\text{Molar mass of compound}} \times 100$
Molar concentration	$C = \frac{n}{V}$
Moles from concentration	$n = CV$
Mass for solution preparation	$m = CVM$
Dilution	$C_1V_1 = C_2V_2$
Titre	Final burette reading − Initial burette reading

Symbols and units

- n: number of moles, mol.
- m: mass, g.
- M: molar mass, g mol^{-1}.
- N: number of particles.
- N_A: Avogadro constant, mol^{-1}.
- C: concentration, mol L^{-1}.
- V: volume, L.
- A_r: relative atomic mass.
- M_r: relative formula mass.

REVISION EXERCISES

SECTION A: MULTIPLE-CHOICE QUESTIONS

30 MARKS • Answer all questions. Each question carries 1 mark.

Question 1. What is a mole?

A. The mass of one atom of an element.
B. The SI unit for measuring the amount of a substance.
C. The volume of a liquid.
D. The number of elements in a compound.

Question 2. What is the value of the Avogadro constant?

A. 6.022×10^{20}
B. 6.022×10^{21}
C. 6.022×10^{23}
D. 6.022×10^{25}

Question 3. Relative atomic mass is defined in relation to:

A. One atom of hydrogen.
B. One-twelfth of the mass of a carbon-12 atom.
C. One molecule of oxygen.
D. One mole of carbon dioxide.

Question 4. Which statement about relative atomic mass is correct?

A. It always has a unit of grams.
B. It is always a whole number.
C. It is a weighted average of the masses of naturally occurring isotopes.
D. It is the same as the mass number of every isotope.

Question 5. What is the relative formula mass of water (H_2O)? (H = 1, O = 16)

A. 16
B. 17
C. 18
D. 20

Question 6. Calculate the relative formula mass of calcium carbonate ($CaCO_3$). (Ca = 40, C = 12, O = 16)

A. 56
B. 84
C. 100
D. 116

Question 7. What is the molar mass of sodium chloride? (Na = 23, Cl = 35.5)

A. 35.5 g mol^{-1}
B. 46.0 g mol^{-1}
C. 58.5 g mol^{-1}
D. 60.0 g mol^{-1}

Question 8. Calculate the number of moles in 24 g of magnesium. (Mg = 24)

A. 0.5 mol
B. 1 mol
C. 2 mol
D. 24 mol

Question 9. What is the mass of 2 moles of water? (H = 1, O = 16)

A. 18 g
B. 20 g
C. 36 g
D. 40 g

Question 10. Calculate the number of moles in 11 g of carbon dioxide. (C = 12, O = 16)

A. 0.25 mol
B. 0.50 mol
C. 1.00 mol
D. 2.00 mol

Question 11. How many molecules are present in one mole of water?

A. 6.022×10^{20}
B. 6.022×10^{21}
C. 6.022×10^{23}
D. 6.022×10^{25}

Question 12. Which formula represents the simplest whole-number ratio of atoms in a compound?

A. Molecular formula
B. Empirical formula
C. Structural formula
D. Ionic equation

Question 13. What is the empirical formula of hydrogen peroxide (H_2O_2)?

A. H_2O_2
B. HO
C. H_2O
D. HO_2

Question 14. A compound has an empirical formula CH_2O and a molecular mass of 180. What is its molecular formula? (C = 12, H = 1, O = 16)

A. CH_2O
B. $C_2H_4O_2$
C. $C_3H_6O_3$
D. $C_6H_{12}O_6$

Question 15. Which of the following is the correct formula for calculating percentage composition?

A. $\frac{\text{Molar mass}}{\text{Mass of element}} \times 100$

B. $\frac{\text{Mass of element in one mole}}{\text{Molar mass of compound}} \times 100$

C. $\text{Molar mass} \times 100$

D. $\frac{\text{Number of moles}}{\text{Mass}} \times 100$

Question 16. What is the percentage of oxygen in water? (H = 1, O = 16)

A. 11.11%
B. 50%
C. 88.89%
D. 90%

Question 17. What is meant by molarity?

A. The mass of solvent in a solution.
B. The number of moles of solute per litre of solution.
C. The volume of solute in a solvent.
D. The mass of a solution per litre.

Question 18. Calculate the concentration of a solution containing 0.5 moles of solute in 2 litres of solution.

A. 0.10 mol L^{-1}
B. 0.25 mol L^{-1}
C. 1.00 mol L^{-1}
D. 2.50 mol L^{-1}

Question 19. Which apparatus is most suitable for measuring an accurate fixed volume of a solution during titration?

A. Beaker
B. Conical flask
C. Pipette
D. Test tube

Question 20. Which apparatus is used to deliver measured volumes of titrant during a titration?

A. Burette
B. Measuring cylinder
C. Funnel
D. Evaporating dish

Question 21. Which indicator is colourless in acidic solution and pink in alkaline solution?

A. Methyl orange
B. Phenolphthalein
C. Litmus
D. Bromothymol blue

Question 22. What is the main purpose of an indicator during acid-base titration?

A. To increase the mass of the solution.
B. To increase the concentration of the acid.
C. To show the end point through a colour change.
D. To produce a precipitate.

Question 23. Which equation represents the neutralisation reaction between hydrochloric acid and sodium hydroxide?

A. $HCl + NaOH \rightarrow NaCl + H_2O$

B. $HCl + NaOH \rightarrow Na_2O + HCl$

C. $HCl + NaOH \rightarrow H_2 + Cl_2$

D. $HCl + NaOH \rightarrow Na + H_2O$

Question 24. What is dilution?

A. Increasing the amount of solute in a solution.
B. Reducing the concentration of a solution by adding solvent.
C. Removing all the solvent from a solution.
D. Converting a solution into a solid.

Question 25. Which equation is used to calculate dilution?

A. $C_1V_1 = C_2V_2$

B. $n = m \times M$

C. $C = \frac{V}{n}$

D. $M = \frac{n}{V}$

Question 26. What happens to the concentration of a solution when distilled water is added to it?

A. It increases.
B. It decreases.
C. It remains constant.
D. It becomes zero immediately.

Question 27. Which apparatus is most suitable for preparing a solution to an accurate final volume?

A. Test tube
B. Beaker
C. Volumetric flask
D. Evaporating dish

Question 28. Why should acid be added to water rather than water to concentrated acid during dilution?

A. To make the acid more concentrated.
B. To prevent excessive heat and dangerous splashing.
C. To change the colour of the acid.
D. To prevent the acid from dissolving.

Question 29. What is the correct formula for calculating the titre during titration?

A. Initial reading + final reading.
B. Initial reading − final reading.
C. Final reading − initial reading.
D. Final reading × initial reading.

Question 30. Why is accurate measurement of chemical quantities important in laboratory work?

A. It helps produce reliable and reproducible results.
B. It makes chemicals change colour.
C. It eliminates the need for laboratory safety.
D. It prevents all chemical reactions.

SECTION B: STRUCTURED QUESTIONS

50 MARKS • Answer all questions.

Question 1: The mole and relative atomic mass (8 marks)

b) Define the mole. (2 marks)

c) State the value of the Avogadro constant. (1 mark)

d) Explain why relative atomic mass has no unit. (2 marks)

e) An element has two isotopes with the following data:

Isotope	Relative isotopic mass	Percentage abundance
X-10	10	80%
X-11	11	20%

Calculate the relative atomic mass of the element. (3 marks)

Question 2: Relative formula mass and mole calculations (8 marks)

a) Define relative formula mass. (2 marks)

b) Calculate the relative formula mass of aluminium sulphate, $Al_2(SO_4)_3$. (3 marks)

Use:

- Al = 27
- S = 32
- O = 16

d) Calculate the number of moles in 29.25 g of sodium chloride. (2 marks)

Use Na = 23 and Cl = 35.5.

e) Calculate the mass of 0.5 moles of calcium carbonate. (1 mark)

Use Ca = 40, C = 12 and O = 16.

Question 3: Empirical and molecular formulae (8 marks)

A compound contains 40% carbon, 6.67% hydrogen and 53.33% oxygen by mass.

c) Define empirical formula. (2 marks)

d) Determine the empirical formula of the compound. (4 marks)

Use:

- C = 12
- H = 1
- O = 16

c) If the molecular mass of the compound is 180, determine its molecular formula. (2 marks)

Question 4: Percentage composition and concentration (8 marks)

a) Define percentage composition. (2 marks)

b) Calculate the percentage composition of calcium carbonate, $CaCO_3$. (3 marks)

Use:

- Ca = 40
- C = 12
- O = 16

c) Calculate the concentration in mol L^{-1} of a solution containing 0.2 moles of sodium chloride in 500 mL of solution. (3 marks)

Question 5: Preparation and dilution of solutions (8 marks)

a) Define a standard solution. (2 marks)

b) Calculate the mass of sodium hydroxide required to prepare 250 mL of a 0.2 mol L^{-1} solution. (3 marks)

Use Na = 23, O = 16 and H = 1.

c) Calculate the volume of 2.0 mol L^{-1} hydrochloric acid required to prepare 250 mL of 0.5 mol L^{-1} hydrochloric acid. (2 marks)

d) State one precaution when diluting concentrated acids. (1 mark)

Question 6: Acid-base titration (10 marks)

25.0 mL of sodium hydroxide solution is completely neutralised by 20.0 mL of 0.10 mol L^{-1} hydrochloric acid.

a) Define acid-base titration. (2 marks)

b) Name the apparatus used to:

iii. Deliver the acid during titration. (1 mark)

iv. Measure a fixed volume of sodium hydroxide solution. (1 mark)

c) Write the balanced chemical equation for the reaction between hydrochloric acid and sodium hydroxide. (2 marks)

d) Calculate the concentration of the sodium hydroxide solution. (3 marks)

e) State one precaution observed when reading the burette. (1 mark)

ANSWERS AND MARKING SCHEME

Section A: Multiple-choice answer key

Question	Answer	Question	Answer	Question	Answer
1	B	11	C	21	B
2	C	12	B	22	C
3	B	13	B	23	A
4	C	14	D	24	B
5	C	15	B	25	A
6	C	16	C	26	B
7	C	17	B	27	C
8	B	18	B	28	B
9	C	19	C	29	C
10	A	20	A	30	A

Section B: Suggested marking scheme

Question 1 (8 marks)

c) The mole is the SI unit for measuring the amount of a substance. One mole contains exactly $6.02214076 \times 10^{23}$ elementary particles. (2)

d) $6.022 \times 10^{23}\ mol^{-1}$. (1)

- Relative atomic mass is a ratio comparing two masses. (1)
- A ratio of quantities with the same units has no unit. (1)

$$A_r = \frac{(10 \times 80) + (11 \times 20)}{100}$$

$$= \frac{800 + 220}{100}$$

$$= \frac{1020}{100}$$

$$\boxed{10.2}$$

Award:

- Correct formula. (1)
- Correct substitution. (1)
- Correct answer. (1)

Question 2 (8 marks)

e) Relative formula mass is the sum of the relative atomic masses of all the atoms represented in the formula of a substance. (2)

$$M_r = 2(27) + 3[32 + 4(16)]$$

$$= 54 + 3(96)$$

$$= 54 + 288$$

$$\boxed{342}$$

Award:

- Correct expression. (1)
- Correct substitution and working. (1)
- Correct answer. (1)

$$M_r(NaCl) = 23 + 35.5 = 58.5$$

$$n = \frac{29.25}{58.5}$$

$$\boxed{0.5\ mol}$$

Award:

- Correct molar mass. (1)
- Correct answer. (1)

$$M_r(CaCO_3) = 40 + 12 + 48 = 100$$

$$m = 0.5 \times 100$$

$$\boxed{50\ g}$$

Question 3 (8 marks)

f) An empirical formula is the simplest whole-number ratio of atoms of each element in a compound. (2)

g) Assume 100 g of the compound.

Element	Mass (g)	RAM	Moles
C	40	12	3.33
H	6.67	1	6.67
O	53.33	16	3.33

Divide by the smallest value, 3.33:

- C = 1
- H = 2
- O = 1

$$\boxed{CH_2O}$$

Award:

- Correct assumption and mole calculations. (2)
- Correct mole ratio. (1)
- Correct empirical formula. (1)

$$M_r(CH_2O) = 12 + 2 + 16 = 30$$

$$n = \frac{180}{30} = 6$$

$$(CH_2O) \times 6$$

$$\boxed{C_6H_{12}O_6}$$

Award:

- Correct empirical formula mass and multiplying factor. (1)
- Correct molecular formula. (1)

Question 4 (8 marks)

h) Percentage composition is the percentage by mass of each element present in a compound. (2)

$$M_r(CaCO_3) = 40 + 12 + (3 \times 16)$$

$$= 100$$

$$\%Ca = \frac{40}{100} \times 100 = 40\%$$

$$\%C = \frac{12}{100} \times 100 = 12\%$$

$$\%O = \frac{48}{100} \times 100 = 48\%$$

Award:

- Correct RFM. (1)
- Correct calculations. (1)
- Correct percentages. (1)

Convert volume:

$$500\ mL = 0.5\ L$$

Use:

$$C = \frac{n}{V}$$

$$C = \frac{0.2}{0.5}$$

Award:

- Correct volume conversion. (1)
- Correct formula and substitution. (1)
- Correct answer. (1)

Question 5 (8 marks)

a) A standard solution is a solution whose concentration is accurately known. (2)

Given:

- .
- $V = 0.25\ L.$
- Molar mass of NaOH = 40 g mol^{-1}.

$$n = C \times V$$

$$= 0.2 \times 0.25$$

$$= 0.05\ mol$$

$$m = n \times M$$

$$= 0.05 \times 40$$

$$\boxed{2.0\ g}$$

Award:

- Correct conversion of volume. (1)
- Correct calculation of moles. (1)
- Correct mass. (1)

$$C_1V_1 = C_2V_2$$

$$2.0 \times V_1 = 0.5 \times 250$$

$$V_1 = \frac{125}{2}$$

$$\boxed{62.5\ mL}$$

Award:

- Correct formula. (1)
- Correct answer. (1)

f) Any one:

- Always add acid slowly to water, never water to concentrated acid.
- Wear suitable protective equipment.
- Use appropriate measuring apparatus. (1)

Question 6 (10 marks)

a) Acid-base titration is a laboratory technique used to determine the concentration of an acid or base by reacting it with a solution of accurately known concentration. (2)

v. Burette. (1)

vi. Pipette. (1)

$$\boxed{HCl + NaOH \rightarrow NaCl + H_2O}$$

Step 1: Convert the acid volume into litres.

$$20.0\ mL = 0.0200\ L$$

Step 2: Calculate moles of hydrochloric acid.

$$n = CV$$

$$= 0.10 \times 0.0200$$

$$= 0.0020\ mol$$

Step 3: Use the mole ratio.

The balanced equation gives a 1:1 ratio.

$$n(NaOH) = 0.0020\ mol$$

Step 4: Convert the sodium hydroxide volume into litres.

$$25.0\ mL = 0.0250\ L$$

Step 5: Calculate concentration.

$$C = \frac{n}{V}$$

$$= \frac{0.0020}{0.0250}$$

Award:

- Correct volume conversion and acid mole calculation. (1)
- Correct mole ratio. (1)
- Correct final concentration. (1)

e) Any one:

- Read the bottom of the meniscus at eye level.
- Ensure there are no air bubbles in the burette jet.
- Record the initial and final readings accurately. (1)

THE MOLE

SET 2 REVISION QUESTIONS

Questions

1. In an experiment magnesium ribbon was heated in air. The product formed was found to be heavier than the original ribbon. Potassium manganate (VII) was on the other hand, heated in air and product formed was found to be lighter. Explain the differences on the observation made

2. In a filtration experiment 25cm^3 of a solution of Sodium Hydroxide containing 8g per litre was required for complete neutralization of 0.245g of a dibasic acid. Calculate the relative molecular mass of the acid (Na = 23.0, O = 16, H= 1)

3. D grams of Potassium hydroxide were dissolved is distilled water to make 100 cm^3 of solution. 50cm^3 of the solution required 50cm^3 of 2.0M nitric acid for complete neutralization.
Calculate the mass D of Potassium hydroxide (RFM of KOH = 56)
$KOH_{(aq)} + HNO_{3(aq)} \rightarrow KNO_{3(aq)} + H_2O_{(l)}$

4. When excess dilute hydrochloric acid was added to sodium sulphite, 960cm^3 of sulphuric (IV) Oxide gas was produced. Calculate the mass of sodium sulphate that was used.
(Molar gas volume = 24000cm^3 and Molar mass of sulphite = 126g)

5. The equation of the formation of iron (III) chloride is
$2Fe_{(s)} + 3Cl_{2(g)} \rightarrow 2FeCl_3$
Calculate the volume of chlorine which will react with iron to form 0.5g of Iron (III) chloride.
(Fe = 56 Cl=35.5). Molar gas volume at 298K = 24dm^3)

6. 15.0cm^3 of ethanoic acid (CH_3COOH) was dissolved in water to make 500cm^3 of solution. Calculate the concentration of the solution in moles per litre [C=12, H = 1, O = 16, density of ethanoic acid is 1.05g/cm^3]

7. When 1.675g of hydrated sodium carbonate was reacted with excess hydrochloric acid, the volume carbon (IV) oxide gas obtained at room temperature and pressure was 150cm^3. Calculate the number of moles of water of crystallization in one mole of hydrated sodium carbonate:- (Na=23, H =1, C=12, O=16, MGV at R.T.P = 24000cm^3)

8. How many chloride ions are present in 1.7g of magnesium chloride crystals? (Avogadro's constant = 6.0 x 10^{23}, Mg = 24, Cl = 35.5)

9. Calculate the volume of oxygen gas used during the burning of magnesium (O = 16, molar gas volume = 24,000cm^3 at room temperature)

10. A hydrated salt has the following composition by mass. Iron 20.2 %, oxygen 23.0%, sulphur 11.5%, water 45.3%

    i. Determine the formula of the hydrated salt (Fe=56, S=32, O=16, H=11)

    ii. 6.95g of the hydrated salt in (i) above were dissolved in distilled water and the total volume made to 250cm^3 of solution. Calculate the concentration of the resulting salt solution in moles per litre. (Given that the molecula mass of the salt is 278)

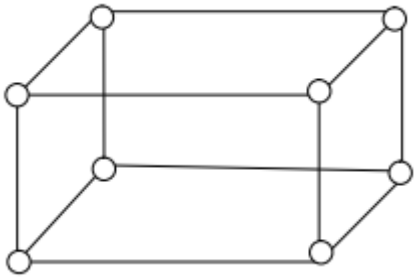
11.

    i. Lead (II) ions react with iodide ions according to the equation;
    $Pb^{2+}_{(aq)} + 2I^-_{(aq)} \rightarrow PbI_{2(s)}$
    300cm^3 of a 0.1m solution of iodide ions was added to a solution containing excess lead (II) ions. Calculate the mass in grams of lead II iodide formed

    ii. Identify the colour of the product formed in (i)

12.

i. The diagram below represents part of the structure of sodium chloride crystal



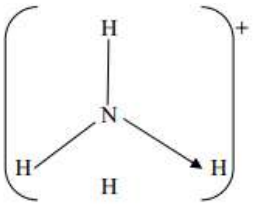
The position of one of the sodium ions in the crystal is shown as;

i. On the diagram, mark the positions of the other three sodium ions

ii. The melting and boiling points of sodium chloride are 801°C and 1413°C respectively. Explain why sodium chloride does not conduct electricity at 25°C, but does not at temperatures between 801°C and 1413°C

ii. Give a reason why ammonia gas is highly soluble in water

iii. The structure of ammonium ion is shown below;



Name the type of bond represented in the diagram by N → H

iv. Carbon exists in different crystalline forms. Some of these forms were recently discovered in soot and are called fullerenes

i. What name is given to different crystalline forms of the same element

ii. Fullerenes dissolve in methylbenzene while the other forms of carbon do not. Given that soot is a mixture of fullerenes and other solid forms of carbon, describe how crystals of fullerenes can be obtained from soot

iii. The relative molecular mass of one of the fullerenes is 720. What is the molecular mass of this fullerene

13. Calculate the volume of oxygen gas used during the burning of magnesium (O = 16, molar gas volume = 24,000cm^3 at room temperature)

14. Study the information in the table below and answer the questions that follow

Number of carbon atoms per molecule	Relative molecular mass of the hydrocarbon
2	28
3	42
4	56

i. Write the general formula of the hydrocarbons in the table

ii. Predict the relative atomic mass of the hydrocarbons with 5 carbon atoms

iii. Determine the relative atomic mass of the hydrocarbon in (ii) above and draw its structural formula (H=1.0, C=12.0)

15. Galvanized iron sheets are made by dipping the sheets in molten Zinc.

i. Explain how zinc protects iron from rusting

ii. Name the process applied in galvanization of iron with zinc

16. A factory uses nitric acid and ammonia gas as the only reactant for the preparation of the fertilizer if the daily production of the fertilizer is 4800kg. Calculate the mass of ammonia gas used daily (N = 14.0, O= 16.0, H = 1.0)

17. Calculate the volume of sulphur (VI) oxide gas that would be required to produce 178kg of oleum in step 3 molar gas volume at s.t.p = 22.4 litres (H = 1, O = 16, S = 32)

18. A sample of biogas contains 35.2% by mass of methane. A biogas cylinder contains 5.0kg of the gas. Calculate:

    i. Number of moles of methane in the cylinder (Molar mass of methane = 16)

    ii. Total volume of carbon (IV) oxide produced by the combustion of methane in the cylinder (Molar gas volume = 24.0dm^3 at room temperature and pressure)

19. 0.84g of aluminium were reacted completely with chlorine gas. Calculate the volume of chlorine gas used. (Molar gas volume is 24dm^3, Al = 27)

20. 3.52g of Carbon (IV) Oxide and 1.40g of water are produced when a mass of a hydrocarbon is completely burnt in oxygen. Determine the empirical formula of the hydrocarbon; (H = 1 , C= 12, O = 16)

21. Calculate the number of water molecules when 34.8g $Na_2CO_3.xH2O$ is heated and 15.9g of anhydrous Na_2CO_3 obtained (H=1, O=16, Na= 23, C = 12)

22. A weighed sample of crystallined sodium carbonate ($Na_2CO_3.nH2O$) was heated in a crucible until there was no further change in mass. The mass of the sample reduced by 14.5%. Calculate the number of moles (n) of water of crystallization (Na = 23, O = 16, C = 12, H = 1)

23. In a reaction 20cm^3 of 0.1 M Sodium Carbonate completely reacted with 13cm^3 of dilute sulphuric acid. Find the molarity of the sulphuric acid used.

24. An organic compound P contains 68.9% carbon, 13.5% hydrogen and 21.6% oxygen. The relative formula mass of p is 74. Determine its molecular formula. [C=12, H=1, O=16]

25. Campers GAZ cylinder contains about 1.12dm^3 of butane measured at 0° and 1atm. Given that 25% of heat is lost, what is the maximum volume of water at room temperature which can be boiled to 100°C in order to make some coffee?
$C_4H_{10(g)} + 6½O_{2(g)} \rightarrow 4CO_{2(g)} + 5H_2O_{(l)}$; $\Delta H^{\theta} = -3{,}000KJmol^{-1}$
(Specific heat capacity of water = 4.2J $g^{-1o}C$, density of water 1gcm^{-3} Molar gas volume 22.41dm^3 at s.t.p)

26. An aqueous solution containing anhydrous sodium carbonate was prepared by dissolving 19.6g of the salt in 250cm^3 of distilled. Calculate the volume of 2M of magnesium chloride solution required to precipitate all the carbonate ions in the solution. (Na=23, C= 12; O = 16; Mg = 24; Cl =35.5)

27. 10.08g of ethanedioic acid ($H_2C_2O_4.xH_2O$) crystals were dissolved in water and made to 1dm^3 solution. 25.0 cm^3 of this solution was completely neutralized by 20cm^3 of 0.2M sodium hydroxide solution.
Calculate

    i. Molarity of the acid

    ii. the value of x in $H_2C_2O_4.xH_2O$ acid

28. 1.6g of magnesium metal is reacted with excess hydrochloric acid. Calculate the volume of hydrogen gas produced (Molar gas volume at stp = 22.4dm^3 Mg=24)

29. 60 litres of sulphur(IV) oxide were made to react with 40 litres of oxygen.

    i. Which reactant was in excess and by how much?

    ii. What is the volume of the product?

30. During welding of cracked railway lines by thermite 12.0g of oxide of iron is reduced by aluminium to 8.40g of iron. Determine the empirical formula of the oxide (Fe= 56.0, O= 16.0)

31. 0.84g of aluminium reacted completely with chlorine gas. Calculate the volume of chlorine gas used (Molar gas volume is 24dm^3, Al = 27)

Answers

1. When a magnesium ribbon is heated in air it combines with oxygen forming magnesium oxide.
   When potassium manganate (VII) is heated it decomposes giving off oxygen which escapes in air

2. RFM of NaOH = 40
   Moles of NaOH = $^{8}/_{40}$ = 0.2M ✓
   Moles of NaOH in $25cm^3$
   $\frac{25 \times 0.2}{1000} = 0.005$
   Mole ratio 1:2
   Moles of acid = $^{0.005}/_{2}$
   = 0.0025
   $\frac{1 \times 0.245}{0.0025} = 98$

3. No. Of moles of HNO_3 acid
   $\frac{50 \times 2}{1000} = 0.1$moles
   Mole ratio 1:1
   The KOH will have 0.1moles; $\frac{0.1 \times 100}{50} = 0.2$moles
   Then D grams is 0.2×56
   = 11.2g

4. Number of moles of Q = $\frac{960\ cm^3 \times 1\ mole}{24000\ cm^3}$
   = 0.04moles
   Equation:
   $Na_2SO_{3(s)} + 2HCl(aq) \rightarrow 2NaCl_{(aq)} + SO_{2(g)} + H_2O_{(l)}$
   Mole ratio $Na_2SO_3 : SO_2$ is 1:1
   ∴No. of moles of Na_2SO_3 = 0.04moles
   Mass of $Na_2SO_3 = 126gmol^{-1} \times 0.04$
   = 5.04g

5. From the equation
   - (3x24) litres of chlorine react with iron to produce [(56 x 2) + (35.5 X3)] g of $FeCl_3$.
   325 g of Fecl3 is produced by 72 litres of Cl_2
   Then 0.5g of $Fecl_3$ is produced by:
   $\frac{0.5 \times 72}{325}$ =0.11078 litres
   = 110.78 cm^3

6. RMM (CH_3OOH) = 60
   Mass of $15cm^3$ and = 1.05 x 15 = 15.75g
   Moles in $500cm^3$ solution = $\frac{15.75}{60}$ = 0.2625
   Molarity = $\frac{1000 \times 0.2625}{5000}$
   = 0.525M

7. If 24000 cm^3 = 1mole
   $150cm^3$ = ?
   $\frac{150 \times 1}{24000}$
   = 0.00625 moles of CO_2
   Since the ratio of Na_2CO_3; O_2 produced is 1:1 the mass of Na_2CO_3 = 0.00625 x 106 = 0.6625g

Na_2CO_3	H_2O
Mass 0.6625g RFM 106 Mole $^{0.6625}/_{106} = 0.00625$ Ratio $^{0.00625}/_{0.00625}$ $= 1$ $Na_2CO_3.9H_2O$	1.0125g 18 $^{1.0125}/_{18} = 0.5625$ $^{0.05625}/_{0.00625}$ $= 9$

8. $MgCl_2 \rightarrow Mg^{2+}(s) + 2Cl$
R.F.M of $MgCl_2 = 24 + 71$
$= 95$
Moles of Mass = $\frac{1.7}{95}$
R.F.M
$= 0.01789$moles
1 mole of $MgCl_2$ = 2moles of Cl^- ions
0.01789moles of $MgCl_2 = 0.01789 \times 2$
$= 0.03478$ moles of Cl^- ions
1mole = 6.0×10^{23} ions
0.03578moles = $\frac{0.03578 \times 6.0 \times 10^{23}}{1}$
$= 2.1468 \times 10^{22}$ ions of Cl^-

9. Mass of $O_2 = (4.0 - 2.4) = 1.6g$
Moles of $O_2 = {}^{1.6}/_{16} = 0.1$
If 1 mol O_2 _____ $24000cm^3$
0.1 Mol Mg = 0.5 mol $O_2 = 1200cm^3$
OR
2mg : O_2
2(24) 24000
$^{2.4}/_{2(24)} = {}^{x}/240000$
$x = \frac{2.4 \times 24000}{2(2.4)} = 1200cm^3$

10.

i. **Fe** **S** **O** **H_2O**
$^{20.2}/_{56}$ $^{11.5}/_{32}$ $^{23.0}/_{16}$ $^{45.3}/_{18}$
$^{0.36}/_{0.36}$ $^{0.36}/_{0.36}$ $^{1.44}/_{0.36}$ $^{2.52}/_{0.36}$
1 **1** **4** **7**
Empirical formula: $FeSO_4.7H_2O$

ii. 6.95g = $^{6.95}/_{278} = 0.025$
∴ 0.05 moles in $250cm^3 = 0.025 \times {}^{1000}/_{250} = 0.1$

11.

i. R.F.M of $PbI_2 = 207 + (127 \times 2) = 461$
2 moles of I^- ions produces 1 mole of PbI_2
Moles of I-ions = $\frac{0.1 \times 300}{1000} = 0.03$ mole
Mole ratio $PbI_2 : I^-$ mole of PbI_2 formed = $^{0.03}/_{2} = 0.05$
1 : 2
Mass of PbI_2 formed = 0.015 mole × 461
= 6.915 g

ii. Yellow precipitateMocks Topical Analysis www.easyelimu.com 20

12.

i.

i.

ii. At 25°C, sodium chloride is in solid form. Ions cannot move. Between 801°C and 1413°C sodium chloride is in liquid state, ions are mobile

ii. Both ammonia and water are polar moleculer and hydrogen bonds are formed

iii. N → H // co-ordinate bond / Dative bond

iv.

i. Allotrope

ii. Add methylbenzene to soot in a beaker. Shake and filter. Warm the filtrate to concentrate it. Allow the concentrate to cool for crystals to form. Filter to obtain crystals of fullerene

iii. $^{720}/_{12} = 60$

13. Mass of $O_2 = (4.0 - 2.4) = 1.6g$
Moles of $O_2 = {}^{1.6}/_{16} = 0.1$
If 1 mol $O_2 \rightarrow 24000cm^3$
0.1 Mol Mg = 0.5 mol $O_2 = 1200cm^3$
OR
2mg : O_2
2(24) 24000
$^{2.4}/_{2(24)} = {}^{x}/240000$
$x = \frac{2.4 \times 24000}{2(2.4)} = 1200cm^3$

14.

i. C_nH_{2n}, where n = No. of carbon atoms

ii. 70

iii. C_5H_{10}, $CH_3CH{=}CHCH_2CH_3$
OR $CH_3CH_2CHCH_2 = CH_2$

15.

i. Zinc is more reactive// higher reduction potential than copper it will react with// get oxidized in preference to iron oxygen to form Zinc Oxide coat which protects iron from rusting

ii. Sacrificial protection or cathodic protection

16. $NH_{3(g)} + HNO_{3(g)} \rightarrow NH_4NO_{3(s)}$
RMM of $NH_4NO_3 = 80$
Moles of $NH_4NO_3 = {}^{4800}/_{80} = 60$moles
RMM of $NH_3 = 17$
Mass of $NH_3 = 60 \times 17 = 1020KJ$

17. From the equation of step 3
$SO_{3(g)} + H_2SO_{4(l)} \rightarrow H_2S_2O_{7(l)}$
RFM of $H_2S_2O_7 = 2 + (2 \times 32) + (7 \times 16) = 178$ ✓ ½ mark
178g of Oleum are produced by 22.4 liters of SO3 ✓ ½ mark
178 kg of Oleum will produce
$\frac{178 \times 1000 \times 22.4}{178g}$l ✓ 1½ mark
= 22,4000 liters ✓ ½ mark
(Total 13 marks)

18.

i. $\frac{35.2 \times 1000}{100 \times 16}$
= 10Moles
Or mass of CH4 = $\frac{35.2 \times 5}{1000}$ = 1.76g
Mass in g = 1.76 x 1000 = 1760kg
Moles of methane = $^{1760}/_{16}$
= 110 Moles

ii. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ – (ignore states)
Volume = 110 x 24.0
= 2640 dm^3
Mark consequential from equation and b(ii) (Without equation max *TZM*)

19. Volume of Cl_2 used
= 0.047 x 24
= 1.128dm^3

20. Mass due Carbon in CO2 = $^{12}/_{4}$ x 35.2
= 0.96
Moles carbon = $^{0.96}/_{12}$ = 0.08
Mass due Hydrogen in H_2O = $^{2}/_{18}$ x 1.40
= 0.156
Moles hydrogen = $^{0.156}/_{1}$ = 0.156
Mole ratio C:H = 1:1.95
E.F = CH_2

21. $Na_2CO_{3.x}H2O \rightarrow Na_2CO_3 + H_2O$ √1

34.8g	15.9g	18.9g
	106	18
	0.15 √1	1.15
	0.15	0.15

x = 7 √1
Total 3 marks

22. % of H_2O lost = 14.5%^
5 of anhydrous Na_2CO_3 = 85.5% (½mk)
R.F.M of Na_2CO_3 = 106 (½mk)
RMM of H_2O = 18 (½mk)

Na_2CO_3	**H_2O**
85.5	14.5
106	18
0.8066	0.8066
0.8055	0.8055

23. n = 1 ($Na_2CO_3.H_2O$) (½mk)

24. Moles of Na_2CO_3 = $\frac{20 \times 0.1}{1000}$ = 0.002 moles
$Na_2CO_3 + H_2SO_{4(aq)} \rightarrow Na_2SO_{4(aq)} + H_2O_{(l)} + CO_{2(g)}$
Mole ratio 1 : 1
Moles of H_2SO_4 = Moles of Na_2CO_3
= 0.002 moles
Molarity of H2SO4 = $\frac{10000 \times 0.002}{13}$ = 0.154 moles

25.

Element	C	H	O
%	68.9	13.5	21.6
Molar mass	12	1	16
Moles	$^{68.9}/_{12}$ 5.403	$^{13.5}/_{1}$ 13.5	$^{216}/_{16}$ 1.35
MR	$^{5.403}/_{1.33}$ 4	$^{13.5}/_{1.35}$ 10	$^{1.35}/_{1.35}$ 1
Ratio	4	10	1

26.

h ($C_4H_{10}O$) = 74
h (12 x 4) + (10 x 1) +16 = 74
74h = 74
h= 1
Formula $C_4H_{10}O$

27. Moles C_4H_{10} = $^{1.12}/_{22.4}$ = 0.05 mol
Heat produced + 0.05 × (3000) = 150 kJ
Usefull heat = $\frac{75\times150}{100}$ = 112.5 kJ
Let volume of water = V
Room temperature = 25°C
Boiling point = 100°C
Change in temperature, ΔT = 100 − 25 = 75°C ½ mk
Q = ΔT × mass × C
= 75 × V × 4.2 =112500
315V = 112500
V = $^{112500}/_{315}$ ½ mk
V = 357cm^3 ½ mk

28. RFM Na_2CO_3 = 43 + 12 + 48 = 106
Mol. Na_2CO_3 = $^{19.6}/_{106}$ = 0.8149057
Molarity of Na_2CO_3 = $^{0.1849057}/_{0.25}$ = 0.73962M
$Na_2CO_{3(aq)} + MgCl_{2(aq)} \rightarrow MgCO_{3(s)} + 2NaCl_{(aq)}$
Mole ratio $NaCO_3$: $MgCl_2$ is 1:1
∴ mol. $MgCl_2$ Reacted = 0.1849
If 2.0 mol. = 1000cm^3 solution $MgCl_2$
= 0.1849mol = $\frac{0.1849 \times 1000}{2}$
= 92.45 or 92.5 cm^3

29.

i. ACID BASE
1 2
½ ×0.004 20cm^3 × 0.2 moles
= 0.002 moles ✓½ 1000cm^3 = 0.004 moles
25cm^3 _____ 0.002 moles ✓ ½

$1000cm^3$ _____ ?

$1000cm^3 \times 0.002$ moles = 0.08M✓ ½

ii. 0.08 moles _____ 10.08g $H_2C_2O_4.xH2O$ ✓ ½

1 mole _____ ?

$\frac{1 \text{ mole}}{0.08 \text{ moles}} \times 10.08 = 126$ ✓ ½

126 _____ $H_2C_2O_4.xH_2O$

18x = 126 – 90 ✓ ½

18x = 36

x = 2 ✓ ½

30. $Mg_{(g)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$

24g _____ $22.4dm^3$

16g _____ ?

$\frac{1.6g}{24g} \times 22.4dm^3$ ✓ ½ = 1.4933 dm^3

31.

i. $2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$, $SO_2 : O_2$

2 1 2 60 : 30 ✓½

60l 40l

Oxygen ✓½ by 10 litres

ii. 60 litres

32. Mass of Oxygen = 12 – 8.4 = 3.5g

Element	Fe	O
Mass	8.4	3.6
RAM	56	16
No. of moles	$^{8.4}/_{56}$ 0.15	$^{3.6}/_{16}$ 0.225
Mole ration	$^{0.15}/_{0.15}$ 1 2	$^{0.225}/_{0.15}$ 1.5 × 2 3

33. The empirical formula is Fe_2O_3

34. $2AL\ 3CL_2 = 2ALCL_3$

Mole of alumminium $\frac{0.84}{27}$ = 0.0311.bt accrdin 2 d equation 2 mole of AL react with 3mole of Cl.

1mole of Al required 1.5mole of cl

0.0311mole of Al required 0.0311 ×1.5mole of Cl = 0.04665mole.

1 mole of a gas occupied $22.4dm^3$,0.04665 mole will occupy $0.04665 \times 22.4 = 1.0450dm^3$ of Cl

THE MOLE SUMMARY NOTES

- A mole is defined as the mass of a substance that contains as many as particles(atoms, molecules, or ions) as the number of atoms in 12g of carbon-12.

- In the above definition, 12 is the mass number of carbon. So, one mole of carbon atoms has a mass of 12 grams. The relative atomic mass, which can be written as RAM, is the number just above the element in the periodic table
- This number is also called Avogadro's number. And is written as **6×10^{23}.**

1mole = 6.023×10^{23} particles

The mass of one mole of a substance is called **molar mass**.

The molar mass of:

(i) An **element** has mass equal to relative **atomic** mass /RAM(in grams) of the element e.g.

- Molar mass of carbon(C)= relative atomic mass = 12.0g
- **6.023×10^{23} particles of carbon = 1 mole = 12.0 g**

- Molar mass of sodium(Na) = relative atomic mass = 23.0g
- **6.023×10^{23} particles of sodium = 1 mole = 23.0 g**

- Molar mass of Iron (Fe) = relative atomic mass = 56.0g
- **6.023×10^{23} particles of iron = 1 mole = 56.0 g**

(ii)

- A **molecule** has mass equal to relative molecular mass/RMM (in grams)of the molecule. Relative molecular mass is the **sum** of the relative atomic masses of the elements making the molecule.
- The number of atoms making a molecule is called **atomicity**. Most **gaseous** molecules are **diatomic (e.g. O_2, H_2, N_2, F_2, Cl_2, Br_2, I_2)** noble gases are **monoatomic (e.g. He, Ar, Ne, Xe)**,Ozone gas(**O_3**) is **triatomic** e.g.

- Molar mass **Oxygen molecule(O_2)** = relative molecular mass = (16.0 x 2)g = 32.0
- **6.023×10^{23} particles of Oxygen molecule = 1 mole = 32.0 g**

- Molar mass **chlorine molecule(Cl_2)** =relative molecular mass = (35.5x 2)g =71.0g
- **6.023×10^{23} particles of chlorine molecule = 1 mole = 71.0 g**

- Molar mass **Nitrogen molecule(N_2)** = relative molecular mass =(14.0x 2)g =28.0g
- **6.023×10^{23} particles of Nitrogen molecule = 1 mole = 28.0 g**

- A **compound** has mass equal to relative formular mass /RFM (in grams)of the molecule.
- Relative formular mass is the **sum** of the relative atomic masses of the elements making the compound. e.g.

(i)

Molar mass **Water(H_2O)** = relative formular mass = [(1.0 x 2) + 16.0]g = 18.0g

6.023 x 10^{23} particles of Water molecule = 1 mole = 18.0 g

6.023 x10^{23} particles of Water molecule has:

- **-2** x 6.023 x10^{23} particles of Hydrogen atoms
- **-1** x 6.023 x10^{23} particles of Oxygen atoms

(ii)

Molar mass **sulphuric (VI) acid(H_2SO_4)** = relative formular mass

= [(1.0 x 2) + 32.0 + (16.0 x 4)]g = 98.0g

6.023 x10^{23} particles of sulphuric(VI)acid(H_2SO_4) = 1 mole = 98.0g

6.023 x10^{23} particles of sulphuric(VI)acid(H_2SO_4) has:

- **-2** x 6.023 x10^{23} particles of **H**ydrogen atoms
- **-1** x 6.023 x10^{23} particles of **S**ulphur atoms
- **-4** x 6.023 x10^{23} particles of **O**xygen atoms

QUESTIONS.

(Avogadro's constant L = 6.0 x 10^{23})

(1). Calculate the number of atoms present in 0.23 g of dilute sulphuric (VI) acid

(2). Calculate the number of atoms present in 0.23 g of sodium carbonate (IV) decahydrate

(3). How many molecules of Argon gas do we have when we say 3 moles of Argon gas?

(4). How many atoms of sodium do we have when we say we have 6 moles of sodium metal?

(5). Find the number of moles in 3.02 x 10^{24} atoms of Na.

(6). Find the number of moles make 1.510 x 10^{23} molecules of Ammonia.

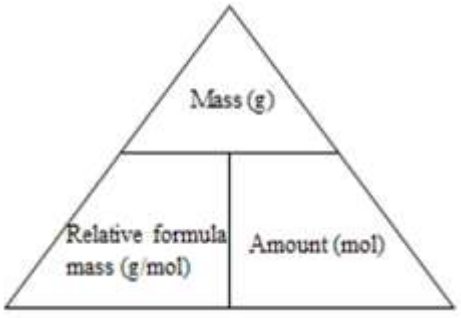
Interconversion of Moles, Mass & Molar Mass

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- When the mass of an atom is compared to that of another, it is referred to as **relative atomic mass-RAM.**
- The relative atomic mass of an atom is defined as the ratio of the average mass of one atom of an element to one twelfth of the mass of an atom of carbon-12.
- The molar mass (Mw), also known as molecular weight (Mw), is the sum of the total mass in grams of all the atoms that make up a mole of a particular molecule. The unit used to measure is grams per mole (g/mol).

Molar mass answers the question, how many grams are in one mole of a given element?

The mole formula is: mole = mass (g) / molar mass (g/mol)



Questions;

(1). Calculate the number of moles in;

a. 0.23 g of Sodium atoms

b. 0.23 g of Chlorine atoms

c. 0.23 g of Chlorine molecules

d. 0.23 g of dilute sulphuric (VI)acid

(2). Calculate the mass of 0.25 moles of berylium.

(3). Calculate the molar mass of an element if ala mass of 5.6g contains 0.1 moles of the element.

Empirical and molecular formula

1. The empirical formula of a compound is its simplest formula. It is the simplest whole number ratios in which atoms of elements combine to form the compound.
2. It is mathematically the lowest common multiple (LCM) of the atoms of the elements in the compound.
3. Practically the empirical formula of a compound can be determined as in the following examples.

To determine the empirical formula of copper oxide

(a). Method 1: From copper to copper(II)oxide

Procedure.

Weigh a clean dry covered crucible **(M_1)**. Put two spatula full of copper **powder** into the crucible. Weigh again (M_2). Heat the crucible on a strong Bunsen flame for five minutes. Lift the lid, and swirl the crucible carefully using a pair of tong. Cover the crucible and continue heating for another five minutes. Remove the lid and stop heating. Allow the crucible to cool. When cool replace the lid and weigh the contents again **(M_3)**.

Sample results

Mass of crucible(M_1)	15.6g
Mass of crucible + copper before heating(M_2)	18.4
Mass of crucible + copper after heating(M_3)	19.1

Sample questions

1. Calculate the mass of copper powder used.

Mass of crucible + copper before heating (M_2) = 18.4

Less Mass of crucible (M_1) = 15.6g

18.4g - 15.6g = 2.8g

Mass of copper = 2.8 g

2. Calculate the mass of Oxygen used to react with copper.

Method I

Mass of crucible + copper after heating($\mathbf{M_3}$) = 19.1g

Mass of crucible + copper before heating($\mathbf{M_2}$) = 18.4g

19.1g - 18.4g = 0.7g

Mass of Oxygen = 0.7 g

Method II

Mass of crucible + copper after heating($\mathbf{M_3}$) = 19.1g

Mass of crucible = -15.6g

Mass of copper (II) Oxide = 3.5 g

Mass of copper (II) Oxide = 3.5 g

Mass of copper = - 2.8 g

Mass of Oxygen = **0.7g**

3.Calculate the number of moles of:

(i)

Copper used (Cu = 63.5)

number of moles of copper;

= mass used/Molar mass =

= 2.8/63.5 = **0.0441moles**

(ii)

Oxygen used (O = 16.0)

number of moles of oxygen = mass used/Molar mas

= 0.7/16.0 = **0.0441moles**

4. Determine the mole ratio of the reactants

Moles of copper = 0.0441moles

Moles of oxygen = 0.0441moles

= 0.0441moles/0.0441moles

Mole ratio Cu: O = **1:1**

5. What is the empirical, formula of copper oxide formed.

- CuO (copper (II) oxide)

6. State and explain the observations made during the experiment.

Observation

- Colour change from **brown** to **black**

Explanation

- Copper powder is brown. On heating it reacts with oxygen from the air to form black copper (II) oxide

7. Explain why magnesium ribbon/shavings would be unsuitable in a similar experiment as the one above.

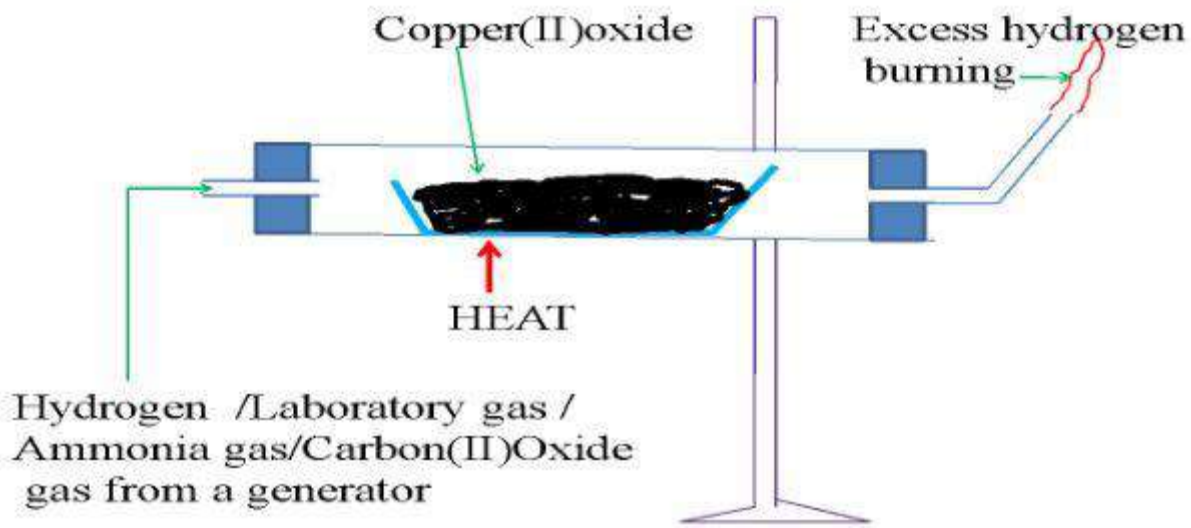
- Hot magnesium generates enough heat energy to react with **both** Oxygen and Nitrogen in the air forming a white solid mixture of Magnesium oxide and magnesium nitride. This causes experimental mass errors.

(b). <u>Method 2: From copper(II)oxide to copper</u>

Procedure.

- Weigh a clean dry porcelain boat ($\mathbf{M_1}$). Put two spatula full of copper (II) oxide **powder** into the crucible. Reweigh the porcelain boat ($\mathbf{M_2}$).Put the porcelain boat in a glass tube and set up the apparatus as below;

Determining the empirical formular from copper (ii) oxide to copper;



- Pass slowly(to prevent copper(II)oxide from being blown away)a stream of either dry Hydrogen /ammonia/laboratory gas/ carbon(II)oxide gas for about two minutes from a suitable generator.
- When all the in the apparatus set up is driven out ,heat the copper (II) oxide strongly for about five minutes until there is no further change. Stop heating.
- Continue passing the gases until the glass tube is cool.
- Turn off the gas generator.

- Carefully remove the porcelain boat form the combustion tube.
- Reweigh ($\mathbf{M_3}$).

Sample results

Mass of boat(M_1)	15.6g
Mass of boat before heating(M_2)	19.1
Mass of boat after heating(M_3)	18.4

Sample questions

1. Calculate the mass of copper(II)oxide used.

Mass of boat before heating ($\mathbf{M_2}$) = 19.1

Mass of empty boat ($\mathbf{M_1}$) = 15.6g

$\mathbf{M_2}$ - $\mathbf{M_1}$ = Mass of copper (II) Oxide

19.1g - 15.6G = 3.5g

Mass of copper(II)Oxide = 3.5 g

2. Calculate the mass of

(i) Oxygen.

Mass of boat before heating($\mathbf{M_2}$) = 19.1

Mass of boat after heating ($\mathbf{M_3}$) = 18.4g

$\mathbf{M_2}$ - $\mathbf{M_3}$ = Mass of oxygen

19.1 - 18.4 = 0.7g

Mass of oxygen = 0.7 g

(ii)Copper

Mass of copper (II) Oxide = 3.5 g

Mass of oxygen = 0.7 g

3.5 - 0.7 = 0.7g

Mass of oxygen = 2.8 g

3. Calculate the number of moles of:

(i) Copper used (Cu = 63.5)

number of moles of copper = mass used/Molar mass

2.8/63.5 = **0.0441moles**

(ii) Oxygen used (O = 16.0)

number of moles of oxygen = mass used/Molar mass

0.7/16.0 = **0.0441moles**

4. Determine the mole ratio of the reactants

Moles of copper/Moles of oxygen

= 0.0441moles/0.0441moles

= 1/1

Mole ratio Cu:O = **1:1**

5.What is the empirical, formula of copper oxide formed.

- CuO (copper (II) oxide)

6. State and explain the observations made during the experiment.

Observation;

- Colour change from **black** to **brown**

Explanation;

- Copper (II) oxide powder is black. On heating it is reduced by a suitable reducing agent to brown copper metal.

QUESTIONS

(1). A oxide of copper contain 80% by mass of copper. Determine its empirical formula. (Cu = 63.5, 16.0)

(2). 1.60g of an oxide of Magnesium contain 0.84g by mass of Magnesium. Determine its empirical formula(Mg = 24.0, 16.0)

(3). An oxide of Silicon contain 47% by mass of Silicon. What is its empirical formula(Si = 28.0, 16.0)

(4). A compound contain 70% by mass of Iron and 30% Oxygen. What is its empirical formula(Fe = 56.0, 16.0)

(5). During heating of a hydrated copper (II) sulphate (VI) crystals, the following readings were obtained:

Mass of evaporating dish = 300.0g

Mass of evaporating dish + hydrated salt = 305.0g

Mass of evaporating dish + anhydrous salt = 303.2g

Calculate the number of water of crystallization molecules in hydrated copper (II) sulphate (VI)

(Cu = 64.5, S = 32.0,O = 16.0, H = 1.0)

Calculating the Molecular Formula of a Compound –

The molecular formula is the actual number of each kind of atoms present in a molecule of a compound.

- The empirical formula of an ionic compound is the same as the chemical formula but for simple molecular structured compounds, the empirical formula may not be the same as the chemical formula.
- The molecular formula is a multiple of empirical formula .It is determined from the relationship:

(i)

n = Relative formular mass/Relative empirical formula

where **n** is a whole number.

(ii)

Relative empirical formula x **n** = Relative formular mass, where **n** is a whole number.

Practice sample examples

(a). A hydrocarbon was found to contain 92.3% carbon and the remaining Hydrogen.

If the molecular mass of the compound is 78, determine the molecular formula(C=12.0, H=1.0)

Mass of Hydrogen = 100 – 92.3 => 7.7% of Oxygen

Element	Carbon	Hydrogen
Symbol	C	H
Moles present = $\frac{\%\ \text{composition}}{\text{Molar mass}}$	$\frac{92.3}{12}$	$\frac{7.7}{1}$
Divide by the smallest value	$\frac{7.7}{7.7}$	$\frac{7.7}{7.7}$
Mole ratios	1	1

Empirical formula is CH

The molecular formular is thus determined:

n = Relative formular mass/Relative empirical formula

n = 78/13 = 6

The molecular formula is (C H) x 6 = C_6H_6

QUESTIONS

(1). On complete combustion of a sample of hydrocarbon, 3.52 g of carbon (IV) oxide and 1.44g of water were formed. Determine the molecular formula of the hydrocarbon. (Relative molecular mass of hydrocarbon is 56) (Carbon (10) oxide = 44) water=18) (H=1.0) (C=12.0)

(2). An alkanol has the following composition by mass: Hydrogen 13.5%, oxygen 21.6% and carbon 64. . 9%.

a. Determine the empirical formula of the alkanol (C=12.0; H=1.0; 0=16.0) (2 mks)

b. Given that empirical formula and the molecular formula of the alkanol are the same, draw the structure of the alkanol

(3). A hydrated salt has the following composition By mass: iron 20.2% Oxygen 23.0% sulphur 11.5% and 45.3% water of = crystallization. If RMM = 278

Determine the formula of the hydrate salt.

(4). A compound of carbon, hydrogen and oxygen contain 54.55% carbon, 9.09% and remaining 36.36% oxygen. If its relative molecular mass is 88, determine its molecular formula(C=12.0, H=1.0, O=16.0)

(5). A hydrocarbon burns completely in excess air to form 5.28 g of carbon (IV) oxide and 2,16g of water. If the molecular mass of the hydrocarbon is 84, draw and name its molecular structure.

(6). Compound A contain 5.2% by mass of Nitrogen .The other elements present are Carbon, hydrogen and Oxygen. On combustion of 0.085g of A in excess Oxygen,0.224g of carbon(IV)oxide and 0.0372g of water was formed. Determine the empirical formula of A (N=14.0, O=16.0 , C=12.0 , H=1.0

Concentration and Molarity of Solutions

- Concentration refers to the amount of a substance per defined space.
- Another definition of concentration is that concentration is the ratio of solute in a solution to either solvent or total solution.
- Molarity is a unit of concentration, defined as the number of moles of solute divided by the number of litres of solution.
- Molarity is the most common measure of concentration used in chemistry.
- Molarity is given as capital M for the units mol/L (or mol/dm^3 & 1L = $1dm^3$ = $1000cm^3$)

Concentration is affected by the following factors:

1. Mass of solute,
2. Dilution with volume of solvent and
3. Evaporation to remove some solvent by reducing its volume.

- Concentration given in g/L similar to how density is expressed in g/cm^3. The mass may be converted to moles and given as mol/L.
- Other units used are molality, normality, mass percent, mole fraction, parts per million, parts per billion e.t.c.

M = n(moles of solute)/v(volume of solution)

EXAMPLE;

(a). If 4.00g of sodium hydroxide were dissolved in $400cm^3$ of distilled water. Determine the concentration in molarity of the resulting basic solution.

(Na = 22.99, O = 16.00, H = 1.01).

(i)

By first principles method

Chemical Formula: NaOH

Molar mass of NaOH: 23 + 16 + 1 = 40 g Moles in 4.0 g: 4/40 = 0.1 moles

Volume used: $400cm^3$.

If 400 cm^3 contains 0.1 moles

Then 1000 cm^3 will have (1000 x 0.1)/400

Concentration = 0.250 mol/L (0.250 M)

(ii)

By formula

Chemical Formula: NaOH

Molar mass of NaOH: 23 + 16 + 1 = 40 g Moles in 4.0 g: 4/40 = 0.1 moles

Volume used: 400/1000 = 0.4 L

Concentration = 0.1/0.4

Concentration = 0.250 mol/L (0. 250 M)

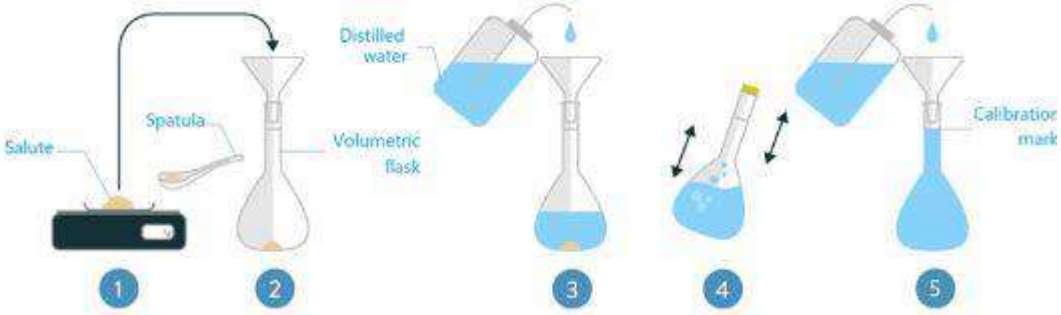
QUESTIONS

1. Calculate the molarity of a solution if;
2. 0.5 grams of sodium chloride is dissolved to make 0.05 litres of solution.
3. 734 grams of lithium sulfate are dissolved to make 2500ml of solution.
4. 6.7 x 10^{-2} grams of $Pb(C_2H_3O_2)_4$ are dissolved to make 3.5ml of solution.
5. Calculate the mass of : 25cm³ of 0.2³ sodium hydroxide solution(Na =23.0, O =16.0, H=1.0)
6. The density of sulphuric (VI) is 1.84gcm³ Calculate the molarity of the acid.

Preparation of molar solution

Procedure

- Weigh accurately 4.0 g of sodium hydroxide pellets into a 250 cm³ volumetric flask.
- Using a wash bottle add about 200 cm³ of distilled water.
- Stopper the flask.
- Shake vigorously for three minutes.
- Remove the stopper for a second then continue to shake for about another two minutes until **all** the solid has dissolved.
- Add more water slowly up to **exactly** the 250cm³ **mark**.





- For accurate concentrations, one must make careful use of measuring apparatus such as: volumetric flasks, pipettes, and burettes.
- Accurate weighing is an essential part of chemistry since an extra 0.001 g might result in a different concentration. Use measurements and calculations to the appropriate number of significant figures or decimal places (usually 4).
- One of the core principles of science, and an important moral rule, is to describe experimental procedures completely and carefully so that another person can follow and reproduce the results.
- To avoid contamination, ensure that the spatula and all other apparatus are extremely clean.
- Always use volumetric flasks to prepare molar solutions and nothing else.

QUESTIONS

(1). What mass of lithium phosphate (Li_3PO_4) would you need to make?

a. 2.5litre of 1.06 M lithium phosphate solution?

b. 250 cm^3 of 2M solution. (Li=6.94, P=30.97, O= 16.00)

(2). A chemist has 4.0 g of silver nitrate, ($AgNO_3$) and needs to prepare 2.0 L of a 0.010 M solution.

a. Will there be enough silver nitrate? If so, how much silver nitrate will be left over?

b. What would be the concentration of he dissolved only 2.0 g in 500cm^3 of water? (Ag = 107.87, N = 14.01, O = 16.00)

(3). A chalice contains 36.45 grams ammonium chlorite, NH_4ClO_2, in 2.36 liters of solution - calculate the molarity.

(4). What mass would be needed to make 250 cm^3 of 0.20M solution?(N=14.01, Cl=35.45, O=16.00, H=1.01)

(5). 15.0cm^3 ethanoic acid (CH_3COOH) was dissolved in water to make 500 cm^3 of solution. Calculate the concentration of the solution in moles per litre. (C=12.0; H=1.0; O=16.0) density of ethanoic is 1.05g/cm^3

Dilution of Solutions

- **A Stock Solution** is a concentrated solution that will be diluted to some lower concentrated for actual use.
- Stock solutions save preparation time, conserve materials, reduce storage space, and improve the accuracy with which working solutions are prepared.
- **A serial dilution** is where the diluted material of the previous step is used to make the subsequent dilution.
- **A step dilution** involves using the same concentration to make a dilution.
- To dilute a solution means to add more solvent without adding more solute.
- Preparing a molar solution by dilution of a more concentrated stock solution is easier and quicker than by weighing the salt/solute and adding to a solvent each time you need to prepare the solution.
- The fact that the amount of solute does not change on dilution allows us to develop a calculation techniques.

We use an accurate volume V1 cm^3 of a stock (original) solution having concentration/ molarity M1, (mol/L) to prepare volume V2 cm^3 of dilute solution with lesser concentration of M2 (mol/L).

Measure accurately 25 cm^3 of 2M HCl. Transfer the solution into a 250 cm^3 volumetric flask. Add distilled water to the acid and make up to 250 cm^3 of solution.

Determine the number of moles in the 25 cm^3 of 2M HCl

Determine the molarity of the solution contained in the 250 cm^3 flask

Solution;

M = moles/volume

Moles = M x Volume

2moles – 1000 cm^3/25 cm^3

= 0.05moles

These moles are the ones that are still in the 250cm^3 of solution after water is added.

So;

0.05 moles = 250 cm^3/1000 cm^3

= 0.2M

So;

(2M x 25cm^3) = 50moles

(0.2M x 250cm^3) = 50 moles

M1xV1= M2xV2

The Dilution equation,

We know that the mass hence moles of the solute remain the same, therefore moles of solute before dilution = moles of solute after dilution, and that

Moles = Molarity x Volume [moles = M x V] for a given volume of any solution whose concentration/molarity is known. Therefore; moles in the stock/original solution is M1V1 , and also moles in the final dilute solution is M2V2,

Dilution equation equates the two moles as below:

M1V1 = M2V2.

QUESTIONS

1. 53.4 mL of a 1.50 M solution of NaCl is on hand, but you need some 0.800 M solution. How many mL of 0.800 M can you make?
2. 100.0 mL of 2.500 M KBr solution is on hand. You need 0.5500 M. What is the final volume of solution which results?
3. A stock solution of 1.00 M NaCl is available. How many milliliters are needed to make 100.0 mL of 0.750 M
4. What volume of 0.250 M KCl is needed to make 100.0 mL of 0.100 M solution?

Stoichiometry

- A balanced chemical equation is the recipe for a reaction: it contains a list of all the reactants (the ingredients) and products (the cookies) as well as their relative proportions.
- Using a balanced chemical equation to calculate amounts of reactants and products is called **stoichiometry**.
- The **coefficients** from the balanced chemical reaction tell us the proportions of the reactants and products.
- We can use ratios of the coefficients to convert between amounts of reactants and products in our reaction.

- **A mole ratio** is the ratio between the amounts in moles of any two compounds involved in a chemical reaction.
- Mole ratios are used as conversion factors between products and reactants in many chemistry problems.

- **The mole ratio** may be determined by examining the coefficients in front of formulas in a balanced chemical equation.

Key things to consider while doing stoichiometry is:

1. Reactants and products must be known.
2. Write a well balanced chemical equation.
3. Derive the mole ratio from the coefficient used in balancing.
4. Convert mass given to moles.
5. Use the mole ratio to find the moles of the unknown.
6. Use the moles of the unknown and its rmm to find the mass of the unknown.

Example:

If 4.0 g of calcium was burnt in unlimited supply of oxygen, how much Calcium Oxide was produced?

$2Ca + 1O_2 \rightarrow 2CaO$

Moles of calcium 4/40 = 0.1 moles

Mole ratio,

2 : 1

0.1 --> ?

(0.1 x 1)/2 = 0.05 moles

Mass = moles x MM

= 0.05 x 40

= 2.0 g

- **Theoretical yield** is the amount of product that can be produced/ synthesized from reactants under ideal conditions.
- Experimental yield is the amount of product actually synthesized in the experiment.
- The percentage yield is determined by calculation:

(Actual yield x 100%)/Theoretical yield

- It indicates the percent of theoretical yield that was obtained from the final product in an experiment.
- If we are not told the reagent that is in excess, then we have to find the limiting reagent:
- **A limiting reagent** is the reactant that is used up first leading to a halt in the reaction.
- The other reactant is then referred to as the reagent **in excess.**

QUESTIONS

(1). Given the following reaction:

$Cu + 2AgNO_3 \rightarrow 2Ag + Cu(NO_3)_2$

How many moles of Ag will be produced from 16.0g of Cu, assuming AgNO3 is available in excess.

NB; moles(round to three significant figures)

(2).

$1Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCL(aq) + 1CO_2(g) + 1H_2O\ (l)$

a. If we had reacted 2.5g of sodium carbonate reacting with an excess of the acid, how much NaCl will be produced?

b. If this reaction was to be performed in the lab, will the mass of NaCl retrieved be exact as per your calculations? Explain.

Ionic Reactions

Ionic equations

- An ionic equation is a chemical statement showing the movement of ions (cations and anions) from reactants to products.
- **Solids**, **gases** and **liquids** do not ionize/dissociate into free ions. **Only** ionic compounds in **aqueous/solution** or **molten** state ionize/dissociate into free cations and anions (**ions**)
- An ionic equation is usually derived from a stoichiometric equation by using the following guidelines;

Guidelines for writing ionic equations

(1). Write the balanced stoichiometric equation

(2). Indicate the state symbols of the reactants and products

(3). **Split** into cations and anions all the reactants and products that exist in **aqueous** state.

(4). **Cancel out** any cation and anion that appear on **both** the product and reactant side.

(5). Rewrite the chemical equation. It is an ionic equation.

Practice;

(**a**) Precipitation of an insoluble salt

- All insoluble salts are prepared in the laboratory from double decomposition /precipitation. This involves mixing **two soluble** salts to form **one soluble** and **one insoluble** salt

1. When silver nitrate(V) solution is added to sodium chloride solution, sodium nitrate (V) solution and a white precipitate of silver chloride are formed.

Balanced stoichiometric equation;

$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

Split reactants product existing in aqueous state as cation/anion;

$\mathbf{Ag^+(aq) + NO_3^-(aq) + Na^+(aq) + Cl^-(aq) \rightarrow AgCl(s) + Na+(aq) + NO_3\text{-}\ (aq)}$

Cancel out ions appearing on reactant and product side;

$Ag^+(aq) + NO_3^-(aq) + Na^+(aq) + Cl^-(aq) \rightarrow AgCl(s) + Na^+(aq) + NO_3^-(aq)$

Rewrite the equation

$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ (ionic equation)

2. When barium nitrate(V) solution is added to copper(II)sulphate(VI) solution, copper(II) nitrate(V) solution and a white precipitate of barium sulphate(VI) are formed.

Balanced stoichiometric equation

$Ba(NO_3)_2(aq) + CuSO_4(aq) \rightarrow BaSO_4(s) + Cu(NO_3)_2$ (aq)

Split reactants product existing in aqueous state as cation/anion

$Ba^{2+}(aq) + 2NO_3^-(aq) + Cu^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s) + 2NO_3^-(aq) + Cu^{2+}(aq)$

Cancel out ions appearing on reactant and product side

$Ba^{2+}(aq) + 2NO_3^-(aq) + Cu^{2+}(aq) + SO_4^{2}\text{-}(aq) \rightarrow BaSO_4(s) + 2NO_3^-(aq) + Cu^{2+}(aq)$

Rewrite the equation

$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ (ionic equation)

3.A yellow precipitate of Potassium Iodide is formed from the reaction of Lead(II)nitrate(v) and potassium iodide.

Balanced stoichiometric equation

$Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$

Split reactants product existing in aqueous state as cation/anion;

$Pb^{2+}(aq) + 2NO_3^-(aq) + 2K^+(aq) + 2I^-(aq) \rightarrow PbI_2$ (s) $+ 2NO_3^-(aq) + 2K^+(aq)$

Cancel out ions appearing on reactant and product side

$Pb^{2+}(aq) + 2NO3^-(aq) + 2K^+(aq) + 2I^-(aq) \rightarrow PbI_2(s) + 2NO3^-(aq) + 2K^+(aq)$

Rewrite the equation

$Pb^{2+}(aq) + 2I^{-}(aq) \rightarrow PbI_2(s)$ (ionic equation)

Neutralization

- Neutralization is the reaction of an acid with a **soluble** base/alkali or **insoluble** base.

(i)Reaction of alkalis with acids

(1). Reaction of nitric(V)acid with potassium hydroxide

Balanced stoichiometric equation

$HNO_3(aq) + KOH(aq) \rightarrow H_2O(l) + KNO_3(aq)$

Split reactants product existing in aqueous state as cation/anion

$H^{+}(aq) + NO_3^{-}(aq) + K^{+}(aq) + OH^{-}(aq) \rightarrow H_2O(l) + NO_3^{-}(aq) + K^{+}(aq)$

Cancel out ions appearing on reactant and product side

$H^{+}(aq) + NO_3^{-}(aq) + K^{+}(aq) + OH^{-}(aq) \rightarrow H_2O(l) + NO_3^{-}(aq) + K^{+}(aq)$

Rewrite the equation;

$H^{+}(aq) + OH^{-}(aq) \rightarrow H_2O(l)$ (ionic equation)

(2). Reaction of sulphuric(VI)acid with ammonia solution

Balanced stoichiometric equation

$H_2SO_4(aq) + 2NH_4OH(aq) \rightarrow H_2O(l) + (NH_4)2SO_4(aq)$

Split reactants product existing in aqueous state as cation/anion

$2H^{+}(aq) + SO_4^{2-}(aq) + 2NH_4^{+}(aq) + 2OH^{-}(aq) \rightarrow 2H_2O(l) + SO_4^{2-}(aq) + 2NH_4^{+}(aq)$

Cancel out ions appearing on reactant and product side

$2H^{+}(aq) + SO_4^{2-}(aq) + 2NH_4^{+}(aq) + 2OH^{-}(aq) \rightarrow 2H_2O(l) + SO_4^{2-}(aq) + 2NH_4^{+}(aq)$

Rewrite the equation;

$2H^{+}(aq) + 2OH^{-}(aq) \rightarrow 2H_2O(l)$

$H^{+}(aq) + OH^{-}(aq) \rightarrow H_2O(l)$ (ionic equation)

(3). Reaction of hydrochloric acid with Zinc hydroxide

Balanced stoichiometric equation

$2HCl(aq) + Zn(OH)_2(s) \rightarrow 2H_2(l) + ZnCl_2(aq)$

Split reactants product existing in aqueous state as cation/anion;

$2H^+(aq) + 2Cl^- (aq) + Zn(OH)_2(s) \rightarrow 2H_2O(l) + 2Cl^-(aq) + Zn^{2+}(aq)$

Cancel out ions appearing on reactant and product side

$2H^+(aq) + 2Cl^-(aq) + Zn(OH)_2(s) \rightarrow 2H_2O(l) + 2Cl^-(aq) + Zn^{2+}(aq)$

Rewrite the equation;

$2H+(aq) + Zn(OH)_2 (s)$

QUESTIONS

1. Write a the ionic equation for;
2. Reaction of hydrochloride acid with zinc metal
3. Reaction of sodium carbonate with zinc nitrate
4. Reaction of magnesium hydroxide with sulfuric acid
5. Reaction of potassium sulphate with lead nitrate
6. Reaction of sodium hydroxide with sulfuric acid.

Titration

1. **Titration** is an experimental technique used to determine the concentration of an unknown solution.
2. It usually involves acids and bases, but may be extended to any addition of one solution to another to find out the amounts required for reaction.
3. Since volume measurements play a key role in titration, it is also known as **volumetric analysis**.
4. A reagent, called the **titrant or titrator** is prepared as a standard solution.
5. A known concentration and volume of titrant/titrator reacts with a solution of **analyte or titrand,** whose concentration is unknown, in order to determine concentration

➔The procedure involves adding one solution to another solution, in the presence of an indicator that shows when the two solutions have completely reacted.

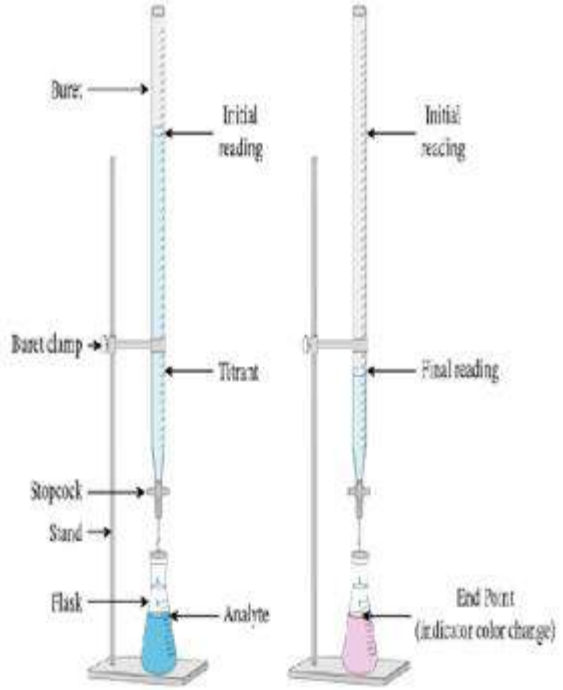
➔If the concentration and volume of one of the solutions is known and the volume of the other solution is known, then the unknown concentration can be calculated providing the stoichiometry of the reaction is known.

During volumetric analysis, the solution whose exact concentration is known is called a **standard solution.**

Steps of Titration

1. The burette is filled with the acid. A burette is used to place the acid of unknown concentration.
2. The alkali is added to the conical flask using a pipette.
3. An indicator is added to the alkali. An indicator is added to the alkali in the conical flask, which causes a colour change to occur. When titrating a strong acid and strong alkali any commercial indicator is used, While when titrating a strong acid and a weak base methyl orange is used and finally when titrating a weak acid with a strong base phenolphthalein is used
4. The acid is added into the alkali. The acid from the burette is allowed to run into the alkali, swirling constantly to ensure the reactants mix well.
5. The acid Is added slowly when the indicator changes colour.
6. The acid stops being added when there is a permanent colour change
7. The titre is recorded in the table.

The titration is repeated three times;



Titration number	1	2	3
Final burette reading (cm^3)	20.0	20.0	20.0
Initial burette reading (cm^3)	0.0	0.0	0.0
Volume of solution used(cm^3)	20.0	20.0	20.0

Calculating Concentration of titrant

The known volume and concentration of the alkali enable the moles to be calculated.

The balanced symbol equation enable the moles ratio of acid: alkali to be determined. Hence the number of moles of acid can be calculated.

The mean titre is the volume of the acid. Using the moles and the volume, the concentration of the unknown acid can be determined.

QUESTIONS

(1). Calculate the molarity of MCO_3 if 5.0cm³ of MCO_3 react with 25.0cm³ of 0.5M hydrochloric acid.(C = 12.0 ,O = 16.0)

(2). 2.0cm³ of 0.5M hydrochloric acid react with 0.1M of M_2CO_3. Calculate the volume of 0.1M M_2CO_3 used.

(3). 5.0cm³ of 0.1M sodium iodide react with 0.1M of Lead(II)nitrate(V). Calculate

a. The volume of Lead(II)nitrate (V) used.

b. The mass of Lead (II) Iodide formed.

DIRECT TITRATION;

- A direct titration is the basic titration method that involves the reaction between the unknown compound and the compound with known concentration. Here, the addition of excess reagents is not done as in back titrations. The unknown compound is directly reacted with the known compound. Therefore, the end point of the titration indicates the end of the reaction. By using that endpoint, the amount of unknown compound present in the sample solution can be determined.

You are provided with:

- 0.1M sodium hydroxide solution A
- Hydrochloric acid solution B

You are required to determine the concentration of solution B in moles per litre.

Procedure

Fill the burette with solution B. Pipette 25.0cm³ of solution A into a conical flask. Titrate solution A with solution B using phenolphthalein indicator to complete the titration table 1.

Sample results Titration table 1

Titration number	1	2	3
Final burette reading (cm³)	20.0	20.0	20.0
Initial burette reading (cm³)	0.0	0.0	0.0
Volume of solution B used(cm³)	20.0	20.0	20.0

Sample worked questions

1. Calculate the average volume of solution B used

Average titre = (Titre 1 + Titre 2 +Titre 3)/3 => (20.0 +20.0 +20.0)/3 = **20.0cm³**

2. How many moles of:

(i)solution A were present in 25cm³ solution.

Moles of solution A = (Molarity x volume)/1000 = (0.1 x 25)/1000 = **2.5×10^{-3}** moles

(ii)solution B were present in the average volume.

Chemical equation: $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

Mole ratio 1:1 → Moles of A = Moles of B = **2.5 x**

10^{-3} moles

(iii) solution B in moles per litre.

Moles of B per litre = (moles x 1000)/Volume = ($2.5 \times 10^{-3} \times 1000$)/20 = **0.1M**

Questions

(1). You are provided with;

Aqueous sulphuric (VI) acid labelled A.

Solution B containing 8.48g per litre of sodium carbonate

You're required to determine the:

Concentration of solution A.

Procedure:

(i) Using a pipette, place 25.0cm^3 of solution A into a 250 ml volumetric flask.

(ii) Add distilled water to make 250cm^3 solution. Label this solution M. Place solution M in a burette.

(iii) Clean the pipette and use it to place 25.0cm^3 of solution B into a conical flask.

(iv) Add 2 drops of methyl orange indicator provided and titrate with solution M.

(v) Record your results in the table below.

(vi) Repeat the titration two more times and complete the table.

Titration number	1	2	3
Final burette reading (cm3)	25.0	25.0	25.0
Initial burette reading (cm3)	0.0	0.0	0.0
Volume of solution M used(cm3)	25.0	25.0	25.0

Calculate the:

1. Average volume of solution M used [1 mark]
2. Concentration of sodium carbonate in solution B (2 marks) (Na = 23.0, O = 16.0, C = 12.0
3. Concentration of sulphuric (VI) acid in solution M. (2 marks)

Standard Solutions

- **A standard solution** is one whose concentration is accurately known.
- For some substances a standard solution can be prepared by **weighing accurately** a given mass of pure substance and dissolving in water to give a **specific volume.** Such substances are called **primary Standards** like; sodium Carbonate and sodium ethanedioa.
- They must be stable.
- They should not react with. Components of the atmosphere

- **Most acids and bases** react or absorb components of the atmosphere. They are made by dissolving an **approximate mass** of the substance in water to a specific volume
- Their actual concentration is the determined by titrating them with a solution of a Primary Standard
- **Standardization** is the process in which one determines the concentration of a solution by accurately measuring the volume of it required to react with a known volume of a primary Standard
- The Standardization solution is called a **secondary Standard.**

QUESTION

(1). You are provided with;

- 0.125M HCl labelled solution **M**
- Anhydrous sodium carbonate labelled solid **P**
- Methyl orange indicator.

You required to prepare a solution of sodium carbonate and standardize it using hydrochloric acid solution **M.**

Procedure;

- Transfer all solid **P** into a 250cm³ volumetric flask. Add 100cm³ of distilled water and shake well until all solid dissolves. Add more distilled water and top up the solution to 250cm³ mark. Label this as solution **T.** Using a measuring cylinder measure 50cm³ of solution **T** and put it in a 250cm³ beaker. Dilute it by adding 50cm³ of distilled water. Shake well to form uniform solution, Label this solution as **R.**
- Pipette 25.0cm³ of R into a conical flask. Add two drops of methyl orange indicator. Fill the burette with solution **M.** Carry out titration.
- Record your results in the table below. Repeat the titration twice and complete the table.
- Volume of pipette used ..... cm³

Titration	1	2	3
Final burette readings (cm^3)			
Initial burette reading (cm^3)			
Volume of solution M used cm^3			

a. Calculate;

(i) Average volume of solution M used. (1mrk)

(ii) Moles of solution M used. (1mrk)

b. Write a balanced equation for the reaction between solution R and M.

c. Calculate;

(i) Moles of Na_2CO_3 in 25cm³ of solution R (1mrk)

(ii) Number of moles Na_2CO_3 in 100cm³ of solution R. (1mrk)

(iii) Number of moles Na_2CO_3 in 50cm³ of solution T.

d. Given that Na = 23, C = 12, O = 16

Calculate;

(i) Mass of solid Na_2CO_3 that was dissolved to make solution T. (2mrks)

(ii) The concentration of Na_2CO_3 in solution I in moles per litre. (1mrk)

Redox Titrations

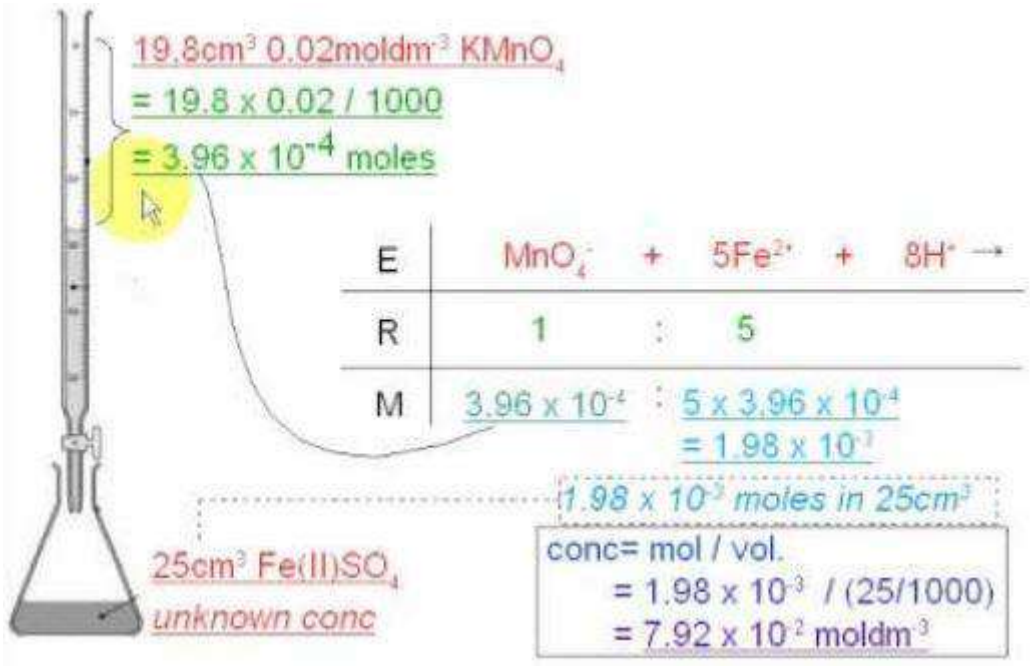
- **A redox titration** is the process of determining the quantity of a sample by monitoring a redox process until the endpoint is reached, when all of the sample has reacted.

Most common oxidizing agents;

- Potassium manganate (VII)
- Potassium dichromate (VI)

EXAMPLE;

Find the concentration of an iron (ii) sulphate solution, given that 25.0cm³ of the solution, when acidified, required 19.8cm³ of 0.0200moldm⁻³ potassium manganate (vii) for oxidation.



QUESTIONS

(1). Find the concentration of Iron (II) sulphate solution, given that 25.0cm³ of the acidified solution required 19.8cm³ of 0.02M potassium manganate (VII) for complete oxidation.

(2). 5.0cm³ of 0.1M sodium iodide react with 0.1M of Lead (II)nitrate(V).

Calculate

a. The volume of Lead (II) nitrate(V) used.

b. The mass of Lead (II) Iodide formed.

(3). A solution of 25.0cm³ of Iron (II) ammonium sulphate needed exactly 20.0cm³ of a solution of potassium dichromate (VI) of concentration 0.05M for complete oxidation. State the color of the solution at the endpoint.

Given the equation: $6Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) + 14H^+(aq) \rightarrow 6Fe^{3+}(aq) + 2Cr^{3+}(aq) + 7H_2O(l)$

Calculate the concentration of Iron (II) ions in the Iron (II) ammonium sulphate. [10 marks]

Back titration

A back titration is a titration method used to determine the concentration of an unknown using an excess amount of a compound with a known concentration. There is a chemical reaction between these compounds. Since the amount of the

compound with a known concentration added is known already, we can determine the amount of the compound that has reacted with the unknown compound by doing a back titration.

1. A back titration may be thought of as a normal titration but done in reverse.
2. A back titration is also called **indirect titration.**

Two steps are followed in a back titration.

1)First, the analyte is permitted to react with an excess reagent.

Next, a titration is conducted on the remaining quantity of the known solution. This is a way to measure the amount that remained unreacted i.e. the excess quantity

EXAMPLE;

(1). In an experiment, the following procedure was followed:

1 g of egg shells were reacted with 25 ml of a 3M HCl acid.

After the reaction stopped, the resulting solution was filtered into a 250 ml volumetric flask. Distilled water was used to top the solution to 250 ml mark and solution labelled Y. 25 ml of this solution was pipetted into a clean conical flask and a few drops of phenolphthalein indicator added. This solution was titrated against a standardized 2M NaOH solution to obtain four values.

The data below was recorded below.

	Trial	1	2	3
Final burette reading/cm^3	29.60	29.75	29.65	29.70
Initial burette reading/cm^3	0.00	0.00	0.00	0.00
Volume of NaOH used/cm^3	29.60	29.75	29.65	29.70

Steps:

Get average titre - Volume of NaOH required for neutralization.

Get moles of this NaOH required for neutralization.

Write a ba;anced chemical equation for reaction that took place.

Use equation get mole ratio and hence moles of HCl in 25 ml aliquot/ flask.

Work out moles of HCl in 250 ml volumetric flask. This will be the moles that remained after the reaction.

Work out original moles of the 25 ml of 3M HCl.

Subtract moles remaining from the original moles to get the moles of HCl that reacted.

Using equation of $CaCO_3$ and HCl, get the mole ratio and hence the moles of $CaCO_3$.

Using molar mass and moles of $CaCO_3$ calculate the mass of $CaCO_3$

Using the mass, convert the mass to percentage of $CaCO_3$ in 1g of the egg shells.

Note:

The resultant mixture was diluted to form 250 ml solution then a small volume, 25 ml, taken from the diluted solution to be analyzed by titration.

QUESTIONS;

(1). When 4g of a metal carbonate MCO_3 was dissolved in 160cm³ of 1M hydrochloric acid and then the resultant solution diluted to one litre, 25.0cm³ of this solution required 20.0cm³ of 0.1M sodium hydroxide solution for complete neutralization. Calculate

a. The number of moles per litre of excess hydrochloric acid that reacted with sodium hydroxide, NaOH.

b. The number of moles per litre of acid that reacted with the carbonate.

c. The number of moles of carbonate that reacted with the acid.

d. The formula mass of the carbonate, MCO_3

e. The atomic mass of the metal M. (C = 12.0, O = 16.0)

(2). A 0.4108 gram sample of $CaCO_3$ (100.087 g/mol) is added to a flask along with 15.00 mL of 2.000 M HCl.) Enough water is then added to make 250.0 mL of solution A. A 20.00 mL aliquot of solution A is taken and titrated with 0.1160 M NaOH. How many mL of NaOH are used?

(3). A 0.9030 gram sample of $M(OH)_2$ was mixed with 20.00 mL of 2.000 M HCl and enough water added to make 100.0 mL of solution A. A 10.00 mL aliquot of solution A was taken and titrated with 17.64 mL of 0.05121 M NaOH. What is the metal, M?

Molar Gas Volume

- **Atomicity** is the number of atoms of constituent elements combined to form a molecule.

Example;

- Noble gases (helium, neon, argon, krypton, etc.) have one atom each in their molecules such as He, Ne, Ar and Kr. So, the atomicity of noble gases is 1.

Example.

- Hydrogen gas (H_2), nitrogen gas (N_2), oxygen gas (O_2) have two atoms in each molecule. So their atomicity is 2.

- The terms, monoatomic, diatomic, triatomic e.t.c are used to describe the atomicity
- **AVOGADRO'S LAW - EQUAL VOLUMES OF GASES UNDER THE SAME CONDITIONS OF TEMPERATURE & PRESSURE CONTAIN THE SAME NUMBER OF MOLECULES/MOLES.**
- The molar volume, symbol Vm, is the volume occupied by one mole of a substance (chemical element or chemical compound) at a given temperature and pressure.
- It is equal to the molar mass (M) divided by the mass density (ϱ).
- It has the SI unit cubic metres per mole (m³/mol).

MOLAR GAS VOLUME

- One mole of any gas has a volume of 24000cm³ (24 Litres = 24dm³) at rtp (room temperature, 25^0C and pressure, 1 atmosphere).
- At stp (standard temperature, 0^0C and Pressure, 1 atmosphere) the molar gas volume (gas would occupy) is 22.4cm³ (22.4L=24dm³)

EXAMPLE;

(1). Calculate the volume of carbon(IV)oxide at r.t.p produced when 5.0 g of calcium carbonate is strongly heated.(Ca = 40.0, C = 12.0,O = 16.0,1 mole of gas = 22.4 at r.t.p)

Chemical equation

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

Mole ratios 1: 1: 1

Molar Mass $CaCO_3$ =100g

Method 1

100g $CaCO_3(s) \rightarrow 24dm^3$ $CO_2(g)$ at r.t.p

5.0 g $CaCO_3(s) \rightarrow (5.0g \times 24dm^3)/100g = 1.2dm^3/1200cm^3$

Method 2

Moles of 5.0 g $CaCO_3(s)$ = 5.0 g/100g = 0.05 moles

Mole ratio 1:1

Moles of $CO_2(g)$ = 0.05moles

Volume of $CO_2(g)$ = 0.05 x $24000cm^3$ = $1200cm^3$ /$1.2dm^3$

QUESTIONS

(1). 1.0g of an alloy of aluminium and copper were reacted with excess hydrochloric acid. If $840cm^3$ of hydrogen at s.t.p was produced, calculate the % of copper in the alloy. (Al = 27.0,one mole of a gas at s.t.p = $22.4dm^3$)

(2). When excess dilute hydrochloric acid was added to sodium sulphite, $960cm^3$ of sulphur (IV) oxide gas was produced. Calculate the mass of sodium sulphite that was used. (Molar mass of sodium sulphite = 126g: and molar gas volume = $24000cm^3$)

(3). Calculate the volume of carbon (iv) oxide measured at S.T.P that is evolved when 1 mole of copper (II) carbonate is heated to a constant mass

(4). How many molecules are there in $360cm^3$ of nitrogen as r.t.p

(5). Define the following terms

a. Monatomic gas

b. Diatomic gas

c. Atomicity of an element

Gay Lussac's Law

- **Gay Lussacs** law states that "when gases combine/react they do so in simple volume ratios to each other and to their gaseous products at constant/same temperature and pressure"
- Gay Lussacs law thus only apply to gases
- Given the volume of one gas reactant, the other gaseous reactants can be deduced thus:

Examples

(1). Calculate the volume of Oxygen required to completely react with $50cm^3$ of Hydrogen.

Chemical equation:

$2H_2(g) + O_2(g) \rightarrow 2H_2O$**(l)**

Volume ratios 2 : 1 : 0

Reacting volumes $50cm^3 : 25cm^3$

$= 50cm^3$ of Oxygen is used

QUESTIONS

(1). Calculate the volume of air required to completely reacts with $50cm^3$ of Hydrogen.(assume Oxygen is 21% by volume of air

(2). If $5cm^3$ of a hydrocarbon CxHy burn in $15cm^3$ of Oxygen to form $10cm^3$ of Carbon(IV)oxide and $10cm^3$ of water vapour/steam, obtain the equation for the reaction and hence find the value of x and y in CxHy.

(3). $100cm^3$ of nitrogen (II) oxide NO combine with $50cm^3$ of Oxygen to form $100cm^3$ of a single gaseous compound of nitrogen. All volumes measured at the same temperature and pressure. Obtain the equation for the reaction and name the gaseous product.

(4). When $15cm^3$ of a gaseous hydrocarbon was burnt in $100cm^3$ of Oxygen ,the resulting gaseous mixture occupied $70cm^3$ at room temperature and pressure. When the gaseous mixture was passed through, potassium hydroxide its volume decreased to $25cm^3$.

a. What volume of Oxygen was used during the reaction

b. Determine the molecular formula of the hydrocarbon

(5). Given the following reaction:

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

If $20cm^3$ of Hydrogen gas reacts with $10cm^3$ of oxygen gas, how much steam ($H_2O(9)$will be evolved?

More Lessons

Explore lessons in other subtopics

Gas Laws - Chemistry Notes Form 3

Organic Chemistry 1 - Chemistry Notes Form 3

Nitrogen and its Compounds - Chemistry Notes Form 3

Sulphur and its Compounds - Chemistry Notes Form 3

Chlorine and its Compounds - Chemistry Notes Form 3

STRAND 2.0: MATTER AND CHEMICAL REACTIONS

SUB-STRAND 2.3: HYDROCARBONS

Introduction

Hydrocarbons are important organic compounds found in fuels, cooking gas, petroleum products and many materials used in everyday life. They are also important raw materials in the manufacture of plastics, synthetic fibres, detergents, paints and other industrial products.

In Kenya, hydrocarbons are used in homes, schools, transport, agriculture, manufacturing and energy production. Petrol, diesel, kerosene, liquefied petroleum gas (LPG) and natural gas are examples of fuels that contain hydrocarbons.

The study of hydrocarbons helps learners understand the relationship between the structure of organic compounds, their properties, their uses and their effects on the environment.

1.0 MEANING AND CLASSIFICATION OF HYDROCARBONS

1.1 Definition of hydrocarbons

A **hydrocarbon** is an organic compound made up of only two elements: carbon and hydrogen.

- Carbon atoms form the backbone or chain of the hydrocarbon molecule.
- Hydrogen atoms attach to the carbon atoms.
- Hydrocarbons may have straight chains, branched chains or ring structures.
- They occur naturally in crude oil and natural gas.
- They are important sources of energy and raw materials for industries.

Examples of hydrocarbons:

- Methane – CH_4
- Ethane – C_2H_6
- Propane – C_3H_8
- Butane – C_4H_{10}
- Ethene – C_2H_4
- Ethyne – C_2H_2

1.2 Classification of hydrocarbons

Hydrocarbons are broadly classified into two main groups:

52. Saturated hydrocarbons.
53. Unsaturated hydrocarbons.

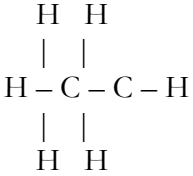
A. Saturated hydrocarbons

Saturated hydrocarbons are hydrocarbons in which carbon atoms are joined together by **single covalent bonds only**.

- They contain the maximum possible number of hydrogen atoms for their carbon skeleton.
- They are generally less reactive than unsaturated hydrocarbons.
- The main group of saturated hydrocarbons studied at this level is the alkanes.
- Examples include methane, ethane, propane and butane.

Example: Ethane, C_2H_6.

Structural representation:



The two carbon atoms are connected by one single bond.

B. Unsaturated hydrocarbons

Unsaturated hydrocarbons are hydrocarbons that contain at least one carbon-carbon double bond or triple bond.

They are divided into:

i. Alkenes

- Contain at least one carbon-carbon double bond (C=C).
- They are more reactive than alkanes because of the double bond.
- They undergo addition reactions.
- Examples include ethene (C_2H_4), propene (C_3H_6) and butene (C_4H_8).

ii. Alkynes

- Contain at least one carbon-carbon triple bond (C≡C).
- They undergo addition reactions.
- Examples include ethyne (C_2H_2), propyne (C_3H_4) and butyne (C_4H_6).

1.3 Comparison of saturated and unsaturated hydrocarbons

Feature	Saturated hydrocarbons	Unsaturated hydrocarbons
Carbon-carbon bonds	Single bonds only	At least one double or triple bond
Main groups	Alkanes	Alkenes and alkynes
General reactivity	Relatively less reactive	Generally more reactive
Typical reactions	Substitution and combustion	Addition, oxidation and combustion
Bromine water	Do not normally decolourise it under ordinary conditions	Usually decolourise it
Examples	Ethane, propane	Ethene, ethyne

Important: Decolourisation of bromine water is a common test for unsaturation. The test should be carried out under appropriate laboratory conditions and with proper safety precautions.

2.0 GENERAL FORMULAE OF HYDROCARBONS

A general formula represents the relationship between the number of carbon atoms and hydrogen atoms in a homologous series.

A **homologous series** is a family of organic compounds with:

- The same general formula.
- Similar chemical properties.
- A gradual change in physical properties.
- Successive members differing by a $–CH_2–$ unit.

2.1 General formula of alkanes

Alkanes have the general formula:

$$\boxed{C_nH_{2n+2}}$$

Where:

- C represents carbon.
- H represents hydrogen.
- n represents the number of carbon atoms.

Examples:

- If $n = 1$, hydrogen atoms = $2(1) + 2 = 4$, giving CH_4.
- If $n = 2$, hydrogen atoms = $2(2) + 2 = 6$, giving C_2H_6.
- If $n = 3$, hydrogen atoms = $2(3) + 2 = 8$, giving C_3H_8.

2.2 General formula of alkenes

For open-chain alkenes containing one double bond, the general formula is:

$$\boxed{C_nH_{2n}}$$

Examples:

- Ethene – C_2H_4
- Propene – C_3H_6
- Butene – C_4H_8

Note: The simplest alkene is ethene because a carbon-carbon double bond requires at least two carbon atoms.

2.3 General formula of alkynes

For open-chain alkynes containing one triple bond, the general formula is:

$$\boxed{C_nH_{2n-2}}$$

Examples:

- Ethyne – C_2H_2
- Propyne – C_3H_4
- Butyne – C_4H_6

2.4 Summary of the general formulae

Homologous series	Type of bond	General formula
Alkanes	Single bond	C_nH_{2n+2}
Alkenes	One double bond	C_nH_{2n}
Alkynes	One triple bond	C_nH_{2n-2}

These formulae apply to open-chain hydrocarbons with one relevant type of carbon-carbon bonding. Cyclic compounds and compounds with multiple double or triple bonds may have different formulae.

3.0 NOMENCLATURE OF HYDROCARBONS

3.1 Meaning of nomenclature

Nomenclature is the systematic method of naming chemical compounds according to internationally accepted rules.

The International Union of Pure and Applied Chemistry (IUPAC) provides standard rules for naming organic compounds.

3.2 Naming hydrocarbons according to the number of carbon atoms

The first part of the name indicates the number of carbon atoms in the longest continuous carbon chain.

Number of carbon atoms	Prefix	Example alkane

Number of carbon atoms	Prefix	Example alkane
1	Meth-	Methane
2	Eth-	Ethane
3	Prop-	Propane
4	But-	Butane
5	Pent-	Pentane
6	Hex-	Hexane

The ending indicates the type of carbon-carbon bond:

- **-ane** for alkanes.
- **-ene** for alkenes.
- **-yne** for alkynes.

Examples:

- Two carbon atoms with single bonds: ethane.
- Two carbon atoms with a double bond: ethene.
- Two carbon atoms with a triple bond: ethyne.

3.3 Naming alkanes

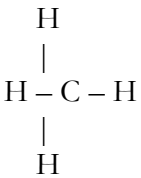
Alkanes are named by using the appropriate carbon prefix followed by the suffix **-ane**.

The first six alkanes are:

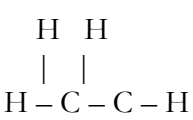
Number of carbon atoms	Name	Molecular formula
1	Methane	CH_4
2	Ethane	C_2H_6
3	Propane	C_3H_8
4	Butane	C_4H_{10}
5	Pentane	C_5H_{12}
6	Hexane	C_6H_{14}

Examples of structural formulae

Methane (CH_4)



Ethane (C_2H_6)



```
   |   |
   H   H
```

Propane (C_3H_8)

```
   H   H   H
   |   |   |
H – C – C – C – H
   |   |   |
   H   H   H
```

Butane (C_4H_{10})

```
   H   H   H   H
   |   |   |   |
H – C – C – C – C – H
   |   |   |   |
   H   H   H   H
```

Note: In the displayed structures, each carbon atom must have four covalent bonds. In a condensed structural formula, propane may be written as $CH_3CH_2CH_3$.

3.4 Naming alkenes

Alkenes contain at least one carbon-carbon double bond.

- Select the longest carbon chain containing the double bond.
- Number the chain from the end nearest the double bond.
- Use the appropriate prefix to show the number of carbon atoms.
- Use the suffix **-ene**.
- Indicate the position of the double bond when necessary.

Examples:

Name	Molecular formula	Condensed structural formula
Ethene	C_2H_4	$CH_2=CH_2$
Propene	C_3H_6	$CH_2=CHCH_3$
But-1-ene	C_4H_8	$CH_2=CHCH_2CH_3$
But-2-ene	C_4H_8	$CH_3CH=CHCH_3$
Pent-1-ene	C_5H_{10}	$CH_2=CHCH_2CH_2CH_3$
Pent-2-ene	C_5H_{10}	$CH_3CH=CHCH_2CH_3$
Hex-1-ene	C_6H_{12}	$CH_2=CHCH_2CH_2CH_2CH_3$
Hex-2-ene	C_6H_{12}	$CH_3CH=CHCH_2CH_2CH_3$
Hex-3-ene	C_6H_{12}	$CH_3CH_2CH=CHCH_2CH_3$

Example: But-1-ene

- But- means four carbon atoms.
- -ene means the compound contains a double bond.

- 1 indicates that the double bond starts at carbon 1.

Example: But-2-ene

- But- means four carbon atoms.
- -ene indicates a double bond.
- 2 indicates that the double bond starts at carbon 2.

3.5 Naming alkynes

Alkynes contain at least one carbon-carbon triple bond.

The naming procedure is similar to that of alkenes, but the suffix **-yne** is used.

Examples:

Name	Molecular formula	Condensed structural formula
Ethyne	C_2H_2	$HC{\equiv}CH$
Propyne	C_3H_4	$HC{\equiv}CCH_3$
But-1-yne	C_4H_6	$HC{\equiv}CCH_2CH_3$
But-2-yne	C_4H_6	$CH_3C{\equiv}CCH_3$
Pent-1-yne	C_5H_8	$HC{\equiv}CCH_2CH_2CH_3$
Pent-2-yne	C_5H_8	$CH_3C{\equiv}CCH_2CH_3$
Hex-1-yne	C_6H_{10}	$HC{\equiv}CCH_2CH_2CH_2CH_3$
Hex-2-yne	C_6H_{10}	$CH_3C{\equiv}CCH_2CH_2CH_3$
Hex-3-yne	C_6H_{10}	$CH_3CH_2C{\equiv}CCH_2CH_3$

3.6 Rules for naming simple hydrocarbons

1. Identify the longest continuous carbon chain.
2. Identify whether the compound is an alkane, alkene or alkyne.
3. Number the carbon chain from the end nearest the multiple bond in alkenes and alkynes.
4. Identify the position of the double or triple bond.
5. Use the correct prefix for the number of carbon atoms.
6. Use the correct suffix: -ane, -ene or -yne.
7. Include the position number where necessary.

Worked example

Name the compound:

$CH_3CH_2CH{=}CH_2$

Step 1: Count the carbon atoms. There are four.

Step 2: The compound contains a double bond, so it is an alkene.

Step 3: Number from the end nearest the double bond.

Step 4: The double bond begins at carbon 1.

Answer: **But-1-ene.**

4.0 ISOMERISM IN HYDROCARBONS

4.1 Definition of isomerism

Isomerism is the existence of two or more compounds that have the same molecular formula but different structural arrangements of atoms.

The compounds are called **isomers**.

4.2 Types of isomerism studied in hydrocarbons

At this level, learners mainly study structural isomerism, including:

- Chain isomerism.
- Position isomerism in unsaturated hydrocarbons.

4.3 Isomers of alkanes

Alkanes with four or more carbon atoms can form different carbon-chain arrangements.

A. Isomers of butane (C_4H_{10})

Butane has two structural isomers.

1. Butane (straight-chain butane)

Condensed formula:

$CH_3–CH_2–CH_2–CH_3$

- Contains four carbon atoms in one continuous chain.
- It is also called n-butane.

2. 2-methylpropane (branched-chain butane)

Condensed formula:

$CH_3–CH(CH_3)–CH_3$

- Contains a three-carbon main chain.
- Has a methyl branch on carbon 2.
- It is also called isobutane.

B. Isomers of pentane (C_5H_{12})

Pentane has three structural isomers.

1. Pentane

$CH_3–CH_2–CH_2–CH_2–CH_3$

- Has five carbon atoms in a continuous straight chain.
- Also called n-pentane.

2. 2-methylbutane

$CH_3–CH(CH_3)–CH_2–CH_3$

- Has a four-carbon main chain.

- Has one methyl group attached to carbon 2.
- Also called isopentane.

3. 2,2-dimethylpropane

$C(CH_3)_4$

- Has a three-carbon main chain.
- Has two methyl groups attached to carbon 2.
- Also called neopentane.

Important points about alkane isomers

- They have the same molecular formula.
- They have different structural formulae.
- They may have different boiling points and melting points.
- They generally have similar chemical properties because they belong to the same homologous series.

4.4 Isomers of alkenes

Alkenes can show isomerism because:

- The carbon chain can be arranged differently.
- The position of the double bond can change.
- Some alkenes also show geometrical isomerism, where the arrangement around the double bond differs.

A. Isomers of butene (C_4H_8)

Common structural isomers include:

1. But-1-ene

$CH_2=CH–CH_2–CH_3$

- Has four carbon atoms.
- The double bond begins at carbon 1.

2. But-2-ene

$CH_3–CH=CH–CH_3$

- Has four carbon atoms.
- The double bond begins at carbon 2.

3. 2-methylpropene

$CH_2=C(CH_3)_2$

- Has a branched carbon chain.
- Contains a double bond.

Geometrical isomerism in but-2-ene

But-2-ene can exist in two geometrical forms:

- **Cis-but-2-ene:** The two methyl groups are on the same side of the double bond.

- **Trans-but-2-ene:** The two methyl groups are on opposite sides of the double bond.

This occurs because rotation around the carbon-carbon double bond is restricted.

B. Isomers of pentene (C_5H_{10})

Common structural isomers include:

1. Pent-1-ene: $CH_2=CHCH_2CH_2CH_3$
2. Pent-2-ene: $CH_3CH=CHCH_2CH_3$
3. 2-methylbut-1-ene: $CH_2=C(CH_3)CH_2CH_3$
4. 3-methylbut-1-ene: $CH_2=CHCH(CH_3)CH_3$
5. 2-methylbut-2-ene: $CH_3C(CH_3)=CHCH_3$

Key point: Isomers have the same molecular formula but different structures. The difference in structure may affect their physical properties and chemical behaviour.

5.0 PREPARATION OF HYDROCARBONS

Hydrocarbons can be prepared using different chemical methods. The methods depend on whether the required hydrocarbon is saturated or unsaturated.

At this level, learners focus on the general preparation of ethane and ethene.

5.1 Preparation of ethane

Ethane is a saturated hydrocarbon with the molecular formula C_2H_6.

One laboratory method of preparing ethane is by heating sodium propanoate with soda lime.

Soda lime is a mixture of sodium hydroxide and calcium oxide.

The reaction removes one carbon atom from the sodium carboxylate salt.

Chemical equation:

$$CH_3CH_2COONa + NaOH \xrightarrow{CaO,\ heat} C_2H_6 + Na_2CO_3$$

Products:

- Ethane gas (C_2H_6).
- Sodium carbonate (Na_2CO_3).

Explanation of the method

1. Sodium propanoate is mixed with soda lime.
2. The mixture is heated in a suitable hard-glass apparatus.
3. Ethane gas is produced.
4. The gas is collected using an appropriate method, taking its low solubility in water into account.
5. The gas may be tested for combustion.

Important: This is a decarboxylation reaction because carbon dioxide is removed from the carboxylate-derived compound.

Another method of preparing ethane is by hydrogenation of ethene:

$$CH_2 = CH_2 + H_2 \xrightarrow{Ni,\ heat} CH_3CH_3$$

- Ethene reacts with hydrogen.
- A nickel catalyst is used.
- The double bond is converted into a single bond.
- Ethane is formed.

5.2 Preparation of ethene

Ethene is an unsaturated hydrocarbon with molecular formula C_2H_4.

A common laboratory method is dehydration of ethanol.

Dehydration is the removal of water from a compound.

Chemical equation:

$$CH_3CH_2OH \xrightarrow[\text{heat}]{\text{concentrated } H_2SO_4} CH_2 = CH_2 + H_2O$$

Products:

- Ethene gas.
- Water.

Explanation of the method

1. Ethanol is placed in a suitable reaction flask.
2. A dehydrating agent, such as concentrated sulphuric acid, is used.
3. The mixture is heated under controlled laboratory conditions.
4. Water is removed from ethanol.
5. Ethene gas is produced.
6. The gas is collected using an appropriate method.

Another laboratory method uses aluminium oxide as a catalyst to dehydrate ethanol at an elevated temperature.

$$CH_3CH_2OH \xrightarrow{Al_2O_3,\ heat} CH_2 = CH_2 + H_2O$$

5.3 Comparison between preparation of ethane and ethene

Feature	Ethane	Ethene
Molecular formula	C_2H_6	C_2H_4
Type	Saturated	Unsaturated
Laboratory preparation	Heating sodium propanoate with soda lime	Dehydration of ethanol
Main process	Decarboxylation	Dehydration
Carbon-carbon bond	Single	Double

5.4 Safety precautions during preparation

- Wear safety goggles and laboratory coats.
- Use small quantities of chemicals.
- Handle concentrated acids and alkalis carefully.

- Heat apparatus gently and as directed.
- Keep flammable gases away from naked flames during preparation.
- Ensure the apparatus is properly fitted to prevent gas leakage.
- Never inhale gases directly.
- Carry out the experiment under teacher supervision and in a well-ventilated laboratory.

6.0 PHYSICAL PROPERTIES OF HYDROCARBONS

Physical properties are characteristics that can be observed or measured without changing the chemical composition of a substance.

The physical properties of hydrocarbons include:

1. Colour.
2. Odour.
3. Density.
4. Melting point.
5. Boiling point.
6. Solubility.

6.1 Colour

- Many simple hydrocarbons are colourless.
- Methane, ethane and ethene are colourless gases.
- Many purified liquid alkanes are also colourless.
- Crude oil is usually dark brown or black because it contains a mixture of many substances and impurities.

6.2 Odour

- Many simple pure hydrocarbons have little or no noticeable odour.
- Some petroleum products have a characteristic smell.
- Natural gas is naturally odourless; an odorant is added to commercial supplies to help detect leaks.
- The smell of petrol and kerosene is associated with mixtures of volatile compounds.

Safety: Learners should never smell hydrocarbons directly in the laboratory.

6.3 Density

Density is the mass of a substance per unit volume.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

- Many hydrocarbons are less dense than water.
- Most common liquid hydrocarbons float on water.
- Hydrocarbon gases such as methane and ethane have densities lower than that of air under ordinary conditions.
- Density generally increases with increasing molecular size within a homologous series of liquid hydrocarbons.

Example: Petrol and kerosene generally float on water because they are less dense than water.

6.4 Melting point

The melting point is the temperature at which a solid changes into a liquid at a given pressure.

- Simple hydrocarbons have relatively low melting points compared with many ionic compounds.
- Melting points generally vary with molecular size and molecular shape.
- Branching can affect how well molecules pack together in the solid state.

6.5 Boiling point

The boiling point is the temperature at which a liquid changes into a gas throughout the liquid at a given pressure.

- Small hydrocarbons have low boiling points.
- Larger hydrocarbons generally have higher boiling points.
- This is because larger molecules have stronger intermolecular attractions.
- Branching usually lowers the boiling point compared with a similar straight-chain isomer, although the exact trend depends on molecular structure.

Example: Methane, ethane and propane are gases at room temperature, while many larger alkanes are liquids or solids.

6.6 Solubility

Solubility is the ability of a substance to dissolve in a solvent.

- Hydrocarbons are generally insoluble or only slightly soluble in water.
- They dissolve readily in many non-polar organic solvents.
- Water is polar, whereas most hydrocarbons are non-polar.
- Hydrocarbons and water therefore do not mix easily.

Example: When petrol is mixed with water, two separate layers form.

6.7 General trend in physical properties of alkanes

As the number of carbon atoms increases:

- Molecular mass increases.
- Boiling point generally increases.
- Melting point generally increases overall, though the trend is not perfectly regular.
- Density of liquid members generally increases.
- Volatility generally decreases.
- Viscosity generally increases.

6.8 Summary of physical properties

Property	General observation
Colour	Simple pure hydrocarbons are usually colourless
Odour	Many pure simple hydrocarbons have little or no smell
Density	Many liquid hydrocarbons are less dense than water

Property	General observation
Melting point	Generally increases with molecular size, with irregularities
Boiling point	Generally increases with molecular size
Solubility in water	Generally insoluble or slightly soluble
Solubility in organic solvents	Usually soluble in non-polar solvents

7.0 CHEMICAL PROPERTIES OF ALKANES

Chemical properties describe how substances behave when they take part in chemical reactions and form new substances.

Alkanes are saturated hydrocarbons. They are relatively unreactive under ordinary conditions because they contain strong carbon-carbon and carbon-hydrogen single bonds.

The important chemical reactions of alkanes include:

1. Combustion.
2. Substitution reactions.
3. Cracking.

7.1 Combustion of alkanes

Combustion is a chemical reaction in which a substance reacts with oxygen, releasing energy in the form of heat and sometimes light.

Alkanes are used as fuels because they release energy during combustion.

A. Complete combustion

Complete combustion occurs when a hydrocarbon burns in an adequate supply of oxygen.

The products are:

- Carbon dioxide.
- Water.
- Energy.

Example: Complete combustion of methane

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Example: Complete combustion of ethane

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

Characteristics of complete combustion:

- Usually produces a blue flame for simple gaseous fuels under suitable conditions.
- Releases a large amount of energy.
- Produces carbon dioxide and water.
- Does not produce soot when combustion is truly complete.

B. Incomplete combustion

Incomplete combustion occurs when a hydrocarbon burns in an insufficient supply of oxygen.

Possible products include:

- Carbon monoxide.
- Carbon (soot).
- Water.

Example: Formation of carbon monoxide

$$2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O$$

Example: Formation of carbon (soot)

$$CH_4 + O_2 \rightarrow C + 2H_2O$$

Characteristics of incomplete combustion:

- May produce a yellow or smoky flame.
- May produce soot.
- Releases less energy than complete combustion of the same amount of fuel.
- Can produce poisonous carbon monoxide.

C. Comparison between complete and incomplete combustion

Complete combustion	Incomplete combustion
Occurs when oxygen is sufficient	Occurs when oxygen is insufficient
Produces carbon dioxide and water	May produce carbon monoxide or carbon and water
Releases more energy per amount of fuel completely burned	Releases less energy
Usually produces a clean blue flame	May produce a yellow smoky flame
Produces little or no soot	May produce soot

Importance of combustion

- Provides heat for cooking.
- Produces energy for transport.
- Provides heat in industrial processes.
- Generates electricity in some power stations.
- Supports heating in homes and institutions.

7.2 Substitution reactions of alkanes

A **substitution reaction** is a chemical reaction in which an atom or group of atoms in a molecule is replaced by another atom or group.

Alkanes undergo substitution reactions with halogens such as chlorine in the presence of ultraviolet light.

Example: Reaction between methane and chlorine

$$CH_4 + Cl_2 \xrightarrow{UV} CH_3Cl + HCl$$

Products:

- Chloromethane (CH_3Cl).

- Hydrogen chloride (HCl).

One hydrogen atom in methane is replaced by a chlorine atom.

Example: Reaction between ethane and chlorine

$$C_2H_6 + Cl_2 \xrightarrow{UV} C_2H_5Cl + HCl$$

Products:

- Chloroethane.
- Hydrogen chloride.

Explanation

4. Chlorine molecules are exposed to ultraviolet light.
5. The chlorine molecules split into highly reactive chlorine radicals.
6. A hydrogen atom in the alkane is replaced by chlorine.
7. A hydrogen chloride molecule is also formed.

Further substitution: More hydrogen atoms may be replaced if excess chlorine is present and the reaction continues.

Uses and significance of substitution reactions

- They are used in the manufacture of some organic chemicals.
- They help produce halogenated compounds used as industrial raw materials.
- They demonstrate the chemical behaviour of saturated hydrocarbons.

Safety note: Chlorine is toxic, and ultraviolet radiation can be harmful. This reaction should only be demonstrated using suitable controlled procedures by a qualified teacher.

7.3 Cracking of alkanes

Cracking is the process of breaking large hydrocarbon molecules into smaller, more useful hydrocarbon molecules by heating, often in the presence of a catalyst.

Cracking is important in the petroleum industry because crude oil contains large quantities of heavier hydrocarbons, while there is high demand for lighter fuels and chemical feedstocks.

Reasons for cracking

- To produce shorter-chain hydrocarbons.
- To increase the supply of petrol-range components.
- To produce alkenes used in making plastics.
- To convert less useful heavy fractions into more valuable products.
- To meet the demand for fuels and industrial raw materials.

Types of cracking

A. Thermal cracking

- Uses high temperatures.
- May use high pressure.
- Breaks large molecules into smaller molecules.

B. Catalytic cracking

- Uses a catalyst, commonly a zeolite-based catalyst.
- Usually operates at lower temperatures than thermal cracking.
- Produces useful smaller hydrocarbons, including branched alkanes and alkenes.

Example of cracking

A large alkane can break down to form a smaller alkane and an alkene.

$$C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$$

Decane produces octane and ethene.

Another example:

$$C_{12}H_{26} \rightarrow C_8H_{18} + C_4H_8$$

Dodecane produces octane and butene.

Note: These equations illustrate possible balanced cracking products. Actual cracking produces a mixture of different compounds.

Importance of cracking

- Produces petrol components.
- Produces ethene and propene for plastic manufacture.
- Makes better use of heavy petroleum fractions.
- Provides raw materials for chemical industries.
- Helps meet demand for lighter hydrocarbons.

8.0 CHEMICAL PROPERTIES OF ALKENES

Alkenes are unsaturated hydrocarbons containing at least one carbon-carbon double bond.

The double bond makes alkenes more reactive than alkanes.

The main chemical reactions of ethene and other simple alkenes include:

1. Addition reactions.
2. Polymerisation.
3. Oxidation reactions.
4. Combustion.

8.1 Addition reactions

An **addition reaction** is a reaction in which atoms or groups of atoms are added across a carbon-carbon double bond to form a single product.

The double bond opens up and each carbon atom forms an additional bond.

A. Addition of hydrogen (hydrogenation)

Hydrogen adds across the double bond of an alkene to form an alkane.

$$CH_2 = CH_2 + H_2 \xrightarrow{\text{Ni, heat}} CH_3 - CH_3$$

Ethene reacts with hydrogen to form ethane.

Uses:

- Hardening of some vegetable oils in food processing.
- Manufacture of saturated organic compounds.
- Production of alkanes from alkenes.

Note: Industrial hydrogenation conditions depend on the particular process and catalyst.

B. Addition of bromine

Ethene reacts with bromine to form 1,2-dibromoethane.

$$CH_2 = CH_2 + Br_2 \rightarrow CH_2Br - CH_2Br$$

Observations:

- Orange-brown bromine water loses its colour.
- A colourless product is formed.

Importance: This reaction is used as a test for unsaturation.

C. Addition of hydrogen halides

Hydrogen halides such as hydrogen chloride and hydrogen bromide can add across the double bond.

Example:

$$CH_2 = CH_2 + HCl \rightarrow CH_3CH_2Cl$$

Ethene forms chloroethane.

D. Addition of water (hydration)

Water adds to ethene in the presence of a suitable acid catalyst under controlled conditions.

$$CH_2 = CH_2 + H_2O \xrightarrow{\text{acid catalyst}} CH_3CH_2OH$$

Ethene forms ethanol.

Importance: This is an industrial method of manufacturing ethanol.

8.2 Polymerisation of alkenes

Polymerisation is a chemical process in which many small molecules called monomers join together to form a large molecule called a polymer.

Alkenes undergo addition polymerisation because their double bonds can open up and link many monomer molecules together.

Example: Polymerisation of ethene

Ethene molecules join together to form poly(ethene), also known as polyethylene.

$$n(CH_2 = CH_2) \rightarrow [-CH_2 - CH_2 -]_n$$

Where:

- Ethene is the monomer.
- Poly(ethene) is the polymer.
- n represents a large number of ethene molecules.

Uses of poly(ethene)

- Plastic carrier bags.
- Packaging films.
- Water containers.
- Plastic bottles and containers.
- Insulation around electrical cables.
- Household plastic items.
- Pipes and fittings.

Other examples of alkene polymerisation

Propene polymerises to form poly(propene):

$$n(CH_2 = CHCH_3) \rightarrow [-CH_2 - CH(CH_3) -]_n$$

Uses of poly(propene):

- Woven sacks.
- Ropes.
- Household containers.
- Plastic chairs.
- Food packaging.
- Textile fibres.

Advantages of polymers

- They are generally lightweight.
- Many are strong and durable.
- They resist corrosion.
- They can be moulded into different shapes.
- They are useful in packaging and construction.

Environmental challenges of polymers

- Many plastics do not biodegrade readily.
- Plastic waste can block drainage systems.
- Plastics may pollute rivers, lakes and oceans.
- Animals may swallow plastic materials.
- Burning plastics can release harmful substances.
- Microplastics can contaminate the environment.

Environmental responsibility: Learners should practise reducing unnecessary plastic use, reusing materials, sorting waste and supporting safe recycling.

8.3 Oxidation of alkenes

Oxidation is a chemical process involving the addition of oxygen, removal of hydrogen or an increase in oxidation state.

Alkenes can be oxidised using suitable oxidising agents.

A. Oxidation using cold, dilute potassium manganate(VII)

Cold, dilute potassium manganate(VII) solution is purple.

When an alkene reacts with it under suitable conditions:

- The purple colour disappears.
- A diol may be formed.

Example: Oxidation of ethene to ethane-1,2-diol.

$$CH_2 = CH_2 + [O] + H_2O \rightarrow HOCH_2CH_2OH$$

The product is ethane-1,2-diol.

Observation: Purple potassium manganate(VII) solution becomes decolourised under the appropriate test conditions.

B. Oxidation by combustion

Alkenes also burn in oxygen.

Complete combustion of ethene:

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$

Incomplete combustion may produce carbon monoxide or soot.

8.4 Comparison of chemical properties of alkanes and alkenes

Reaction	Alkanes	Alkenes
Combustion	Yes	Yes
Substitution with chlorine	Yes, under suitable conditions	Not the characteristic reaction
Addition of hydrogen	No ordinary addition across a carbon-carbon single bond	Yes
Addition of bromine	No rapid decolourisation under ordinary test conditions	Yes
Polymerisation	Not a typical reaction	Yes, for suitable alkenes
Oxidation	Combustion and other oxidation processes	Combustion and oxidation at the double bond

9.0 USES OF HYDROCARBONS

Hydrocarbons are important in homes, transport, agriculture, manufacturing and other economic activities.

Their uses depend on their molecular structures, physical properties and chemical properties.

9.1 Uses of alkanes

Alkanes are widely used as fuels and as raw materials in industries.

Alkane	Uses
Methane	Cooking fuel, heating and electricity generation

Alkane	Uses
Ethane	Raw material for producing ethene
Propane	LPG for cooking and heating
Butane	LPG mixtures, portable gas burners and lighters
Pentane	Industrial solvents and manufacture of expanded polystyrene
Hexane	Industrial solvent and extraction of vegetable oils

Important applications

A. Cooking and heating

- Propane and butane are major components of LPG.
- LPG is used in homes, schools, hotels and institutions.
- It provides heat for cooking and water heating.

B. Transport

- Petrol and diesel contain mixtures of hydrocarbons.
- These fuels power many vehicles and machines.
- Kerosene is used in some aviation and heating applications.

C. Industrial energy

- Hydrocarbon fuels provide heat in industrial furnaces.
- Some are used to generate electricity.
- They are used in boilers and industrial heating systems.

D. Manufacture of chemicals

- Ethane is used to manufacture ethene.
- Some alkanes are used as solvents.
- Hydrocarbons provide raw materials for the manufacture of plastics and other organic products.

9.2 Uses of alkenes

Alkenes are important industrial raw materials because of their ability to undergo addition reactions and polymerisation.

Alkene	Uses
Ethene	Manufacture of poly(ethene), ethanol and other chemicals
Propene	Manufacture of poly(propene) and other industrial chemicals
Butenes	Manufacture of other chemicals and polymers
Higher alkenes	Manufacture of detergents and other chemical products

Important applications

A. Manufacture of plastics

- Ethene is used to manufacture poly(ethene).
- Propene is used to manufacture poly(propene).
- These polymers are used in packaging, containers and household items.

B. Manufacture of ethanol

Ethene reacts with steam to form ethanol under suitable industrial conditions.

C. Fruit ripening

Ethene is a natural plant hormone involved in fruit ripening.

- It promotes ripening in fruits such as bananas, mangoes and avocados.
- It is used commercially to control fruit ripening.
- Controlled ripening helps improve the handling and marketing of fruits.

D. Manufacture of other chemicals

Alkenes are used to produce alcohols, solvents, detergents and other industrial materials.

9.3 Uses of alkynes

The most familiar alkyne is ethyne, commonly called acetylene.

Alkyne	Uses
Ethyne	Oxy-acetylene welding and metal cutting
Propyne	Chemical manufacturing and fuel mixtures in specialised applications
Other alkynes	Manufacture of specialised organic chemicals

Uses of ethyne

- Used in oxy-acetylene flames for welding metals.
- Used for cutting metals.
- Used as a raw material in some chemical manufacturing processes.
- Historically used in carbide lamps.

Oxy-acetylene welding: Ethyne burns in oxygen to produce a very hot flame that can melt metals.

Safety: Ethyne is highly flammable. It must be handled using approved equipment and procedures.

9.4 Comparison of the uses of the three groups

Group	Main uses
Alkanes	Fuels, solvents and chemical raw materials
Alkenes	Manufacture of plastics, ethanol and other chemicals; fruit ripening
Alkynes	Welding, metal cutting and chemical manufacture

10.0 FRACTIONAL DISTILLATION OF CRUDE OIL

10.1 Meaning of crude oil

Crude oil is a naturally occurring mixture of hydrocarbons found underground or beneath the seabed.

- It contains hydrocarbons of different molecular sizes.
- It is formed from ancient organic matter over geological time.
- It is a non-renewable natural resource.
- It is processed in petroleum refineries to obtain useful products.

Crude oil is not a single pure substance. It is a mixture of many hydrocarbons.

10.2 Meaning of fractional distillation

Fractional distillation is a separation method used to separate a mixture of liquids with different boiling points.

Crude oil is separated into fractions according to differences in boiling points.

10.3 How fractional distillation is carried out

5. Crude oil is first cleaned to remove water, salts and other impurities.
6. It is heated in a furnace to produce a mixture of vapours and liquids.
7. The heated mixture enters a fractionating column.
8. The column is hot at the bottom and cooler towards the top.
9. Vapours rise through the column.
10. Different hydrocarbons condense at different heights depending on their boiling points.
11. Fractions are collected at different levels.
12. Some heavy fractions may undergo further processing, including cracking.

10.4 Fractions obtained from crude oil

Fraction	General uses
Refinery gases	LPG for cooking and heating
Petrol/gasoline	Fuel for petrol engines
Naphtha	Chemical industry feedstock and petrol blending
Kerosene	Jet fuel components and heating
Diesel/gas oil	Fuel for diesel engines
Fuel oil	Industrial heating and some marine applications
Lubricating oil	Lubrication of machines and engines
Bitumen/residue	Road surfacing and roofing

10.5 Trends in the fractions

As the size of hydrocarbon molecules increases:

- Boiling points generally increase.
- Viscosity generally increases.
- Volatility decreases.
- Fractions become less easily ignited.

- The molecules become heavier.

10.6 Importance of fractional distillation

- Produces fuels for transport.
- Provides fuels for cooking and heating.
- Supplies raw materials for chemical industries.
- Produces lubricants used in machines.
- Provides bitumen for road construction.
- Supports employment and economic activities.

10.7 Environmental challenges associated with petroleum

- Oil spills can pollute water and soil.
- Refinery emissions can contribute to air pollution.
- Petroleum extraction may disturb habitats.
- Burning petroleum fuels releases carbon dioxide.
- Incomplete combustion may release carbon monoxide and soot.
- Petroleum products may contaminate groundwater if improperly stored or disposed of.

11.0 EFFECTS OF COMBUSTION OF FUELS ON ECOSYSTEMS

Combustion of hydrocarbon fuels provides energy but can also cause environmental and health problems.

11.1 Carbon dioxide and climate change

Complete combustion of hydrocarbons produces carbon dioxide.

Carbon dioxide is a greenhouse gas.

Greenhouse gases are gases that absorb and re-emit infrared radiation, contributing to the warming of the Earth's atmosphere.

Effects of increased carbon dioxide:

- Increased average global temperatures.
- Changes in rainfall patterns.
- More frequent or intense heatwaves.
- Melting of glaciers and ice.
- Rising sea levels.
- Changes in habitats and ecosystems.
- Increased pressure on agriculture and water resources.

Kenyan context

Climate change can affect:

- Agricultural production in the Rift Valley and other farming regions.

- Water availability in arid and semi-arid areas.
- Pastoral communities in northern Kenya.
- Biodiversity in forests and national parks.
- Coastal ecosystems and communities.

11.2 Carbon monoxide poisoning

Carbon monoxide is produced during incomplete combustion.

- It is colourless.
- It is odourless.
- It is poisonous.
- It reduces the ability of blood to transport oxygen.
- It can cause headaches, dizziness, unconsciousness and death.

Prevention

- Ensure adequate ventilation.
- Maintain cooking and heating appliances.
- Avoid using charcoal stoves or generators in enclosed rooms.
- Never run a vehicle engine in a closed garage.
- Use approved carbon monoxide detectors where appropriate.

11.3 Soot and particulate matter

Incomplete combustion may release soot and other fine particles.

Effects:

- Irritation of the respiratory system.
- Worsening of asthma and other respiratory conditions.
- Reduced visibility.
- Deposition on leaves and buildings.
- Contribution to air pollution.

11.4 Sulphur dioxide

Some petroleum fuels contain sulphur impurities.

When sulphur-containing fuels burn, sulphur dioxide may be produced.

$$S + O_2 \rightarrow SO_2$$

Effects of sulphur dioxide:

- Irritates the respiratory system.
- Contributes to acid rain.
- Damages vegetation.
- Can acidify water and soil.

- May corrode buildings and monuments.

11.5 Nitrogen oxides

At high combustion temperatures, nitrogen and oxygen in the air can react to form nitrogen oxides.

Effects:

- Contribute to smog formation.
- Irritate the respiratory system.
- Contribute to acid rain.
- Affect plant growth and ecosystem health.

11.6 Oil spills and fuel leakages

Oil spills may occur during:

- Petroleum transportation.
- Storage.
- Extraction.
- Refining.
- Accidental leakage from vehicles and machinery.

Effects:

- Contamination of rivers, lakes and oceans.
- Death of aquatic organisms.
- Damage to habitats.
- Contamination of soil.
- Reduced water quality.
- Economic losses to fishing and tourism communities.

11.7 Summary of environmental effects

Pollutant or activity	Environmental effect
Carbon dioxide	Contributes to global warming
Carbon monoxide	Poisonous to humans and animals
Soot/particulate matter	Causes air pollution and respiratory problems
Sulphur dioxide	Contributes to acid rain
Nitrogen oxides	Contribute to smog and acid rain
Oil spills	Contaminate soil and water
Plastic waste	Pollutes land and aquatic ecosystems

12.0 MITIGATION MEASURES FOR ENVIRONMENTAL PROTECTION

Mitigation refers to actions taken to reduce or prevent the harmful effects of human activities on the environment.

12.1 Use of cleaner energy sources

- Use solar energy where practical.
- Promote wind energy and geothermal energy.
- Support the use of clean electricity for cooking and transport.
- Encourage efficient and cleaner energy technologies.
- Reduce unnecessary dependence on fossil fuels.

Kenya has significant renewable energy resources, including geothermal, wind, hydroelectric and solar energy.

12.2 Improving fuel efficiency

- Maintain vehicles regularly.
- Use fuel-efficient vehicles.
- Avoid unnecessary idling of vehicle engines.
- Use public transport where practical.
- Encourage walking and cycling for short distances.
- Use energy-efficient cooking appliances.

12.3 Controlling industrial emissions

- Install suitable emission-control equipment.
- Use cleaner production technologies.
- Monitor industrial emissions.
- Maintain industrial machinery.
- Apply environmental standards and regulations.
- Ensure proper handling and storage of petroleum products.

12.4 Preventing oil pollution

- Inspect petroleum storage tanks regularly.
- Maintain pipelines.
- Use safe transportation methods.
- Respond quickly to oil spills.
- Dispose of used oils appropriately.
- Avoid pouring oil into drains, rivers or the soil.

12.5 Reducing plastic pollution

- Reduce unnecessary single-use plastics.
- Reuse suitable plastic materials.
- Sort waste at source.
- Support recycling initiatives.

- Use reusable bags and containers.
- Participate in community clean-up activities.

12.6 Planting and protecting trees

- Plant indigenous trees.
- Protect forests and wetlands.
- Restore degraded land.
- Prevent unnecessary cutting of trees.
- Participate in school and community tree-planting programmes.

Trees absorb carbon dioxide during photosynthesis and provide habitats for many organisms.

12.7 Environmental education

- Educate communities about air pollution.
- Promote responsible energy use.
- Organise school environmental clubs.
- Encourage proper waste disposal.
- Conduct awareness campaigns.
- Promote sustainable lifestyles.

13.0 CARBON CREDITS AND ENVIRONMENTAL CONSERVATION IN KENYA

13.1 Meaning of carbon credits

A **carbon credit** is a tradable unit representing the reduction, removal or avoidance of one metric tonne of carbon dioxide equivalent (CO_2e), under an applicable carbon-crediting system.

Carbon credits are used in systems that encourage organisations and individuals to support activities that reduce greenhouse gas emissions or remove carbon from the atmosphere.

13.2 How carbon credits work

1. A project is developed to reduce greenhouse gas emissions or remove carbon dioxide.
2. The project follows an approved carbon-crediting methodology.
3. Its climate benefits are measured and monitored.
4. The results are independently verified according to the applicable standard.
5. Credits may be issued if the project meets the requirements.
6. The credits may be purchased or used by organisations to support their climate commitments.

Example: A project that restores degraded forests may remove carbon dioxide from the atmosphere as trees grow. If the project meets the required standards, it may qualify to generate carbon credits.

13.3 Examples of activities that may generate carbon credits

- Reforestation and forest restoration.
- Protection of existing forests.

- Renewable energy projects.
- Improved clean cooking technologies.
- Methane capture from waste.
- Restoration of degraded land.
- Some improved agricultural practices.

13.4 How carbon credits contribute to environmental conservation in Kenya

- Encourage tree planting and forest conservation.
- Support renewable energy development.
- Promote cleaner cooking technologies.
- Create incentives for sustainable land management.
- Support community conservation projects.
- Encourage investment in low-carbon development.
- May provide income and livelihood opportunities to participating communities.

13.5 Challenges associated with carbon credits

- Some projects may be difficult to monitor.
- Measuring carbon reductions accurately can be expensive.
- Communities may not receive fair benefits if agreements are poorly designed.
- Projects may have negative effects on local land rights if communities are excluded.
- Credits must represent genuine and measurable climate benefits.
- Projects should avoid double counting of the same emission reduction.

13.6 Responsible carbon-credit projects

Good carbon-credit projects should:

- Respect community land and resource rights.
- Involve local communities in decision-making.
- Provide transparent benefit-sharing arrangements.
- Protect biodiversity.
- Demonstrate real climate benefits.
- Be independently monitored and verified.
- Follow applicable Kenyan laws and regulations.

CBE discussion activity: In groups, discuss how a tree-planting project in your county could support environmental conservation and community livelihoods. Identify possible benefits and challenges.

14.0 SAFE HANDLING OF HYDROCARBONS

Hydrocarbons are useful but many are flammable. Some are harmful when inhaled or when they come into contact with the skin.

14.1 General safety precautions

1. Keep hydrocarbons away from naked flames and sparks.
2. Work in a well-ventilated area.
3. Wear protective clothing, gloves and safety goggles as required.
4. Avoid inhaling vapours.
5. Never taste laboratory chemicals.
6. Do not pour hydrocarbons into sinks or drains.
7. Keep containers tightly closed.
8. Store flammable liquids in approved containers.
9. Label all chemical containers clearly.
10. Follow teacher instructions during experiments.

14.2 Safety in homes and schools

- Turn off LPG cylinders when not in use.
- Check for gas leaks using safe approved methods.
- Never use a naked flame to check for a gas leak.
- Keep cooking gas cylinders away from excessive heat.
- Ensure adequate ventilation when using fuel-burning appliances.
- Report damaged gas equipment immediately.
- Store petrol and other fuels safely and away from children.

14.3 What to do in case of a suspected gas leak

- Do not light matches or operate electrical switches.
- Avoid creating sparks.
- If safe to do so, turn off the gas supply.
- Open doors and windows to ventilate the area if it is safe.
- Move people away from the affected area.
- Contact the appropriate emergency service or qualified technician from a safe location.

15.0 PRACTICAL ACTIVITIES AND INVESTIGATIONS

These activities help learners develop scientific inquiry skills through observation, experimentation, recording and interpretation.

Activity 1: Comparing saturated and unsaturated hydrocarbons

Aim: To investigate how an alkane and an alkene behave with bromine water.

Materials:

- Suitable alkane sample.
- Suitable alkene sample.
- Bromine water.
- Test tubes.
- Droppers.
- Safety goggles.
- Gloves.

Procedure:

11. Place a small amount of the alkane sample in a test tube.
12. Add a small quantity of bromine water.
13. Shake gently under suitable laboratory conditions.
14. Record the observation.
15. Repeat using the alkene sample.
16. Compare the observations.

Expected observations:

Sample	Observation
Alkane	Bromine water normally retains its orange-brown colour under ordinary test conditions
Alkene	Bromine water is decolourised

Conclusion: The alkene reacts with bromine by addition across its double bond, while the alkane does not normally react rapidly under ordinary test conditions.

Safety: Bromine is hazardous. This activity should only be performed using an approved microscale procedure under teacher supervision, with suitable protective equipment and ventilation. Where direct handling is unsuitable, use a teacher demonstration or a safer approved alternative.

Activity 2: Investigating solubility of hydrocarbons

Aim: To investigate the solubility of a hydrocarbon in water.

Materials:

- Small quantity of a suitable hydrocarbon.
- Water.
- Stoppered test tube.
- Safety goggles.

Procedure:

1. Place a small amount of water in a test tube.
2. Add a small quantity of the hydrocarbon.
3. Close the test tube using a suitable stopper.

4. Shake gently.
5. Allow the mixture to stand.
6. Observe the layers formed.

Observation:

- Two separate layers form.
- The hydrocarbon layer is usually above the water layer because many liquid hydrocarbons are less dense than water.

Conclusion: Hydrocarbons are generally insoluble in water.

Safety: Use only teacher-approved, low-risk samples and avoid volatile or highly flammable liquids in learner handling activities.

Activity 3: Investigating combustion

Aim: To observe the combustion of a hydrocarbon fuel.

Materials:

- Teacher-approved fuel burner.
- Heat-resistant mat.
- Safety goggles.
- Suitable laboratory equipment.

Procedure:

1. Set up the burner according to laboratory instructions.
2. Ensure that the air supply is adequate.
3. Ignite the fuel safely.
4. Observe the flame.
5. Adjust the air supply only under teacher direction.
6. Compare the appearance of the flames.

Observation:

- Adequate air supply usually produces a cleaner blue flame.
- Restricted air supply may produce a yellow, smoky flame.

Conclusion: The availability of oxygen affects the completeness of combustion.

Safety: This activity must be conducted by or under the direct supervision of a teacher. Do not deliberately expose learners to carbon monoxide or soot.

Activity 4: Modelling polymerisation

Aim: To demonstrate how monomers join to form polymers.

Materials:

- Paper strips or reusable modelling materials.
- Scissors.
- Markers.

Procedure:

1. Represent one ethene molecule using a model.
2. Show how the double bond opens.
3. Join several ethene units together.
4. Identify the repeating unit.
5. Draw the resulting polymer chain.

Conclusion: Many small ethene molecules join together to form a large polymer called poly(ethene).

Activity 5: Environmental conservation project

Aim: To promote environmental conservation in the local community.

Suggested activities:

- Plant indigenous trees.
- Organise a school clean-up.
- Separate waste materials.
- Conduct a campaign against careless burning of waste.
- Educate community members about fuel efficiency.
- Promote responsible disposal of used oils and plastics.

Evidence of learning:

- Photographs of the activity.
- A written report.
- Records of participation.
- A reflection on the environmental benefits.

16.0 KEY TERMS AND DEFINITIONS

Term	Meaning
Hydrocarbon	Organic compound containing only carbon and hydrogen
Saturated hydrocarbon	Hydrocarbon with carbon-carbon single bonds only
Unsaturated hydrocarbon	Hydrocarbon containing at least one carbon-carbon double or triple bond
Alkane	Saturated hydrocarbon with general formula C_nH_{2n+2} for open-chain members
Alkene	Hydrocarbon containing a carbon-carbon double bond
Alkyne	Hydrocarbon containing a carbon-carbon triple bond
Homologous series	Family of organic compounds with the same general formula and similar chemical properties
Isomerism	Existence of compounds with the same molecular formula but different structural arrangements
IUPAC	International Union of Pure and Applied Chemistry
Combustion	Reaction of a substance with oxygen, releasing energy
Substitution	Replacement of an atom or group in a molecule by another atom or group
Cracking	Breaking large hydrocarbon molecules into smaller

	molecules
Addition reaction	Reaction in which atoms or groups add across a multiple bond
Polymerisation	Joining many monomers to form a polymer
Monomer	Small molecule that joins with other similar molecules to form a polymer
Polymer	Large molecule made from repeating smaller units
Oxidation	Chemical process involving electron loss, oxygen addition, hydrogen removal or an increase in oxidation state
Fractional distillation	Separation of liquids based on differences in boiling points
Crude oil	Naturally occurring mixture of hydrocarbons
Density	Mass per unit volume
Solubility	Ability of a substance to dissolve in a solvent
Carbon credit	Tradable unit representing one metric tonne of carbon dioxide equivalent under a carbon-crediting system
Mitigation	Actions taken to reduce or prevent harmful environmental effects

REVISION QUESTIONS

SUB-STRAND 2.3: HYDROCARBONS

SECTION A: MULTIPLE-CHOICE QUESTIONS (30 MARKS)

Instructions: Answer all the questions by selecting the correct answer from the alternatives A, B, C and D. Each question carries 1 mark.

Question 1. Which two elements are present in all hydrocarbons?

A. Carbon and oxygen
B. Carbon and hydrogen
C. Hydrogen and nitrogen
D. Carbon and sulphur

Question 2. Which of the following is a saturated hydrocarbon?

A. Ethene
B. Ethyne
C. Ethane
D. Propene

Question 3. The general formula of open-chain alkanes is:

A. C_nH_{2n}
B. C_nH_{2n-2}
C. C_nH_{2n+2}
D. C_nH_n

Question 4. Which of the following is the molecular formula of propene?

A. C_3H_8
B. C_3H_6
C. C_3H_4
D. C_2H_4

Question 5. An alkyne contains:

A. Carbon-carbon single bonds only
B. A carbon-carbon double bond
C. A carbon-carbon triple bond
D. A carbon-oxygen double bond

Question 6. What is the name of the alkane containing six carbon atoms?

A. Pentane
B. Hexane
C. Heptane
D. Butane

Question 7. Which of the following is the correct name for $CH_3CH_2CH_3$?

A. Ethane
B. Butane
C. Propane
D. Propene

Question 8. What is the IUPAC name of $CH_2=CHCH_2CH_3$?

A. But-1-ene
B. But-2-ene
C. Butane
D. But-1-yne

Question 9. Which of the following is the correct formula for ethyne?

A. C_2H_6
B. C_2H_4
C. C_2H_2
D. C_3H_4

Question 10. Compounds that have the same molecular formula but different structural arrangements are called:

A. Isotopes
B. Isomers
C. Polymers
D. Monomers

Question 11. How many structural isomers does butane have?

A. One
B. Two
C. Three
D. Four

Question 12. Which of the following is an isomer of pentane?

A. 2-methylbutane
B. 2-methylpropane
C. But-1-ene
D. Propane

Question 13. Which of the following is an isomer of but-1-ene?

A. Butane
B. But-2-ene
C. Pent-1-ene
D. Propene

Question 14. Which process is used to prepare ethene from ethanol?

A. Hydrogenation
B. Dehydration
C. Substitution
D. Neutralisation

Question 15. The laboratory preparation of ethane by heating sodium propanoate with soda lime is an example of:

A. Polymerisation
B. Dehydration
C. Decarboxylation
D. Addition

Question 16. Which of the following is a physical property of hydrocarbons?

A. Combustion
B. Substitution
C. Polymerisation
D. Boiling point

Question 17. Why are most hydrocarbons insoluble in water?

A. They are ionic compounds
B. They are non-polar substances
C. They contain oxygen
D. They react rapidly with water

Question 18. Which observation is expected when ethene is shaken with bromine water?

A. The solution turns blue
B. The solution becomes colourless
C. A white precipitate forms
D. No change occurs under ordinary test conditions

Question 19. Complete combustion of ethane produces:

A. Carbon monoxide and hydrogen
B. Carbon dioxide and water
C. Carbon and hydrogen
D. Carbon dioxide and chlorine

Question 20. Which poisonous gas may be produced during incomplete combustion of hydrocarbons?

A. Oxygen
B. Nitrogen
C. Carbon monoxide
D. Hydrogen

Question 21. The reaction between methane and chlorine in ultraviolet light is an example of:

A. Addition
B. Substitution
C. Polymerisation
D. Neutralisation

Question 22. The process of breaking large hydrocarbon molecules into smaller molecules is called:

A. Cracking
B. Hydrogenation
C. Fermentation
D. Crystallisation

Question 23. Which catalyst is commonly used in the hydrogenation of ethene?

A. Sodium chloride
B. Nickel
C. Calcium carbonate
D. Copper sulphate

Question 24. The polymer formed from ethene is called:

A. Poly(propene)
B. Poly(ethene)
C. Poly(ethyne)
D. Poly(methane)

Question 25. Which of the following is a natural plant hormone involved in fruit ripening?

A. Ethane
B. Ethene
C. Ethyne
D. Propane

Question 26. Which hydrocarbon is commonly used in oxy-acetylene welding?

A. Methane
B. Ethane
C. Ethyne
D. Pentane

Question 27. Crude oil is separated into different fractions mainly through:

A. Filtration
B. Fractional distillation
C. Evaporation to dryness
D. Chromatography

Question 28. Which fraction of crude oil is commonly used as fuel in many diesel engines?

A. Refinery gases
B. Petrol
C. Diesel/gas oil
D. Bitumen

Question 29. Which of the following activities helps reduce the environmental effects of burning fossil fuels?

A. Burning waste plastics
B. Leaving vehicle engines running unnecessarily
C. Using energy-efficient appliances
D. Pouring used oil into rivers

Question 30. One carbon credit generally represents:

A. One kilogram of oxygen
B. One metric tonne of carbon dioxide equivalent
C. One litre of petrol
D. One kilogram of crude oil

SECTION B: STRUCTURED QUESTIONS (50 MARKS)

Instructions: Answer all the questions. Show all necessary working where calculations are required.

Question 1: Classification and nomenclature of hydrocarbons (8 marks)

a) Define a hydrocarbon. (1 mark)

b) Distinguish between saturated and unsaturated hydrocarbons. (2 marks)

c) Write the general formula for each of the following:

i. Alkanes. (1 mark)

ii. Alkenes containing one double bond. (1 mark)

iii. Alkynes containing one triple bond. (1 mark)

d) Name the following compounds:

iv. $CH_3CH_2CH_2CH_3$. (1 mark)

v. $CH_2=CHCH_2CH_3$. (1 mark)

Question 2: Isomerism and structures (8 marks)

a) Define structural isomerism. (1 mark)

b) Draw the structural formulae of the two isomers of butane. (2 marks)

c) Draw the structural formulae of the three isomers of pentane. (3 marks)

d) Write the condensed structural formulae of:

i. But-1-ene. (1 mark)

ii. But-2-ene. (1 mark)

Question 3: Preparation and physical properties (8 marks)

a) State the laboratory method used to prepare ethene from ethanol. (1 mark)

b) Write a balanced chemical equation for the preparation of ethene from ethanol. (2 marks)

c) State the laboratory method used to prepare ethane from sodium propanoate. (1 mark)

d) Write a balanced chemical equation for the preparation of ethane from sodium propanoate using soda lime. (2 marks)

e) State two physical properties of hydrocarbons. (2 marks)

Question 4: Chemical properties of hydrocarbons (8 marks)

a) Write a balanced chemical equation for the complete combustion of ethane. (2 marks)

b) Explain why incomplete combustion of hydrocarbons is dangerous to human beings. (2 marks)

c) What is cracking of alkanes? (1 mark)

d) Write a balanced chemical equation showing the cracking of decane to form octane and ethene. (1 mark)

e) Write a balanced chemical equation for the addition of hydrogen to ethene. (2 marks)

Question 5: Polymerisation, uses and petroleum (9 marks)

a) Define polymerisation. (1 mark)

b) Write the equation for the polymerisation of ethene. (2 marks)

c) State three uses of hydrocarbons in everyday life. (3 marks)

d) Explain how fractional distillation separates crude oil into different fractions. (3 marks)

Question 6: Environmental conservation and safety (9 marks)

a) State three environmental effects of burning hydrocarbon fuels. (3 marks)

b) Explain two ways of reducing the harmful effects of fuel combustion. (2 marks)

c) What is a carbon credit? (1 mark)

d) State two ways in which carbon-credit projects can contribute to environmental conservation in Kenya. (2 marks)

e) State one safety precaution when handling hydrocarbons in the laboratory. (1 mark)

ANSWERS AND MARKING SCHEME

SECTION A: MULTIPLE-CHOICE ANSWERS

Question	Answer	Correct response
1	B	Carbon and hydrogen
2	C	Ethane
3	C	C_nH_{2n+2}
4	B	C_3H_6
5	C	Carbon-carbon triple bond
6	B	Hexane
7	C	Propane
8	A	But-1-ene
9	C	C_2H_2
10	B	Isomers
11	B	Two
12	A	2-methylbutane
13	B	But-2-ene
14	B	Dehydration
15	C	Decarboxylation
16	D	Boiling point

Question	Answer	Correct response
17	B	They are non-polar substances
18	B	The solution becomes colourless
19	B	Carbon dioxide and water
20	C	Carbon monoxide
21	B	Substitution
22	A	Cracking
23	B	Nickel
24	B	Poly(ethene)
25	B	Ethene
26	C	Ethyne
27	B	Fractional distillation
28	C	Diesel/gas oil
29	C	Using energy-efficient appliances
30	B	One metric tonne of carbon dioxide equivalent

Total: 30 marks

SECTION B: SUGGESTED ANSWERS AND MARK ALLOCATION

Question 1: Classification and nomenclature (8 marks)

a) A hydrocarbon is an organic compound containing only carbon and hydrogen. (1)

- Saturated hydrocarbons contain carbon-carbon single bonds only. (1)
- Unsaturated hydrocarbons contain at least one carbon-carbon double or triple bond. (1)

i. Alkanes: C_nH_{2n+2}. (1)

ii. Alkenes: C_nH_{2n}. (1)

iii. Alkynes: C_nH_{2n-2}. (1)

i. $CH_3CH_2CH_2CH_3$ – Butane. (1)

iv. CH_2=$CHCH_2CH_3$ – But-1-ene. (1)

Question 2: Isomerism and structures (8 marks)

a) Structural isomerism is the existence of compounds with the same molecular formula but different structural arrangements of atoms. (1)

b) Isomers of butane:

1. Butane: CH_3–CH_2–CH_2–CH_3. (1)
2. 2-methylpropane: CH_3–$CH(CH_3)$–CH_3. (1)

f) Isomers of pentane:

3. Pentane: CH_3–CH_2–CH_2–CH_2–CH_3. (1)

4. 2-methylbutane: $CH_3–CH(CH_3)–CH_2–CH_3$. (1)

5. 2,2-dimethylpropane: $C(CH_3)_4$. (1)

i. But-1-ene: $CH_2=CHCH_2CH_3$. (1)

v. But-2-ene: $CH_3CH=CHCH_3$. (1)

Question 3: Preparation and physical properties (8 marks)

a) Dehydration of ethanol. (1)

$$CH_3CH_2OH \xrightarrow{\text{concentrated } H_2SO_4,\ heat} CH_2 = CH_2 + H_2O$$

- Correct reactant and products. (1)
- Correctly balanced equation and suitable condition. (1)

g) Heating sodium propanoate with soda lime. (1)

$$CH_3CH_2COONa + NaOH \xrightarrow{CaO,\ heat} C_2H_6 + Na_2CO_3$$

- Correct reactants and products. (1)
- Correct balancing and conditions. (1)

f) Any two:

- Many simple hydrocarbons are colourless. (1)
- Many liquid hydrocarbons are less dense than water. (1)
- Most hydrocarbons are insoluble in water. (1)
- Boiling points generally increase with molecular size. (1)
- Many simple hydrocarbons are gases at room temperature. (1)

Award any two correct points. (2)

Question 4: Chemical properties of hydrocarbons (8 marks)

a) Complete combustion of ethane:

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

- Correct products. (1)
- Correctly balanced equation. (1)
- Incomplete combustion can produce poisonous carbon monoxide. (1)
- Carbon monoxide reduces the ability of blood to transport oxygen and may cause unconsciousness or death. (1)

h) Cracking is the breaking down of large hydrocarbon molecules into smaller hydrocarbon molecules by heating, often in the presence of a catalyst. (1)

$$C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$$

$$CH_2 = CH_2 + H_2 \xrightarrow{Ni,\ heat} CH_3CH_3$$

- Correct reactants and product. (1)
- Correct condition/catalyst. (1)

Question 5: Polymerisation, uses and petroleum (9 marks)

a) Polymerisation is the process in which many small molecules called monomers join together to form a large molecule called a polymer. (1)

$$n(CH_2 = CH_2) \rightarrow [-CH_2 - CH_2 -]_n$$

- Correct ethene monomer. (1)
- Correct poly(ethene) repeating unit. (1)

i) Any three:

- Methane, propane and butane are used as fuels. (1)
- Petrol and diesel are used to power vehicles. (1)
- Ethene is used to manufacture poly(ethene). (1)
- Ethyne is used in oxy-acetylene welding. (1)
- Alkenes are used to manufacture ethanol and other chemicals. (1)
- Hydrocarbons are used as industrial solvents and chemical feedstocks. (1)

Award any three correct points. (3)

- Crude oil is heated to produce vapours and liquids. (1)
- The mixture enters a fractionating column that is hot at the bottom and cooler towards the top. (1)
- Different hydrocarbons condense at different levels according to their boiling points and are collected separately. (1)

Question 6: Environmental conservation and safety (9 marks)

b) Any three:

- Carbon dioxide contributes to global warming and climate change. (1)
- Carbon monoxide causes poisoning. (1)
- Sulphur dioxide contributes to acid rain. (1)
- Nitrogen oxides contribute to smog and acid rain. (1)
- Soot causes air pollution and respiratory problems. (1)

Award any three correct points. (3)

c) Any two explained measures:

- Use cleaner renewable energy sources to reduce dependence on fossil fuels. (1)
- Maintain engines and fuel-burning appliances to improve combustion. (1)
- Use energy-efficient appliances to reduce fuel consumption. (1)
- Use public transport to reduce emissions per passenger. (1)
- Install appropriate industrial emission-control equipment. (1)

Award two suitable measures with explanations. (2)

j) A carbon credit is a tradable unit representing one metric tonne of carbon dioxide equivalent under an applicable carbon-crediting system. (1)

k) Any two:

- Supports tree planting and forest restoration. (1)
- Encourages renewable energy projects. (1)
- Supports clean cooking technologies. (1)
- Encourages sustainable land management. (1)
- Can support community conservation and livelihood projects. (1)

Award any two correct points. (2)

e) Any one:

- Keep hydrocarbons away from naked flames. (1)
- Work in a well-ventilated area. (1)
- Wear appropriate protective equipment. (1)
- Store flammable hydrocarbons in approved containers. (1)

Total Section B: 50 marks

QUICK REVISION SUMMARY

Area	Main point to remember
Hydrocarbons	Contain carbon and hydrogen only
Alkanes	Saturated; C_nH_{2n+2}
Alkenes	Contain C=C; C_nH_{2n}
Alkynes	Contain C≡C; C_nH_{2n-2}
Isomers	Same molecular formula, different structures
Ethane preparation	Sodium propanoate + soda lime, heat
Ethene preparation	Dehydration of ethanol
Alkane reactions	Combustion, substitution and cracking
Alkene reactions	Addition, polymerisation and oxidation
Bromine water test	Unsaturated hydrocarbons decolourise bromine water
Crude oil	Separated by fractional distillation
Complete combustion	Produces carbon dioxide and water
Incomplete combustion	May produce carbon monoxide and soot
Polymerisation	Many monomers join to form a polymer
Environmental protection	Cleaner energy, efficient fuel use and conservation
Carbon credits	Represent one metric tonne of CO_2 equivalent

STRAND: NATURAL PHYSICAL SCIENCE

SUBSTRAND 3.1: THIN LENSES

Introduction

- **A lens** is conventionally defined as a *piece of glass which is used to focus or change the direction of a beam of light passing through it.*
- They are mainly made of glass or plastic.
- Lenses are used in making spectacles, cameras, cinema projectors, microscopes and telescopes.

Types of Thin Lenses

- A lens which is thicker at its centre than at its edges converges light and is called **convex** or **converging lens**
- A lens which is thicker at its edges than at its centre diverges light and is known as **concave** or **diverging lens**.

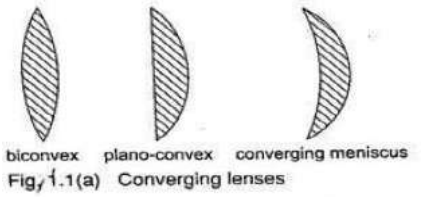


Fig. 1.1(a) Converging lenses

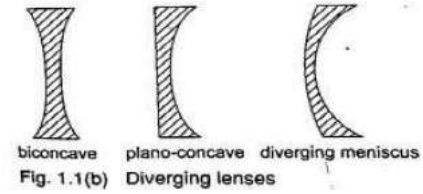
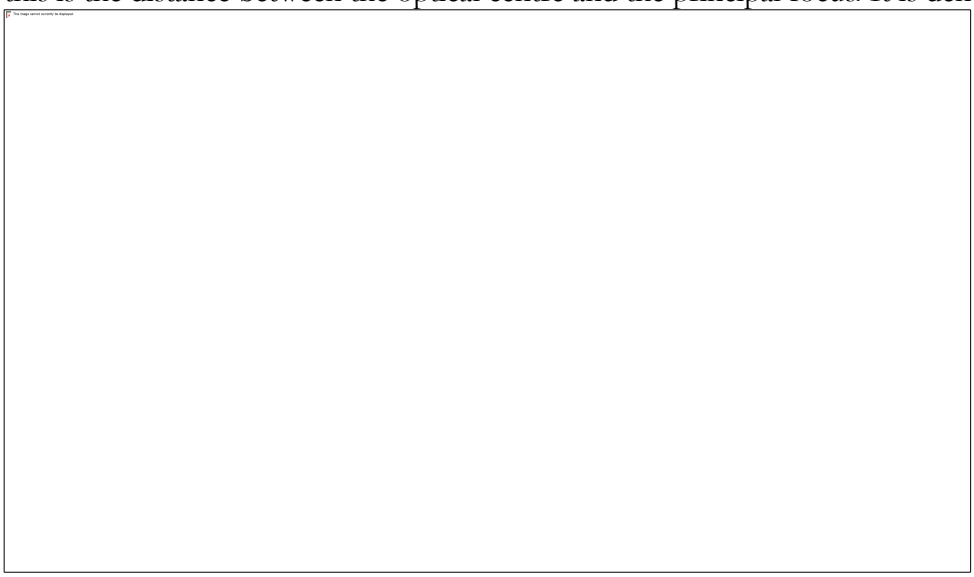


Fig. 1.1(b) Diverging lenses

Properties of Lenses

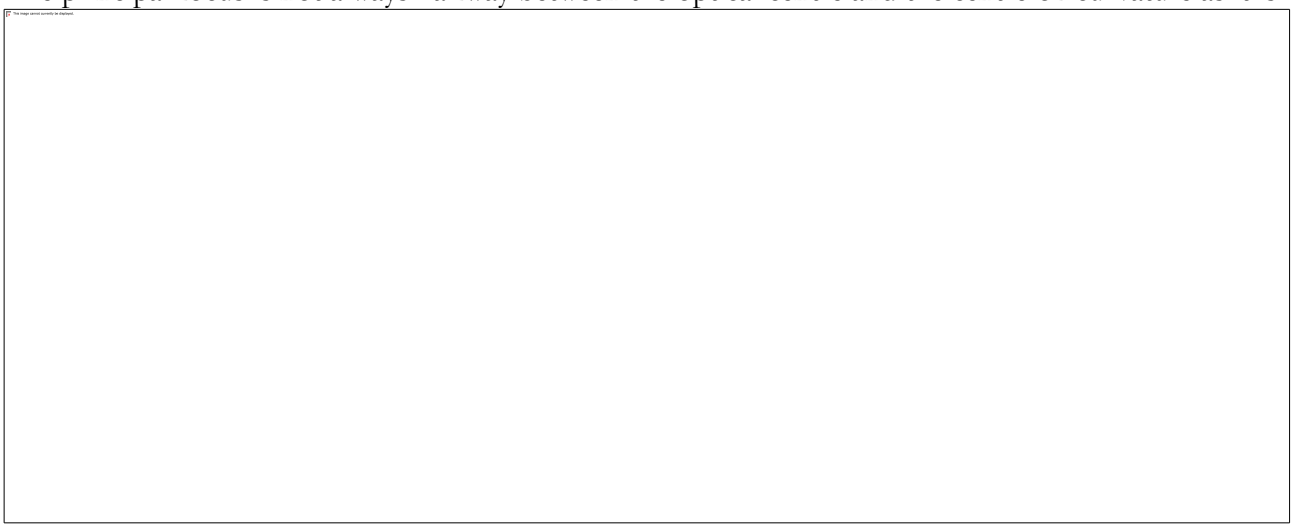
1. Optical centre
    - This is the geometric centre of a lens which is usually shown using a black dot in ray diagrams.
    - A ray travelling through the optical centre passes through in a straight line.

2. Centre of curvature
    - This is the geometric centre of the circle of which the lens surface is part of.
    - Since lenses have two surfaces there are two centres of curvature.
    - C is used to denote one centre while the other is denoted by C^1 .
3. Principal axis
    - This is an imaginary line which passes through the optical centre at right angle to the lens.
4. Principal focus
    - this is a point through which all rays travelling parallel to the principal axis pass after refraction through the lens.
    - A lens has a principal focus on both its sides.
    - F is used to denote the principal focus
5. Focal length
    - this is the distance between the optical centre and the principal focus. It is denoted by 'f' .



Note:

- The principal focus for a converging lens is real and virtual for a diverging lens.
- The principal focus is not always halfway between the optical centre and the centre of curvature as it is in mirrors.



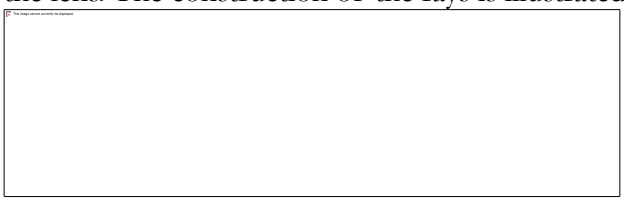
Images Formed by Thin Lenses

- The nature, size and position of the image formed by a particular lens depends on the position of the object in relation to the lens.

Construction of Ray Diagrams

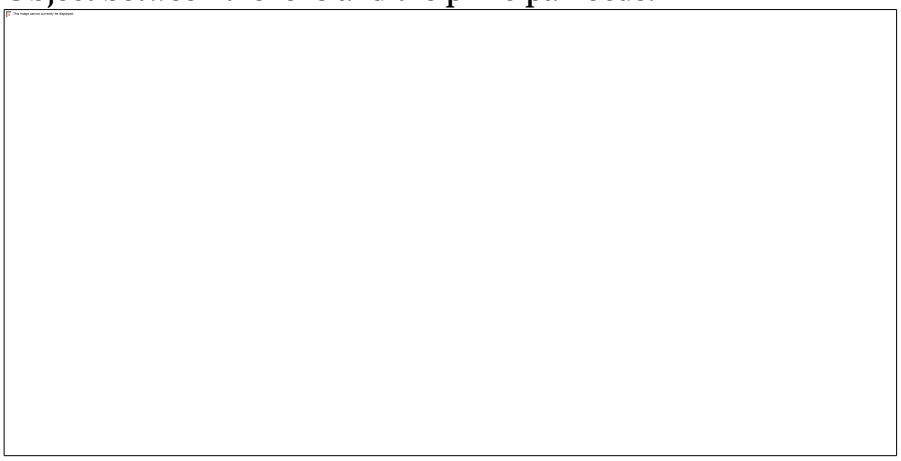
Three rays are of particular importance in the construction of ray diagrams.

1. A ray of light travelling parallel to the principal axis passes through the principal focus on refraction through the lens. In case of a concave lens the ray is diverged in a way that it appears to come from the principal focus.
2. A ray of light travelling through the optical centre goes un-deviated along the same path.
3. A ray of light travelling through the principal focus is refracted parallel to the principal axis on passing through the lens. The construction of the rays is illustrated below.



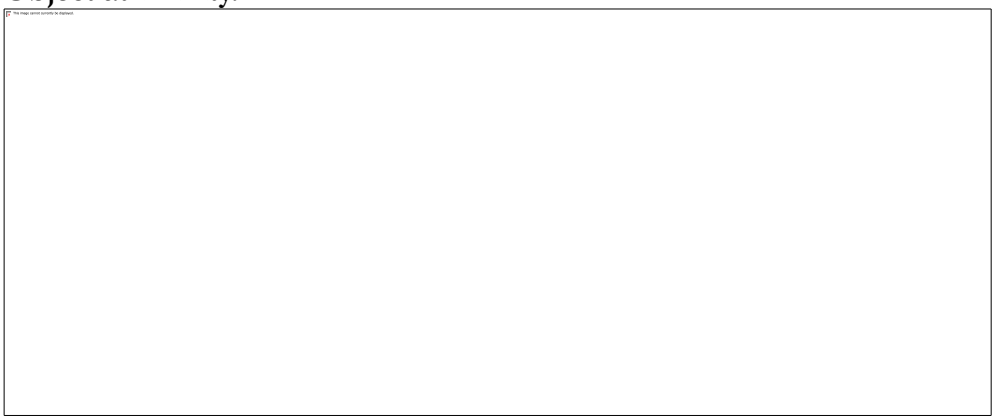
Images Formed by a Converging Lens

1. **Object between the lens and the principal focus.**



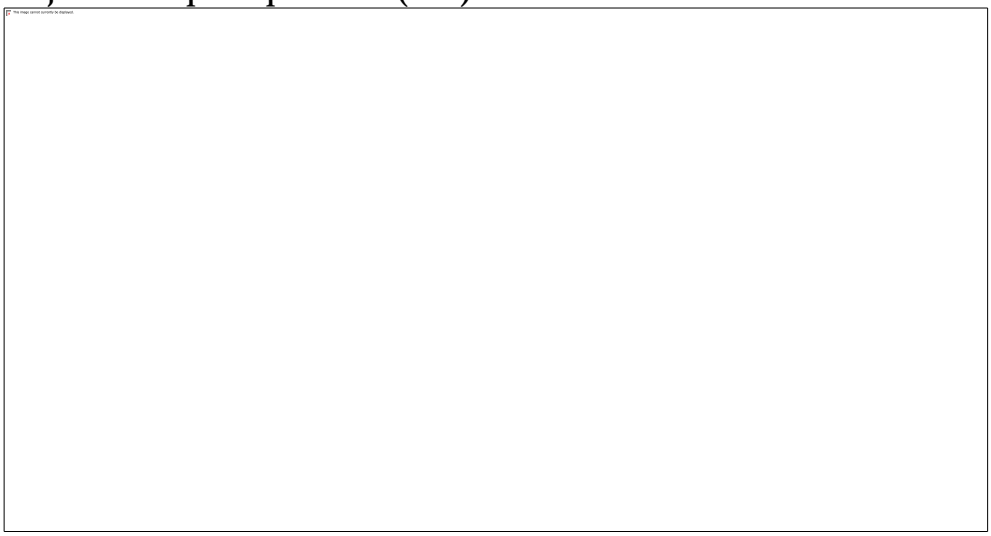
- Image formed behind the object
- Virtual
- Erect
- Magnified

2. **Object at infinity.**



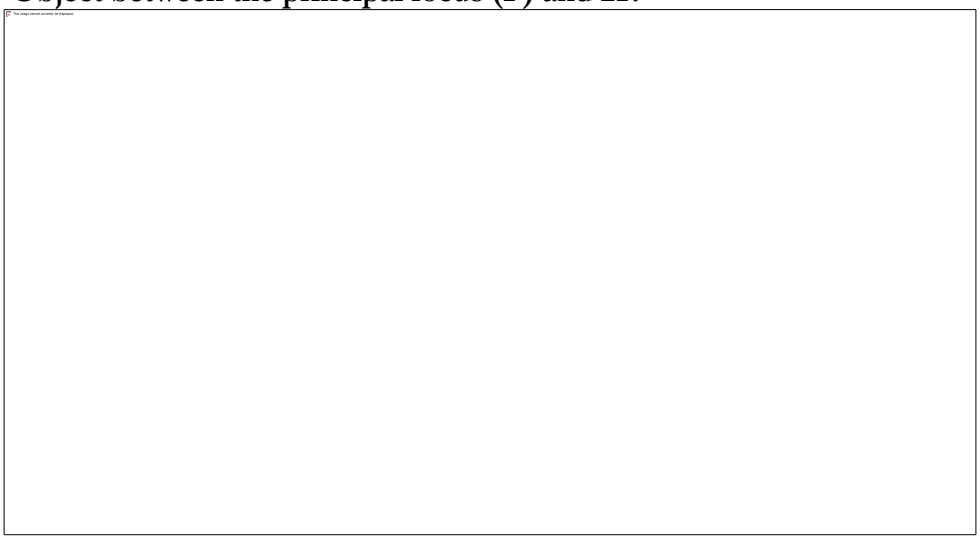
- Image formed at the principal focus of the lens
- Real
- Inverted
- Diminished

3. **Object at the principal focus (at F).**



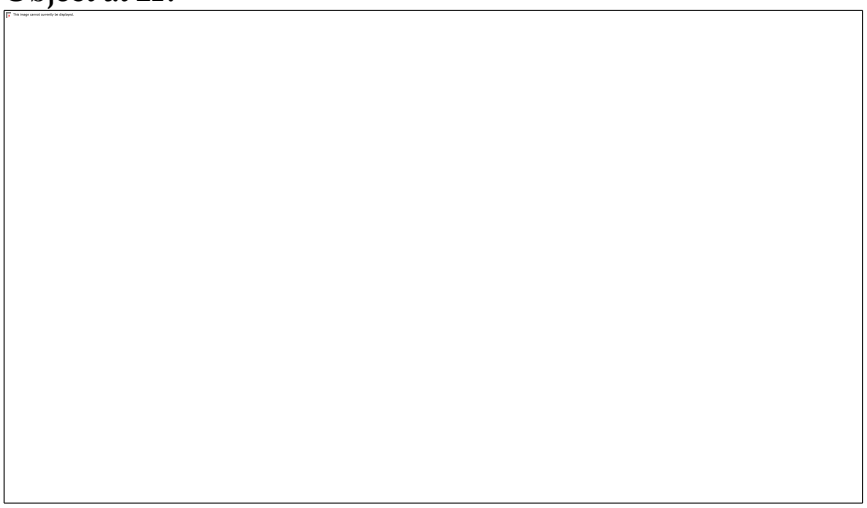
- Image is at infinity.

4. **Object between the principal focus (F) and 2F.**



- Image situated beyond 2 F
- Real
- Inverted
- Magnified

5. **Object at 2F.**



- Image is formed at 2F
- Real
- Inverted
- Same size as the object

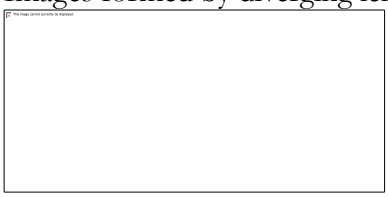
6. **Object beyond F.**



- Image moves nearer to F as object shifts further beyond 2F
- Real
- Inverted
- Diminished

Images Formed by a Diverging Lens

- Images formed by diverging lens are always erect, virtual and diminished for all positions of the object.



Linear Magnification

- The linear magnification produced by a lens defined as the ratio of the height of the image to the height of the object, denoted by letter 'm' ,therefore;
  $m = {}^{\text{height of the image}}/_{\text{height of the object}}$.
- Magnification is also given by = distance of the image from the lens/ dist. of object from lens.
  m = v/u

Example

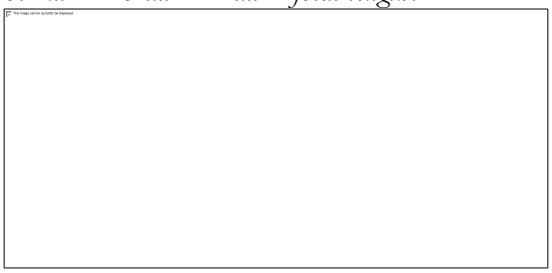
1. An object 0.05 m high is placed 0.15 m in front of a convex lens of focal length 0.1 m. Find by construction, the position, nature and size of the image. What is the magnification

   Solution

   Let 1 cm represent 5 cm. hence 0.05 m = 5 cm = 1 cm – object height

   0.15 m = 15 cm = 3 cm

   0.1 m = 10 cm = 2 cm – focal length.



   a. *Image formed is – image is beyond 2F*
      - Inverted
      - Real
      - Magnified

   b. *Magnification* $= {}^{v}/_{u} = {}^{30\ cm}/_{15\ cm} = 2.$

The Lens Formula

- Let the object distance be represented by 'u' ,the image distance by 'v' andthe focal length by ' f ', then the general formula relating the three quantities is given by;
  $^1/_f = {}^1/_u + {}^1/_v$ **– this is the lens formula.**

Examples

1. An object is placed 12 cm from a converging lens of focal length 18 cm. Find the position of the image.
   Solution
   Since it is a converging lens f = +18 cm (real-is-positive and virtual-is-negative rule)
   The object is real therefore u = +12 cm, substituting in the lens formula, then $^1/_f = {}^1/_u + {}^1/_v$ *or* $^1/_v = {}^1/_f - {}^1/_u = {}^1/_{18} - {}^1/_{12} = -{}^1/_{36}$
   Hence v = - 36 then the image is virtual, erect and same size as the object.

2. The focal length of a converging lens is found to be 10 cm. How far should the lens be placed from an illuminated object to obtain an image which is magnified five times on the screen?
   Solution
   f = + 10 cm; m = $^v/_u$ = 5 hence v = 5u
   Using the lens formula $^1/_f = {}^1/_u + {}^1/v \rightarrow {}^1/_{10} = {}^1/u + {}^1/_{5u}$ (replacing v with 5u) $^1/_{10} = {}^6/_{5u}$, hence 5u = 60 giving u = 12 cm (the lens should be placed 12 cm from the illuminated object)

3. The lens of a slide projector focuses on an image of height 1.5m on a screen placed 9.0 m from the projector. If the height of the picture on the slide was 6.5 cm, determine,

   a. Distance from the slide (picture) to the lens

   b. Focal length of the lens
      Solution
      a) Magnification = $^{\text{height of the image}}/_{\text{height of the object}} = {}^v/_u = {}^{150}/_{6.5}$ = 900/uu = 39 cm (distance from slide to the lens). m = 23.09
      b) $^1/_f = {}^1/_u + {}^1/_v = {}^1/_{39} + {}^1/_{90}$ = 0.02564 + 0.00111
      $^1/_f$ = 0.02675 (reciprocal tables) f = 37.4 cm.

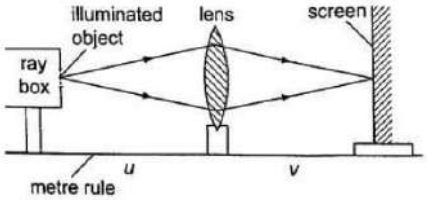
Determining Focal Lengths

1. Determining Focal Length of a Converging Lens

Experiment : To Determine the Focal Length of a Converging Lens Using the Lens Formula.

Procedure

i. Set up the apparatus as shown below



ii. Place the object at reasonable length from the screen until a real image is formed on the screen. Move the lens along the metre rule until a sharply focused image is obtained.

iii. By changing the position of the object obtain several pairs of value of u and v and record your results as shown.

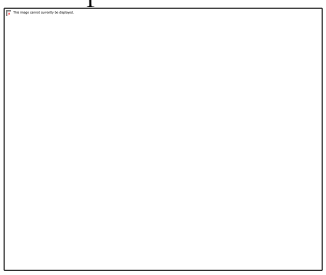
u	v	uv	$^{uv}/_{u+v}$

Discussion

iv. The value $^{uv}/_{u+v}$ is the focal length of the lens and the different sets of values give the average value of 'f'.

v. Alternatively the value 'f' maybe obtained by plotting a graph of $^{1}/_{v}$ against $^{1}/_{u}$.

vi. When plotted the following graph is obtained.

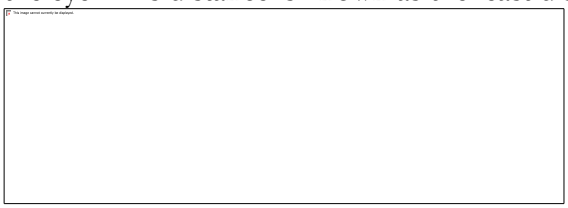


vii. Since $^{1}/_{f} = {}^{1}/_{u} + {}^{1}/_{v}$, at the y-intercept $^{1}/_{u} = 0$, so that $^{1}/_{f} = {}^{1}/_{v}$ or f = v.

viii. The focal length may therefore be obtained by reading off the y-intercept and finding the reciprocal. Similarly at the x-intercept, $^{1}/_{v} = 0$, therefore $^{1}/_{f} = {}^{1}/_{u}$ or f = u hence the focal length can also be obtained by reading off the x-intercept and finding the reciprocal.

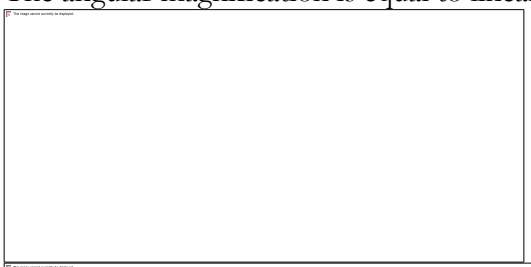
Uses of Lenses on Optical Devices

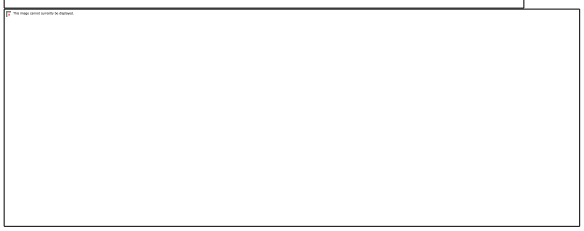
1. *Simple microscope* – it is also referred to as magnifying glass where the image appears clearest at about 25 cm from the eye. This distance is known as the least distance of distinct vision (D) or near vision.



Magnification in a Simple Microscope

- Magnification produced depends on the focal length of the lens. Lens of short focal give greater magnification than those of long focal length.
- The angle β subtended by the image at the eye is much greater than α which is the angle that the object would subtend at the eye when viewed without the lens.
- The ratio of the β toα is known as angular magnification or magnifying power of an instrument.
- The angular magnification is equal to linear magnification.



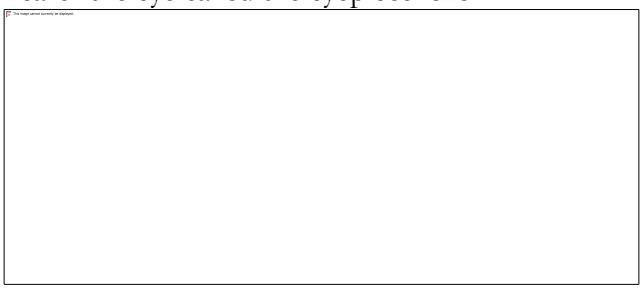


Uses of a Simple Microscope

- To study the features of small animals in biology
- To look closely at small print on a map

- To observe crystals in physics and chemistry
- For forensic investigation by the police

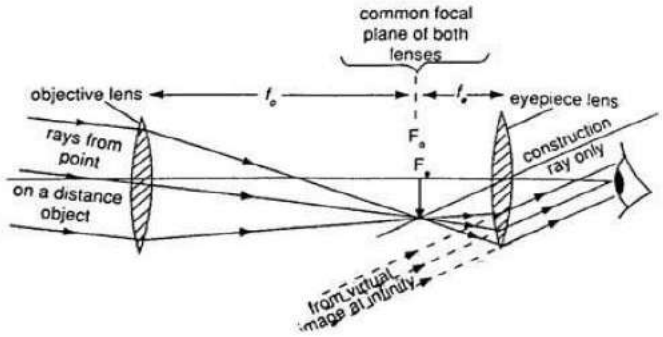
2. *Compound microscope* - It consists of two lenses with one nearer the object called the objective lens and the other nearer the eye called the eyepiece lens.



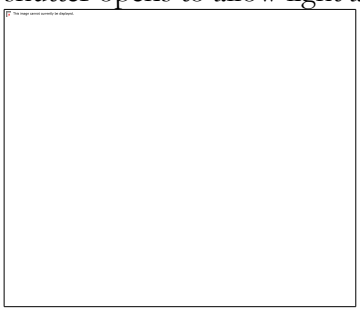
Uses of Compound Microscope

- Used to observe Brownian motion in science
- To study micro-organisms and cells in biology
- Analyze laboratory tests in hospital.

3. *The astronomical telescope* – It is used to view distant stars. It consists of two lenses; objective and eye-piece lenses. The objective lens has a large focal length while the eye-piece lens has a much shorter focal length.



4. *The camera* – consists of a converging lens system, clicking button, shutter, diaphragm and a mounting base for the film all enclosed in a light proof box. The distance is adjusted to obtain a clear focus. The diaphragm has a hole called the aperture with an adjusting control knob to control the amount of light entering the camera. The shutter opens to allow light and close at a given time interval.

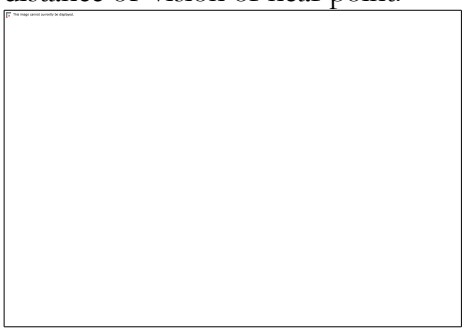


Uses of a Camera

- The sine camera is used to make motion pictures
- High speed cameras are used to record movement of particles
- Close circuit television cameras **(CCTV)** are used to protect high security installations like banks, supermarkets etc.
- Digital cameras are used to capture data that can be fed to computers.

5. *Human eye* – It consists of a transparent cornea, aqueous humour and a crystal-like lens which form a converging lens system. The ciliary muscles contract or relax to change the curvature of the lens. Though the image fo the image as upright. For distant objects ciliary muscles relax while near objects it contracts to control the focal length

and this is known as accommodation. When at 25 cmaway an object appears clearest and this is known as least distance of vision or near point.



Common Eye Defects

- *Short sightedness or myopia* – result of a bulging cornea or an elongated eyeball. Images of distant objects form at locations in front of the retina. The defect is corrected by placing a concave (diverging) lens infront of the eye

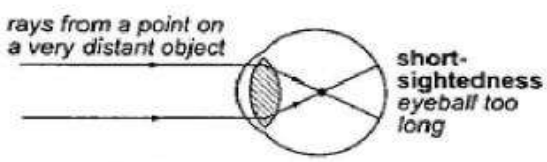


Fig. 1.26 Short-sightedness

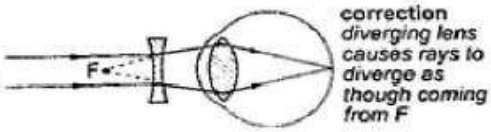


Fig. 1.27 Correction of short-sightedness

- *Long sightedness or hypermetropia* – images are formed beyond the retina. The defect is corrected by placing a converging (convex) lens in front of the eye

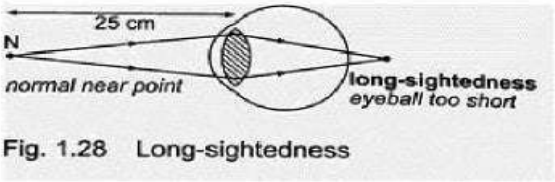


Fig. 1.28 Long-sightedness

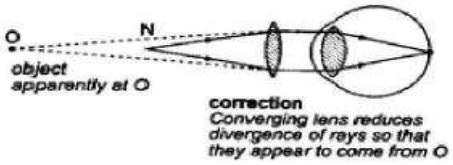


Fig. 1.29 Correction long-sightedness

- *Presbyopia* – this is the inability of the eye to accommodate and this occurs as the eye ages due to the weakening of the ciliary muscles. It can be corrected by the use a pair of spectacles.
- *Astigmatism* – this is a defect where the eye has two different focal lengths as a result of the cornea not being spherical. Corrected by the use of cylindrical lens.
- *Colour blindness* – caused by deficiency of colour detecting cells in the retina.

Power of Lens

- The power of a simple lens is given by the formula: Power = $^1/_f$. The unit for power of a lens is **diopter (D)**.

Example

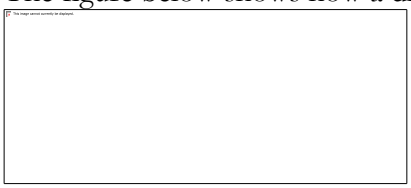
Find the power of a concave lens of a focal length 25 cm.

Solution

Power = $^1/_f = {}^1/_{-0.25}$ = -4 D.

TOPICAL REVISION QUESTION

1. The figure below shows how a distant object is focused in a defective eye.



   i. State the nature of the defect.

   ii. Suggest suitable lens to correct the defect

2.

   i. You are provided with a rectangular glass block, two pins and a piece of white paper. Describe how you would use them to determine the refractive index of the glass using real and apparent image method.

   ii. An object O is placed 15cm from a converging lens of focal length 10cm.

      i. At what distance should a screen be placed so that a focused image is formed on it?

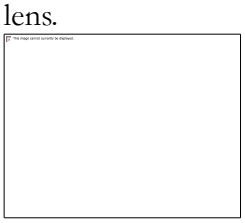
      ii. A diverging lens of focal length 37.5 cm is placed half way between the converging lens and the screen. How far should the screen be from the diverging leans in order to receive a focused image?

   iii. Two lenses L_1 and L_2 placed 12cm from each other. The focal length of L_2 is 4cm. An object 5mm high is placed 4cm from L_1.

      i. Construct a scaled ray diagram on a graph paper to obtain the position of the final image as would be observed by a person on the right hand side of L_2

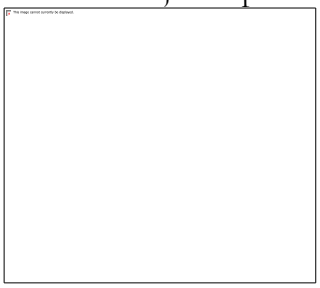
      ii. Determine the magnification obtained by the arrangement.

3. The figure below represents and object O placed 10cm in front of a diverging lens. F is the focal point of the lens.



Draw rays to locate the position of the image. Determine the image distance.

4. A vertical object is placed at the focal point F of a diverging lens as shown in the figure below.



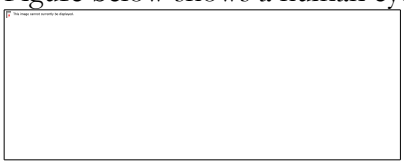
Sketch a ray diagram to show the image of the object. (3mks)

5.

i. Describe with the aid of labeled diagram an experiment to determine the focal length of the lens when provided with the following; an illuminated object, a convex lens, a lens holder, a plane mirror and a metre rule. (5mk)

ii. A small vertical object is placed 28cm in front of a convex lens of focal length 12cm. On the grid provided, draw a ray diagram to locate the image. The lens position is shown. (Use a scale: 1 cm represents 4 cm).

iii. Figure below shows a human eye with a certain defect.

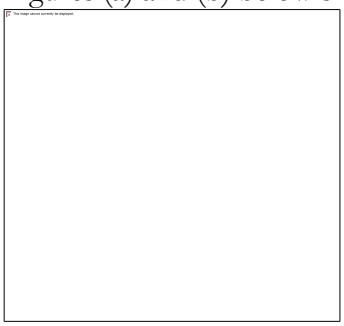


i. Name the defect. (1mk)

ii. On the same diagram, sketch the appropriate lens to correct the defect and sketch rays to show the effect of the lens. (2mks)

6.

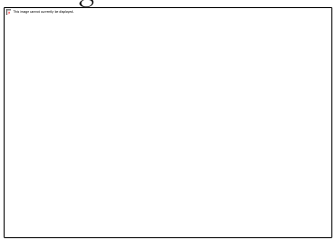
i. Figures (a) and (b) below shows diagrams of the human eye.



i. Sketch in figure (a) a ray diagram to show short sightedness. (1mk)

ii. Sketch in figure (b) a ray diagram to show how a lens can be used to correct the shortsightedness. (2mks)

ii. The figure below shows the features of a simple camera.



i. Name the parts labelled A and B. (2mks)

ii. A still object is placed at a certain distance from the camera. Explain the adjustments necessary for a clear image of the object to be formed. (2mks)

iii. State the functions of the shutter and the parts labelled A and B (3mks)

iii. A lens forms clear image on a screen when the distance between the screen and the object is 80cm. If the image is 3 times the height of the object, determine

i. The distance of the image from the lens. (3mks)

ii. The focal length of the lens. (2mks)

7. An image formed on a screen is three times the size of the object. The object and the screen are 80cm apart when the image is sharply focused. Determine the focal length of the lens.

8. A luminous object and a screen are placed on an optical bench a converging lens is placed between them to throw a sharp image of the object on the screen, the magnification is found to be 2.5. The lens is now moved 30cm nearer to the screen and a sharp image is again formed. Calculate the focal length of the lens.

9. An object is placed 16cm from a converging lens of focal length 12cm. Find.

i. Position of image.

ii. Nature and

iii. Magnification of the image.

10. An object is placed 15cm from a diverging lens and the image is formed 6cm from the lens. What is the focal length of the lens?

11. Calculate the power of a lens whose focal length is given as 10cm.

12. Explain differences between the eye and the camera. State also the similarities.

Answers

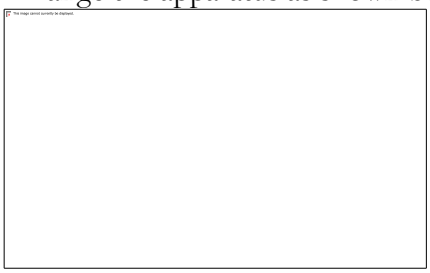
1.

i. Short sightedness (myopia)

ii. Concave lens (diverging lens)

2.

i. Arrange the apparatus as shown below



Adjust the position of the search pin until there is no parallax. Measure A and R

Refractive index = $\frac{\text{Real depth}}{\text{Apparent depth}} = \frac{R}{A}$

ii.

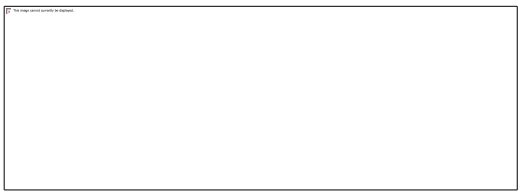
i. u = 15cm, f = 10cm

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

$\frac{1}{v} = \frac{1}{10} - \frac{1}{15} = \frac{1}{30}$

∴v= 30 cm

ii.



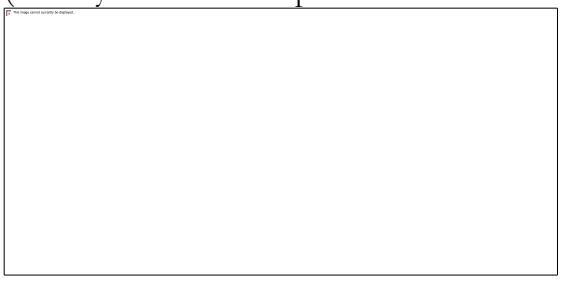
- Now for the diverging lens, V= -15cm since the image is vertical

∴ $\frac{1}{}$ = $\frac{-1}{}$ + $\frac{1}{}$ (note that for concave is –ve)

v 37.5 15
V= 25 cm

iii.

i. Draw rays to form 1st image due to L_1. This image will be treated as the object for L_2. Use lines (Not rays to obtain the position of the final image I_2 then complete the rays as shown below.

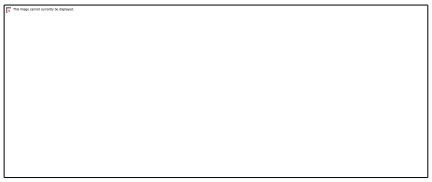


ii. Measure height of I_2 and divide by height of object

3.

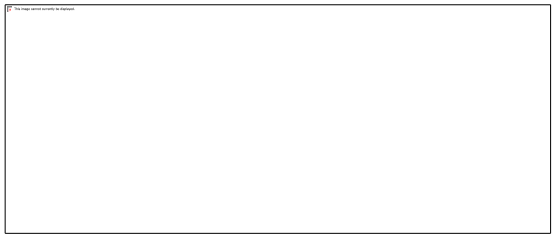


4.



5.

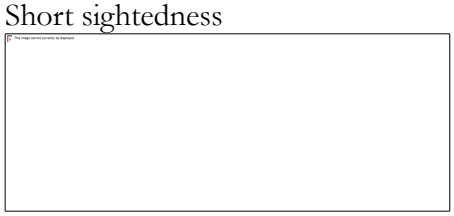
i. - Place candle at a distance as shown below



- Adjust until a sharp image is formed
- Measure U and V and record
- Repeat this procedure for other values of u
- For each set of values find using $^1/_f = {}^1/_u + {}^1/_v$
- Calculate the average value

ii. - Draw one ray from top of object straight through the optical centre of the lens a
- Draw another ray parallel to the principal axis which should pass through principal axis after refraction
- Where they meet, draw the image.

iii. Short sightedness



6.

i.

i.



ii.



ii.

i. A-Diaphragm
B-Film

ii. The distance between the lens is adjusted so that the image is formed on the film

iii. - Shutter- Opens for some given time to alloy rays from the object to fall on the film creating the image impression.
- A (Diaphragm) controls intensity of light entering the camera
- B (Film) – coated with light sensitive components which react with light to create the impression

iii.

i. Magnification = $\frac{v}{u} = 3$

Since $v + u = 80$

$u = 80 - v$

$\frac{v}{80 - v} = 3$

$v = 240 - 3v$

$v = 60$ cm

ii. From above $u = 20$cm

$\frac{1}{F} = \frac{1}{v} + \frac{1}{u}$

$\frac{1}{60} + \frac{1}{20}$

7. f= 15cm

8. f= 14.3cm

9.

i. Given information

$u = 16$cm

$f = 12$cm

Applying $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

then $\frac{1}{v} = \frac{1}{f} + \frac{1}{u}$

$\frac{1}{v} = \frac{1}{12} - \frac{1}{16}$

$= \frac{1}{v} = \frac{4 - 3}{48} = \frac{1}{v}$

$v = 48$

Hence image distance = 48

ii. Nature: image is real
- Inverted

- 48 cm from the lens
- Magnified

iii. Magnification, $m = \frac{v}{u} = \frac{48\text{ cm}}{16\text{ cm}} = 3$

10. **Solution**

Given information

$v = -6$ cm

$u = +15$cm

Applying $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

$\frac{1}{f} = \frac{1}{15} - \frac{1}{6}$

$\frac{1}{f} = \frac{2 - 5}{30}$

$\frac{1}{f} = \frac{-3}{30}$

$\frac{1}{f} = \frac{-1}{10}$

$f = -10$

$f = 10$ cm

11. **Solution**

$P = {}^{1}/_{f}$

$P = \frac{1}{10\text{ cm}} = \frac{1}{{}^{10}/_{100}\text{m}}$

$= 1 \div {}^{10}/_{100}$ m

$= 1 \times {}^{100}/_{10}$

Power = 10 dioptre (D)

12. **Similarity**

- Both have converging lens
- In the eye, retina act as the screen while in the camera a light sensitive film act as one

Differences

- Focal length of the eye lens is variable while that of the camera is fixed.

STRAND 3.0: NATURAL PHYSICAL SCIENCE

TOPICAL REVISION QUESTIONS: 3.1 THIN LENSES

SECTION A: MULTIPLE-CHOICE QUESTIONS (30 MARKS)

Instructions: Answer all questions. Choose the correct answer from alternatives A, B, C and D. Each question carries one mark.

1. Which of the following best describes a lens?

A. A transparent material with at least one curved surface that refracts light.

B. An opaque material that reflects light.

C. A material that absorbs all light passing through it.

D. A material that produces light.

2. Which of the following is a converging lens?

A. Concave lens.

B. Convex lens.

C. Plane glass.

D. Plane mirror.

3. A converging lens is thicker at the:

A. Edges than at the centre.

B. Centre than at the edges.

C. Top than at the bottom.

D. Bottom than at the top.

4. A diverging lens is also known as a:

A. Convex lens.

B. Cylindrical lens.

C. Concave lens.

D. Plane lens.

5. Which of the following describes the action of a diverging lens on parallel rays of light?

A. It brings them to a single point.

B. It reflects them backwards.

C. It spreads them apart.

D. It absorbs them completely.

6. The point on the principal axis of a lens through which a ray of light passes without significant deviation is called the:

A. Principal focus.

B. Optical centre.

C. Focal plane.

D. Centre of curvature.

7. The principal focus of a converging lens is the point where:

A. Parallel rays of light converge after refraction.

B. All light rays are absorbed.

C. Light rays are reflected.

D. Diverging rays become parallel.

8. The distance between the optical centre and the principal focus of a lens is called:

A. Radius of curvature.

B. Image distance.

C. Focal length.

D. Object height.

9. Which symbol is commonly used to represent focal length?

A. U.

B. F.

C. f.

D. V.

10. Which of the following is the SI unit of focal length?

A. Metre.

B. Dioptre.

C. Newton.

D. Watt.

11. The power of a lens is measured in:

A. Metres.

B. Dioptres.

C. Joules.

D. Amperes.

12. The power of a lens is calculated using the formula:

A. P=f

B. $P = \frac{1}{f}$

C. $P=f^2$

D. P=2f

13. A converging lens has a focal length of 0.5 m. Its power is:

A. 0.5 D.

B. 1 D.

C. 2 D.

D. 5 D.

14. Which type of image can be formed on a screen?

A. Virtual image only.

B. Real image only.

C. Both real and virtual images.

D. Neither real nor virtual images.

15. When an object is placed beyond twice the focal length of a converging lens, the image formed is:

A. Virtual, upright and magnified.

B. Real, inverted and diminished.

C. Real, upright and magnified.

D. Virtual, inverted and diminished.

16. When an object is placed at twice the focal length of a converging lens, the image is formed:

A. At the principal focus.

B. At twice the focal length on the opposite side.

C. Between the optical centre and focus.

D. At infinity.

17. When an object is placed between the optical centre and the principal focus of a converging lens, the image formed is:

A. Real, inverted and diminished.

B. Real, inverted and magnified.

C. Virtual, upright and magnified.

D. Virtual, inverted and diminished.

18. A diverging lens always forms an image that is:

A. Real, inverted and magnified.

B. Virtual, upright and diminished.

C. Real, upright and magnified.

D. Real, inverted and diminished.

19. Which of the following rays passes through the optical centre of a thin lens without significant deviation?

A. A ray parallel to the principal axis.

B. A ray passing through the optical centre.

C. A ray passing through the principal focus only.

D. A ray reflected from the lens surface.

20. A ray travelling parallel to the principal axis of a converging lens emerges:

A. Parallel to the principal axis.

B. Through the principal focus.

C. Through the optical centre.

D. Backwards along its original path.

21. Which method can be used to determine the focal length of a converging lens experimentally?

A. Focusing a distant object onto a screen.

B. Measuring the thickness of the lens.

C. Placing the lens in water.

D. Measuring the diameter of the lens.

22. When focusing a distant object using a converging lens, the screen should be adjusted until:

A. A blurred image is obtained.

B. A sharp image is formed.

C. No image is visible.

D. The image becomes virtual.

23. Which part of the human eye controls the amount of light entering the eye?

A. Retina.

B. Iris.

C. Optic nerve.

D. Cornea.

24. The image in the human eye is formed on the:

A. Iris.

B. Pupil.

C. Retina.

D. Cornea.

25. The lens of the human eye focuses light onto the retina by:

A. Reflecting light rays.

B. Refracting light rays.

C. Absorbing light rays.

D. Producing light rays.

26. The ability of the eye lens to change its focal length to focus on objects at different distances is called:

A. Reflection.

B. Dispersion.

C. Accommodation.

D. Diffraction.

27. Which defect of vision makes a person unable to see distant objects clearly?

A. Hypermetropia.

B. Myopia.

C. Presbyopia.

D. Colour blindness.

28. Myopia is corrected using a:

A. Convex lens.

B. Concave lens.

C. Plane mirror.

D. Cylindrical mirror.

29. Hypermetropia is corrected using a:

A. Concave lens.

B. Plane lens.

C. Convex lens.

D. Diverging lens.

30. Which optical instrument uses two convex lenses to produce a highly magnified image of a small object?

A. Simple microscope.

B. Compound microscope.

C. Periscope.

D. Telescope mirror.

SECTION B: STRUCTURED QUESTIONS (50 MARKS)

Instructions: Answer all questions. Show all working in calculations and use well-labelled diagrams where necessary.

31. Types and Properties of Thin Lenses (10 Marks)

a) Define the term thin lens. (2 marks)

b) State two differences between a converging lens and a diverging lens. (4 marks)

c) Name the following parts of a thin lens:

i) The point through which a ray of light passes without significant deviation. (1 mark)

ii) The point where parallel rays converge after refraction through a converging lens. (1 mark)

iii) The distance between the optical centre and the principal focus. (1 mark)

d) State one use of a converging lens in everyday life. (1 mark)

32. Image Formation by Thin Lenses (10 Marks)

a) State the two principal rays used in constructing ray diagrams for a converging lens. (2 marks)

b) Draw a ray diagram to show image formation when an object is placed beyond twice the focal length (2F) of a converging lens. (3 marks)

c) State three characteristics of the image formed in (b). (3 marks)

d) State two characteristics of an image formed by a diverging lens. (2 marks)

33. Experimental Determination of Focal Length (10 Marks)

A learner was provided with a converging lens, a metre rule, a lens holder and a white screen to determine the focal length of the lens.

a) State the apparatus required for this experiment. (2 marks)

b) Describe the procedure the learner should follow to determine the focal length of the converging lens using a distant object. (4 marks)

c) Explain why a distant object is used in this experiment. (2 marks)

d) A learner obtains a sharp image on the screen at a distance of 20 cm from the optical centre of the lens.

i) Determine the focal length of the lens. (1 mark)

ii) Calculate the power of the lens in dioptres. (1 mark)

34. The Human Eye and Defects of Vision (10 Marks)

a) Name the following parts of the human eye and state their functions:

i) Cornea. (2 marks)

ii) Iris. (2 marks)

iii) Retina. (2 marks)

b) Explain how the human eye focuses light from a nearby object onto the retina. (2 marks)

c) Distinguish between myopia and hypermetropia. (2 marks)

35. Applications of Thin Lenses (10 Marks)

a) Name the type of lens used in each of the following optical instruments:

i) Simple microscope. (1 mark)

ii) Compound microscope. (1 mark)

iii) Camera. (1 mark)

b) Explain how a simple microscope produces a magnified image of an object. (3 marks)

c) State two differences between a simple microscope and a compound microscope. (2 marks)

d) Explain the role of the lens in a camera. (2 marks)

ANSWERS

STRAND 3.0: NATURAL PHYSICAL SCIENCE

TOPICAL REVISION QUESTIONS: 3.1 THIN LENSES

MARKING SCHEME / ANSWERS

SECTION A: MULTIPLE-CHOICE QUESTIONS (30 MARKS)

Question	Answer	Question	Answer	Question	Answer
1	B	11	B	21	B
2	A	12	C	22	C
3	C	13	B	23	A
4	B	14	A	24	B
5	C	15	C	25	C
6	A	16	B	26	B
7	B	17	A	27	A
8	C	18	B	28	C
9	A	19	C	29	B
10	B	20	A	30	C

Note: The answer letters should be checked against the exact options in the question paper before final printing.

SECTION B: STRUCTURED QUESTIONS (50 MARKS)

31. Types and Properties of Thin Lenses (10 Marks)

a) A thin lens is a transparent optical device bounded by two surfaces, at least one of which is curved, that refracts light to form images. (2 marks)

b) Differences between converging and diverging lenses:

Converging lens	Diverging lens
Thicker at the centre than at the edges.	Thinner at the centre than at the edges.
Brings parallel rays together.	Spreads parallel rays apart.
Also called a convex lens.	Also called a concave lens.

(4 marks)

c)

- **Optical centre:** The central point of a lens through which a light ray passes without significant deviation. (1 mark)
- **Principal focus:** The point where rays parallel to the principal axis converge, or appear to diverge from, after refraction. (1 mark)
- **Focal length:** The distance between the optical centre and the principal focus. (1 mark)

d) One use: Correcting defects of vision, magnifying objects or forming images in cameras. (1 mark)

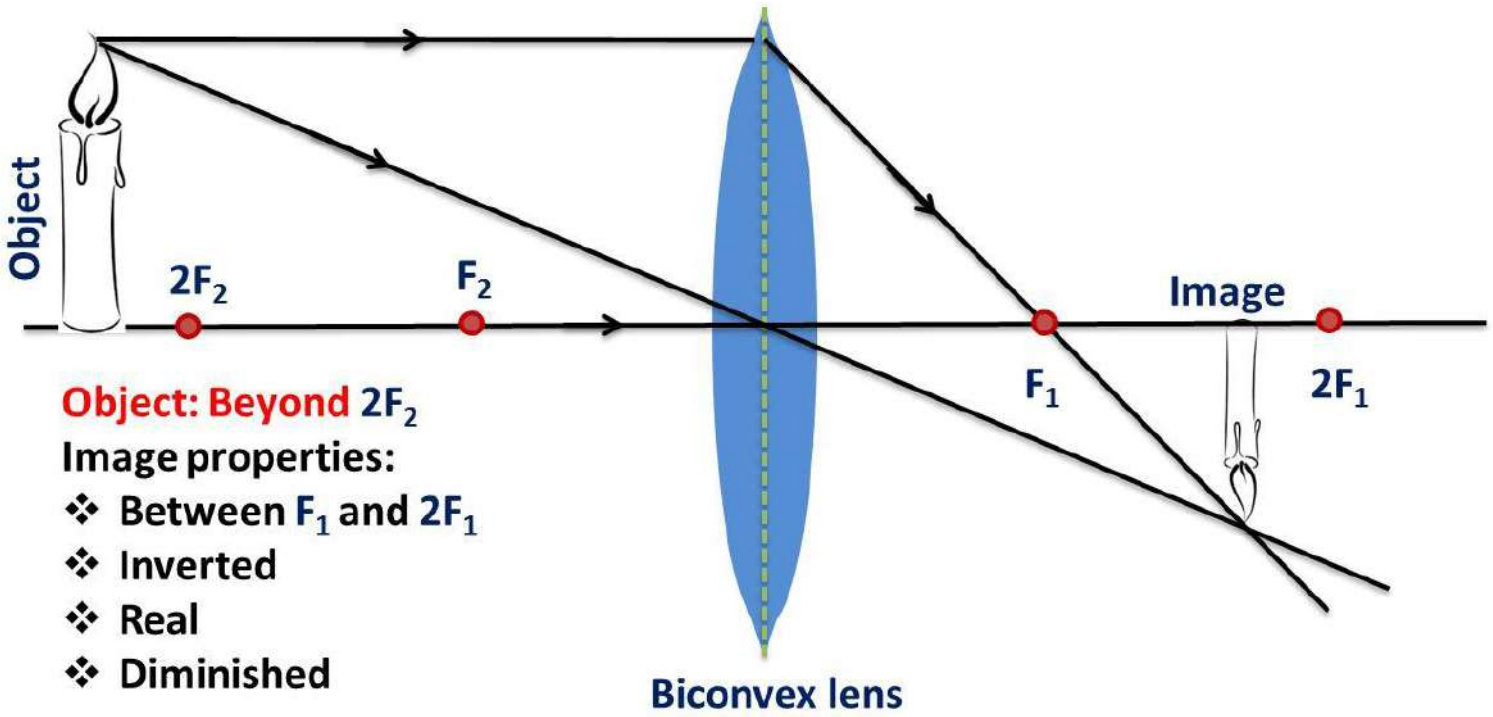
32. Image Formation by Thin Lenses (10 Marks)

a) Two principal rays used in constructing ray diagrams for a converging lens:

1. A ray travelling parallel to the principal axis refracts through the principal focus on the opposite side.
2. A ray passing through the optical centre continues in the same direction without significant deviation.

(4 marks)

b) Ray diagram for an object placed beyond 2F:



(3 marks)

c) Characteristics of the image formed:

- Real.
- Inverted.
- Diminished.
- Formed between F and 2F on the opposite side of the lens.

(2 marks)

d) A diverging lens forms an image that is:

- Virtual.
- Upright.
- Diminished.
- Formed on the same side as the object, between the optical centre and principal focus.

(1 mark)

33. Experimental Determination of Focal Length (10 Marks)

a) Apparatus required:

- Convex lens.
- Lens holder.
- White screen.
- Metre rule.
- Distant object.

(3 marks)

b) Procedure:

1. Mount the convex lens vertically using a lens holder.
2. Point the lens towards a distant object.
3. Place a white screen behind the lens.
4. Move the screen until a sharp, clear image is formed.
5. Measure the distance between the optical centre of the lens and the screen.

(3 marks)

c) A distant object is used because light rays from it are approximately parallel when they reach the lens. The image is therefore formed approximately at the principal focus. (2 marks)

d) Given:

Focal length, f=20 cm =0.20 m

Power of a lens:

$$P = \frac{1}{f}$$

$$P = \frac{1}{0.20}$$

P=5D

(2 marks)

34. The Human Eye and Defects of Vision (10 Marks)

a) Functions of parts of the human eye:

- **Cornea:** Refracts light entering the eye.
- **Iris:** Controls the amount of light entering the eye by adjusting the pupil.
- **Retina:** Contains light-sensitive cells that detect light and convert it into nerve impulses.

(3 marks)

b) Accommodation when viewing a nearby object:

- Ciliary muscles contract.
- Suspensory ligaments become slack.
- The lens becomes thicker and more convex.
- The focal length decreases, increasing the refractive power of the eye.

(3 marks)

c) Differences between myopia and hypermetropia:

Myopia (short-sightedness)	**Hypermetropia (long-sightedness)**
A person sees nearby objects clearly but distant objects appear blurred.	A person sees distant objects clearly but nearby objects appear blurred.
Image forms in front of the retina.	Image forms behind the retina.
Corrected using a concave lens.	Corrected using a convex lens.

(4 marks)

35. Applications of Thin Lenses (10 Marks)

a) Types of lenses used:

- Simple microscope: Convex lens.
- Compound microscope: Two convex lenses (objective and eyepiece).
- Camera: Convex lens.

(3 marks)

b) A simple microscope magnifies an object by using a convex lens to produce a magnified, upright and virtual image when the object is placed within its focal length. (2 marks)

c) Differences between simple and compound microscopes:

Simple microscope	**Compound microscope**
Uses one convex lens.	Uses two convex lenses.
Has relatively low magnification.	Has higher magnification.

Has a simpler construction.	Has a more complex construction.

(3 marks)

d) Role of a camera lens:

- Refracts and focuses light from an object onto the film or image sensor.
- Helps produce a clear image.
- Allows focusing on objects at different distances. (2 marks)

STRAND: NATURAL PHYSICAL SCIENCE

SUBSTRAND 3.2: NEWTON'S LAWS OF MOTION

Introduction

- The laws governing the motion of a body are grouped into three.
- They are based on the effects of force on a body.Some of the effects of force on a body include:
  - ✓ Force can make a stationary body to start moving
  - ✓ Can make a moving to stop.
  - ✓ Can deform a body i.e. change its shape.
  - ✓ Can change the direction of a moving body.
  - ✓ Can change the speed of a moving body.

Newton's First Law of Motion

- The law states: *a body remains in its state of rest or uniform motion in a straight line unless acted upon by an external force.*
- This explains the following common observations:
  - ✓ Passengers in a bus are pushed forward when brakes are applied suddenly or backwards when a bus at rest takes off suddenly. Hence the fitting of seatbelts in vehicles.
  - ✓ A coin placed on a cardboard on top of a glass tumbler drops into the tumbler when the cardboard is pulled sideways.
  - ✓ Athletes run past the finish line of a race before they finally stop.
- These observations show that bodies have an in-built reluctance to changes in their state of motion or rest. The tendency of a body to resist change in its state of rest or motion is called **inertia**. Hence Newton's first law of motion is also referred to as the **law of inertia** .

Newton's Second Law

- This law states: *the rate of change of momentum of a body is directly proportional to the resultant external force acting on the body and takes place in the direction of the force.*
- Moment of a body is defined as the product of its mass and velocity.
- Since velocity is a vector quantity, momentum is also a vector quantity having both magnitude (size) and direction. Momentum P=mass, m × velocity, v
- Hence the **unit of momentum** is the **kilogram-metre per second (kgm/s)**.
- The direction of momentum is the same as that of the velocity. The change of momentum is therefore caused by a change in velocity
- Suppose the velocity of a body of mass m changes from an initial value u to a value v after a time t , then: The initial momentum P_i = mu

The final momentum $P_f = mv$
The change in momentum = final momentum − initial momentum
Thus $\Delta P = P_f - P_i = mv - mu = m(v - u)$
Therefore, the rate of change of momentum $= {}^{\Delta P}/_{t} = {}^{m(v-u)}/_{t}$

- From the equations of linear motion, ${}^{(v-u)}/_{t}$ = acceleration a
  Hence ${}^{\Delta P}/_{t} = ma$.
- From the second law of motion, F α ma. And so the force F= mass m × acceleration, a (F=ma).
  Therefore, $F = ma = {}^{m(v-u)}/_{t}$
  And $Ft = m(v-u)$.
- The product of the force and time is called **impulse**.
- It is a vector quantity since force is a vector quantity.
- The unit of impulse is the **newton-second(Ns).**
- Impulse is also equal to the change in momentum(mv-mu). Hence impulse can also be expressed in **kgm/s.**

Example 2.1

1. Two stones of mass 8kg and 4kg move with velocities 3m/s and 6m/s respectively. Compare their momentum.
   $P_{8kg} = mv = 8 \times 3 = 24kgm/s$
   $P_{4kg} = mv = 4 \times 6 = 24kgm/s$
   Hence they have the same momentum.
2. A ball of mass 35g travelling horizontally at 20m/s strikes a barrier normally and rebounds with a speed of 3m/s. Find the impulse exerted on the ball.
   Impulse $= Ft = m(v-u) = (0.035 \times 20) - (0.035 \times -3)$
   $= 1.26Ns$
   Note that the two speeds are in opposite directions.
3. A kick that lasts 0.03s sends a ball of mass 0.65kg with a velocity of 15m/s northwards. Find:
   a. The change in momentum of the ball.
      Note that the ball is initially at rest, i.e. u = 0m/s.
      $\Delta P = mv - mu = (0.65 \times 15) - (0.65 \times 0) = 9.75kgm/s$
   b. The average force exerted on the ball.
      $F = {}^{m(v-u)}/_{t} = {}^{(9.75kgm/s)}/_{0.03s)} = 325N$
   c. The displacement of the ball in 2 seconds.
      The upward acceleration of the ball is negative $2m/s^2$.
      $S = ut + \frac{1}{2}at^2 = (15 \times 0.03) + (\frac{1}{2} \times -2 \times 0.03^2) = 2m/s$.

Newton's Third Law

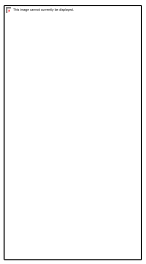
- The law states: *for every action there is an equal and opposite reaction*.
- We look at the working of a lift in relation to the third law of motion in three situations:
   a. **When the lift is at rest.**
      This implies that the resultant force on the lift is zero i.e. action and reaction are equal in size. The force acting on the lift is the weight of the person standing in the lift. This is balanced by the reaction by the floor of the lift.
      Therefore, weight mg=−reaction R,
      Or simply; mg+R=0.
   b. **When the lift descends with an acceleration, a**
      For the lift to move downwards, the weight of the occupant must be greater than the reaction by the floor of the lift.
      Therefore, the resultant force pulling the lift downwards is equal to the difference between the weight

mg and the reaction R;
Resultant force F= mg−R.
From the second law of motion, the resultant force F=ma.
Therefore, ma=mg−R.
And R=mg−ma =m(g−a).

c. **When the lift ascends with an acceleration, a**
In this case, the reaction by the floor of the lift must be greater than the weight of the occupant.
Hence, the resultant force F=ma=R−mg.
And R=ma+mg=m(a+g).

- The following are some cases where the third law of motion has been applied in everyday life:

a. A balloon moves in an opposite direction when air in it is released.



b. When a gun is fired, the bullet leaves the gun while the gun recoils backwards

c. For a person running or walking, one exerts a backward force on the ground with the ground exerting a forward push on the foot of the person. This makes running or walking possible.

Example 2.2

1. A man of mass 75kg stands on a weighing machine in a lift. Determine the reading on the weighing machine when the lift:

a. Ascends with an acceleration of 2m/s 5.
F=ma=R−mg
(75 x 2)=R-(75 x 2)
R=150+750 =900N

b. Descends at a constant velocity of 1.5m/s.
F=ma=mg-R
But a=0 since the velocity is constant.
Therefore, 75 x 0=75 x 2 – R
R=750N

c. Descends with an acceleration of 5.5m/s 5.
75 x 5.5= 75 x 2 – R
R=750 − 183.5=565.5N

2. A car of mass 1500kg is brought to rest from a velocity of 25m/s by a constant force of 3000N. Determine the change in momentum produced by the force and the time it takes the car to come to rest.
ΔP=mv−mu = 1500(0−25)=−37500kgm/s.
Ft=ΔP
We ignore the negative sign in this part because time is a scalar quantity.
3000 x t = 37500
$t = {}^{37500}/_{3000}$ =15.5 seconds.

Collision and the Law of Conservation of Momentum

- The *law of conservation of momentum* of a body states that *when two or more bodies collide, their total linear momentum before and after collision remain constant provided no external force acts on them;*
i.e. momentum before collision= momentum after collision.

- There are basically two types of collisions namely elastic and inelastic collision.

a. **Elastic collision**
This is where the bodies move separate ways after collision. In this collision, not only linear momentum is conserved but also kinetic energy;
Total linear momentum before collision= total linear momentum after momentum.
Total kinetic energy before collision= total kinetic energy after collision.

b. **Inelastic collision**
This is where the colliding bodies stick together and move as one body after collision.
In this type of collision, it is only linear momentum which is conserved but not kinetic energy.
This is because during this collision, some deformation takes place which eats up part of the energy while some is converted to heat, sound or light energy.
Total linear momentum before collision = total linear momentum after collision.

Example 2.3

1. A bullet of mass 20g is shot from a gun of mass 20kg with a muzzle velocity of 200m/s. if the bullet is 30cm long, determine:

   a. The acceleration of the bullet.
   For the bullet: u=0, v=200m/s, s=0.3m
   $v^2 = u^2 + 2as$
   $200^2 = 0 + (2)(0.3a)$
   $a = {}^{40000}/_{0.6} = 6.667 \times 10^3\ m/s^2$

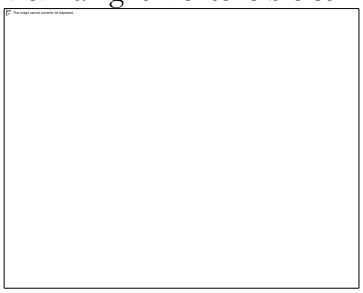
   b. The recoil velocity of the gun.
   Total linear momentum before collision=total linear momentum after collision
   $(20\times0) + (0.02 \times 0) = (20 \times v) + (0.02 \times 200)$
   $v = -{}^{4}/_{20} = -0.2m/s.$

2. A 5kg mass moving with a velocity of 2m/s collides with a 2kg mass moving at 7m/s along the same line. If the two masses join together on impact, find their common velocity if they were moving:

   a. In opposite directions.
   Total linear momentum before collision = total linear momentum after collision
   $(5\times2) + (2\times-7) = (5+2)v$
   $15v = -20$
   $v = -20/15 = -1.33m/s$
   the bodies move in the initial direction of the 2kg mass.

   b. In the same direction.
   Total linear momentum before collision=total linear momentum after collision
   $(5\times2)+(2\times7)=(5+2)v$
   $15v=120$
   $v = {}^{120}/_{15} = 8m/s$

3. A bullet of mass 2g travelling horizontally at 20m/s embeds itself in a block of wood of mass 990g suspended from a light inextensible string so that it can swing freely. Find:



   a. The velocity of the bullet and block immediately after collision.
   $(0.01 \times 20)+(0.99 \times 0) = (0.01+0.99)v$
   $v = {}^{1}/_{1} = 1m/s$

b. The height through which the block rises.
At the maximum height, all the kinetic energy is converted into potential energy.
k.e=p.e
$\frac{1}{2}(mv^2)=mgh$
$\frac{1}{2}(0.01+0.99)1^2=(0.01+0.99)(2)h$
h=0.05m

Friction

- This is a force acting between two surfaces in contact and tends to oppose the intended motion. Friction may be beneficial but can also be a nuisance.

Advantages of Friction

- Makes walking, writing possible.
- Required for braking in cars, bicycles etc.
- Makes rotation of the conveyor belts in factories possible.
- Necessary for lighting matchsticks.
- Useful when using nuts, bolts, screw jacks, vices etc.

Limitations of Friction

- A lot of energy is lost in the form of heat.
- Causes wear and tear on the pars of machines.
- May lead to noise pollution.
  It is therefore important to minimize friction at all cost.

Ways of Minimizing Friction

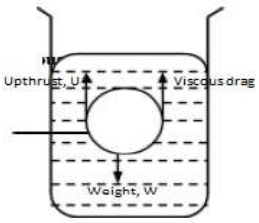
- Using rollers.
- Using ball bearings.
- Lubrication
- Air cushioning.

Factors Affecting Friction

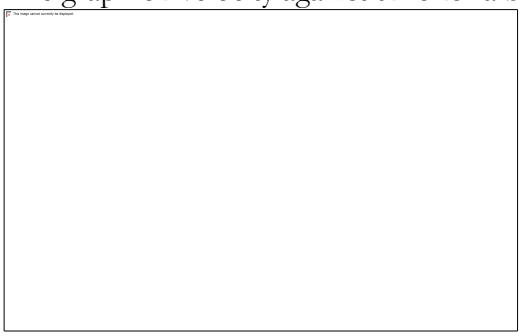
- Frictional force is directly proportional to the normal reaction R;
  $F \propto R$
  Or simply F/R= a constant.
- The constant is called coefficient of friction μ. It is a measure of the nature of the surfaces in contact.
  Hence, frictional force F= normal reaction R × coefficient of friction μ.
- When the two bodies are at rest, then the coefficient of friction is referred to as coefficient of static friction while if they are in relative motion, it is called coefficient of kinetic friction. Coefficient of friction has no units.
- Hence, friction depends on two factors:
  - ✓ The normal reaction R.
  - ✓ The nature of the surface. Frictional force is greater between rough surfaces than between smooth surfaces.
- Note that frictional force is independent of the area of contact of the two surfaces and relative velocity of the bodies.

Viscosity

- Friction exerted by fluids is called **viscosity** or **viscous drag** . It is the force which opposes relative motion between layers of the fluid.
- Viscosity is caused by the forces of attraction between the molecules of the fluid.
- When a body is put in a fluid, three forces act on it, namely:
  - ✓ Weight of the body which acts downwards.
  - ✓ Upthrust due to the fluid which acts upwards.
  - ✓ Viscous drag due to the fluid which acts upwards.



- When the body enters the fluid, its weight is initially higher than the total upward forces i.e. upthrust plus viscous drag.
- The resultant force acting on the body accelerates it towards the bottom of the container. As the body sinks down, the viscous drag increases until the three forces balance i.e. W= U+ F. at this point, the body attains its maximum constant velocity called terminal velocity.
- The resultant force on the body is therefore zero.
- The graph of velocity against time for a body falling through a fluid appears as shown below:



- Note that viscosity decreases with increase in temperature.

QUESTIONS

Strand 3.0: Natural Physical Science

Sub-strand 3.2: Newton's Laws of Motion

SECTION A: MULTIPLE-CHOICE QUESTIONS

Choose the most appropriate answer in each question.

1. A passenger standing in a matatu is thrown forward when the driver applies emergency brakes to avoid hitting a pedestrian. The passenger was not holding onto anything. Which explanation best accounts for this observation?

A. The passenger is pushed forward by the braking force of the vehicle.
B. The passenger's body tends to maintain its initial state of motion.
C. The passenger's weight increases when the vehicle stops.
D. The friction between the passenger's feet and the floor becomes zero.

2. A learner places a coin on a piece of cardboard covering the mouth of a glass. When the cardboard is flicked horizontally, the coin falls into the glass. Which conclusion is best supported by this experiment?

A. The coin has no weight when the cardboard moves.
B. The coin tends to remain in its initial state of rest.
C. The cardboard exerts an upward force on the coin.
D. The coin moves because of air resistance.

3. Two delivery vehicles of masses 1,000 kg and 2,000 kg are moving at the same speed along a straight road. The driver of each vehicle applies the same braking force. Which vehicle is expected to have the greater deceleration?

A. The 1,000 kg vehicle
B. The 2,000 kg vehicle
C. Both vehicles have equal deceleration.
D. Neither vehicle experiences deceleration.

4. A mechanic applies a force of 60 N to push a trolley of mass 15 kg. Friction opposing the motion is 15 N. What acceleration does the trolley acquire?

A. 1 m/s^2
B. 2 m/s^2
C. 3 m/s^2
D. 4 m/s^2

5. A farmer pushes a stationary wheelbarrow. Initially, it is difficult to start moving, but after it starts moving, maintaining its motion requires less effort. Which concept best explains the initial resistance to motion?

A. Momentum
B. Inertia
C. Action and reaction
D. Conservation of energy

6. A student argues that a book resting on a table has no forces acting on it because it is stationary. Which response correctly evaluates the student's argument?

A. The student is correct because stationary objects have no forces.
B. The student is wrong because the weight and normal reaction balance each other.
C. The student is correct because gravity acts only on moving objects.
D. The student is wrong because the normal reaction is always greater than weight.

7. A footballer kicks a stationary ball with a force that causes it to accelerate. If the same force is applied to a ball with twice the mass, what happens to its acceleration?

A. It doubles.
B. It becomes four times greater.
C. It becomes half as much.
D. It remains unchanged.

8. A rocket is launched vertically. Hot gases are expelled downwards at high speed, causing the rocket to rise. Which interpretation is scientifically correct?

A. The gases pull the rocket upwards through gravity.
B. The rocket pushes the gases downwards, and the gases exert an opposite force on the rocket.
C. The rocket rises because its mass becomes zero.
D. The gases have no effect on the rocket's motion.

9. A learner pushes a wall with a force of 100 N but the wall does not move. Which statement is correct?

A. The wall exerts no force on the learner.
B. The wall exerts a force of 100 N in the opposite direction on the learner.
C. The learner's force disappears because there is no movement.
D. The wall exerts a force greater than 100 N because it is stationary.

10. A bus moving at 20 m/s is brought to rest in 5 seconds. If its mass is 4,000 kg, what is the magnitude of the resultant braking force?

A. 4,000 N
B. 8,000 N
C. 16,000 N
D. 20,000 N

11. A learner investigates how mass affects inertia by pushing two trolleys, one empty and one loaded, using the same force. The loaded trolley accelerates less. Which conclusion is most appropriate?

A. Increasing mass decreases inertia.
B. Increasing mass increases resistance to acceleration.
C. Increasing mass increases the applied force.
D. Mass has no effect on acceleration.

12. A goalkeeper catches a fast-moving ball and moves his hands backwards while stopping it. Why is this technique safer?

A. It increases the momentum of the ball.
B. It reduces the time taken to stop the ball.
C. It increases the time over which the ball's momentum changes, reducing the average force.
D. It increases the mass of the ball.

13. A loaded lorry and an empty lorry move at the same speed. Which statement correctly compares their momenta?

A. The loaded lorry has greater momentum because it has greater mass.
B. The empty lorry has greater momentum because it accelerates easily.
C. Both have equal momentum because their speeds are equal.
D. Both have zero momentum because they are moving at constant speed.

14. Two ice skaters initially at rest push each other apart. One skater has a mass of 40 kg and the other has a mass of 60 kg. Which statement best describes their motion immediately after the push?

A. Both move in the same direction.
B. The heavier skater moves faster.
C. They move in opposite directions, and the lighter skater has the greater speed.
D. The lighter skater remains stationary.

15. A car collides with a stationary parked vehicle, and the two vehicles lock together after impact. Which type of collision is represented?

A. Elastic collision
B. Inelastic collision
C. Perfectly elastic collision
D. No collision

16. Two billiard balls collide and move apart. In an ideal elastic collision, which quantities are conserved in the isolated system?

A. Momentum only
B. Kinetic energy only
C. Both momentum and kinetic energy
D. Neither momentum nor kinetic energy

17. A learner claims that momentum is lost when two vehicles collide because their speeds decrease. Which statement provides the best scientific correction?

A. Momentum is destroyed during all collisions.
B. Total momentum is conserved in an isolated system, although kinetic energy may be transformed into other forms.
C. Momentum is conserved only when objects do not touch.
D. Momentum is equal to kinetic energy.

18. A bullet is fired from a rifle. The bullet moves forwards while the rifle recoils backwards. If the bullet has a much smaller mass than the rifle, why does the rifle move backwards at a lower speed?

A. The rifle experiences no reaction force.
B. The rifle has a larger mass and therefore needs a smaller speed to balance momentum.
C. The bullet has no momentum.
D. The rifle loses all its inertia.

19. A 0.5 kg ball moving at 8 m/s is stopped by a player's hands in 0.4 seconds. What is the magnitude of the average stopping force?

A. 2 N
B. 5 N
C. 10 N
D. 20 N

20. A 2 kg trolley moving at 5 m/s collides with a stationary 3 kg trolley. They move together after collision. What is their common velocity?

A. 1 m/s
B. 2 m/s
C. 3 m/s
D. 5 m/s

21. A road safety officer explains that a vehicle travelling at high speed requires a longer stopping distance than the same vehicle travelling slowly, under similar road conditions. Which combination best explains this?

A. Greater momentum and greater distance needed to reduce velocity to zero.
B. Lower inertia and lower momentum.

C. Lower mass and greater friction.
D. Greater weight and zero acceleration.

22. A 1,500 kg vehicle is travelling along a level road. Its engine provides a forward force of 5,000 N while resistive forces total 2,000 N. What is its acceleration?

A. 1 m/s^2
B. 2 m/s^2
C. 3 m/s^2
D. 5 m/s^2

23. A student performs an experiment by placing different masses on a trolley and pulling it with the same force. Which graph would best demonstrate the relationship between acceleration and mass?

A. Acceleration increases directly with mass.
B. Acceleration decreases as mass increases.
C. Acceleration remains constant for all masses.
D. Acceleration is independent of mass.

24. A 50 kg learner jumps forwards from a stationary boat of mass 150 kg. If the learner moves at 3 m/s immediately after jumping, what is the velocity of the boat?

A. 0.5 m/s forwards
B. 1 m/s backwards
C. 1 m/s forwards
D. 3 m/s backwards

25. During a road accident investigation, an officer observes that a vehicle's front section is badly deformed after hitting a barrier. Which statement best explains the energy changes during the collision?

A. All kinetic energy is converted into momentum.
B. Some kinetic energy is transformed into sound, heat and deformation energy.
C. Momentum is converted into mass.
D. Kinetic energy is always conserved in every collision.

26. A student states that when a person walks, the foot pushes the ground backwards and the ground pushes the person forwards. Which evaluation is correct?

A. The statement is wrong because the forces act on the same object.
B. The statement is correct because the two forces act on different objects.
C. The statement is wrong because the ground cannot exert force.
D. The statement is correct only when the person is running.

27. A 4 kg trolley moving at 6 m/s collides with a 2 kg trolley moving in the opposite direction at 3 m/s. They stick together. Taking the initial direction of the 4 kg trolley as positive, what is their common velocity?

A. 1 m/s forwards
B. 2 m/s forwards
C. 3 m/s forwards
D. 5 m/s forwards

28. A student designs a safety system in which an airbag inflates during a collision. Which explanation best justifies its effectiveness?

A. It increases the momentum of the passenger.
B. It increases the time taken to reduce the passenger's momentum, reducing the average force.

C. It prevents the passenger from having inertia.
D. It reduces the passenger's mass during impact.

29. A 0.2 kg ball strikes a wall at 10 m/s and rebounds at 6 m/s in the opposite direction. Taking the direction towards the wall as positive, what is the change in momentum?

A. -0.8 kg m/s
B. -3.2 kg m/s
C. $+0.8$ kg m/s
D. $+3.2$ kg m/s

30. Two students are discussing why a rocket can move in space where there is no air. Which explanation is the most accurate?

A. A rocket requires air to push against.
B. A rocket moves because expelled gases carry momentum in one direction and the rocket gains momentum in the opposite direction.
C. Gravity is the only force that can move a rocket.
D. A rocket moves because its weight disappears in space.

SECTION B: STRUCTURED QUESTIONS **50 Marks**

Answer all questions. Show complete working in all calculations.

Question 31: Inertia and Newton's First Law (8 marks)

A school bus is travelling along a straight road at a constant speed. A learner standing in the bus notices that when the driver suddenly applies the brakes, passengers tend to move forwards. The driver explains that this is why passengers must remain seated or hold onto the available supports.

a) Use Newton's first law to explain why passengers move forwards when the bus stops suddenly. (3 marks)

b) A learner argues that a heavier passenger will always move forwards faster than a lighter passenger during sudden braking. Evaluate this claim using the concept of inertia. (2 marks)

c) Describe an experiment using a coin, a card and a glass to demonstrate inertia. Include the procedure and expected observation. (3 marks)

Question 32: Newton's Second Law and Road Transport (10 marks)

A delivery vehicle of mass 1,500 kg moves along a level road. Its engine produces a forward driving force of 6,000 N. The total resistive force due to air resistance and friction is 1,500 N.

a) Calculate the resultant force acting on the vehicle. (2 marks)

b) Determine the acceleration of the vehicle. (2 marks)

c) If the resistive force increases to 3,000 N while the driving force remains unchanged, calculate the new acceleration. (2 marks)

d) Explain why the vehicle's acceleration changes when the resistive force increases. (2 marks)

e) A second vehicle has twice the mass of the first vehicle but experiences the same resultant force. Compare their accelerations and explain your answer. (2 marks)

Question 33: Conservation of Momentum and Collisions (12 marks)

During a school physics practical, learners use two trolleys on a smooth horizontal track.

Trolley A has a mass of 4 kg and moves at 5 m/s towards trolley B, which has a mass of 6 kg and is initially at rest. After collision, the two trolleys lock together and move as one body.

a) State the law of conservation of linear momentum. (2 marks)

b) Calculate the total momentum of the two trolleys before collision. (2 marks)

c) Calculate the common velocity of the trolleys immediately after collision. (4 marks)

d) Explain why the collision is classified as inelastic. (2 marks)

e) State two forms of energy into which some kinetic energy may be transformed during the collision. (2 marks)

Question 34: Newton's Third Law and Applications (10 marks)

A learner uses a balloon-powered car during a science exhibition. The learner inflates a balloon attached to a lightweight toy car and releases the opening. The car moves forwards as air escapes backwards.

a) Identify the action force and reaction force in this activity. (3 marks)

b) Explain why the car moves forwards when air is expelled backwards. (2 marks)

c) State two other everyday applications of Newton's third law of motion. (2 marks)

d) A learner claims that action and reaction forces cancel each other, so the balloon-powered car should not move. Explain the error in this reasoning. (3 marks)

Question 35: Impulse, Momentum and Safety (10 marks)

A 0.4 kg football is moving towards a goalkeeper at 20 m/s. The goalkeeper catches the ball and brings it to rest in 0.5 seconds.

a) Calculate the initial momentum of the ball. (2 marks)

b) Calculate the change in momentum of the ball. (2 marks)

c) Calculate the magnitude of the average force exerted on the ball by the goalkeeper. (3 marks)

d) Explain why the goalkeeper moves his hands backwards while catching the ball. (2 marks)

e) State one other safety application of increasing the time taken to stop a moving object. (1 mark)

MARKING SCHEME

SECTION A: MULTIPLE-CHOICE ANSWERS (30 MARKS)

Question	Correct answer	Question	Correct answer	Question	Correct answer
1	B	11	B	21	A
2	B	12	C	22	B
3	A	13	A	23	B
4	C	14	C	24	B
5	B	15	B	25	B
6	B	16	C	26	B
7	C	17	B	27	C*
8	B	18	B	28	B
9	B	19	C	29	B
10	C	20	B	30	B

SECTION B: STRUCTURED QUESTIONS – DETAILED MARKING SCHEME

QUESTION 31: INERTIA AND NEWTON'S FIRST LAW (8 MARKS)

a) Use Newton's first law to explain why passengers move forwards when the bus stops suddenly. (3 marks)

Newton's first law states that:

A body remains at rest or continues moving with uniform velocity in a straight line unless acted upon by an unbalanced external force. (1 mark)

When the bus is moving, the passengers are also moving forwards with the bus. (1 mark)

When the driver applies brakes suddenly, the bus slows down, but the passengers' bodies tend to continue moving forwards due to inertia. (1 mark)

b) A learner argues that a heavier passenger will always move forwards faster than a lighter passenger during sudden braking. Evaluate this claim using inertia. (2 marks)

The claim is incorrect. (1 mark)

A heavier passenger has greater inertia because inertia increases with mass. However, greater inertia does not automatically mean that the passenger moves forwards faster. The motion depends on the forces acting on the passenger and the initial motion of the bus. (1 mark)

c) Describe an experiment using a coin, a card and a glass to demonstrate inertia. (3 marks)

Procedure:

1. Place an empty glass on a flat surface. (1 mark)
2. Place a piece of cardboard over the mouth of the glass and put a coin on top of the cardboard. (1 mark)
3. Flick the cardboard quickly in a horizontal direction. The coin falls vertically into the glass because it tends to remain at rest when the cardboard is removed. (1 mark)

Total: 8 marks

QUESTION 32: NEWTON'S SECOND LAW AND ROAD TRANSPORT (10 MARKS)

Given:

- Mass of vehicle, $m = 1500\,kg$
- Driving force = 6000 N
- Initial resistive force = 1500 N

a) Calculate the resultant force acting on the vehicle. (2 marks)

Formula:

$$F_R = F_{\text{driving}} - F_{\text{resistive}}$$

Substitution:

$$F_R = 6000 - 1500$$

$$\boxed{F_R = 4500\,N}$$

Mark allocation:

- Correct formula (1 mark)
- Correct answer (1 mark)

b) Determine the acceleration of the vehicle. (2 marks)

Using Newton's second law:

$$F = ma$$

Making acceleration the subject:

$$a = \frac{F}{m}$$

Substitution:

$$a = \frac{4500}{1500}$$

Mark allocation:

- Correct formula and substitution (1 mark)
- Correct answer with unit (1 mark)

c) If the resistive force increases to 3000 N while the driving force remains unchanged, calculate the new acceleration. (2 marks)

New resultant force:

$$F_R = 6000 - 3000$$

$$F_R = 3000\,N$$

Using:

$$a = \frac{F_R}{m}$$

$$a = \frac{3000}{1500}$$

Mark allocation:

- Correct resultant force (1 mark)
- Correct acceleration (1 mark)

d) Explain why the vehicle's acceleration changes when the resistive force increases. (2 marks)

- Increasing the resistive force reduces the resultant forward force acting on the vehicle. (1 mark)
- According to Newton's second law, a smaller resultant force produces a smaller acceleration when mass remains constant. (1 mark)

e) A second vehicle has twice the mass of the first vehicle but experiences the same resultant force. Compare their accelerations and explain your answer. (2 marks)

First vehicle:

Second vehicle mass:

$$m_2 = 2(1500) = 3000\,kg$$

Using the same resultant force:

$$a_2 = \frac{4500}{3000}$$

- Correct comparison: the second vehicle has half the acceleration of the first. (1 mark)
- Correct explanation: acceleration is inversely proportional to mass for a constant resultant force. (1 mark)

Total: 10 marks

QUESTION 33: CONSERVATION OF MOMENTUM AND COLLISIONS (12 MARKS)

Given:

- Mass of trolley A, $m_1 = 4\,kg$
- Initial velocity of trolley A,
- Mass of trolley B, $m_2 = 6\,kg$
- Initial velocity of trolley B,
- The trolleys stick together after collision.

a) State the law of conservation of linear momentum. (2 marks)

The total linear momentum of a system remains constant provided no resultant external force acts on the system. (2 marks)

b) Calculate the total momentum of the two trolleys before collision. (2 marks)

Formula:

$$p = m_1u_1 + m_2u_2$$

Substitution:

$$p = (4 \times 5) + (6 \times 0)$$

$$p = 20 + 0$$

Mark allocation:

- Correct formula (1 mark)
- Correct answer with unit (1 mark)

c) Calculate the common velocity of the trolleys immediately after collision. (4 marks)

Using conservation of momentum:

$$\text{Momentum before} = \text{Momentum after}$$

$$m_1u_1 + m_2u_2 = (m_1 + m_2)v$$

Substitution:

$$(4 \times 5) + (6 \times 0) = (4 + 6)v$$

$$20 = 10v$$

$$v = \frac{20}{10}$$

Mark allocation:

- Correct conservation equation (1 mark)
- Correct substitution (1 mark)
- Correct rearrangement (1 mark)
- Correct answer with unit (1 mark)

d) Explain why the collision is classified as inelastic. (2 marks)

- The two trolleys stick together and move with a common velocity after collision. (1 mark)
- Kinetic energy is not conserved in an inelastic collision; some is transformed into other forms of energy. (1 mark)

e) State two forms of energy into which some kinetic energy may be transformed during the collision. (2 marks)

Any two:

- Sound energy.
- Heat energy.
- Deformation energy.
- Internal energy.

(1 mark each)

Total: 12 marks

QUESTION 34: NEWTON'S THIRD LAW AND APPLICATIONS (10 MARKS)

a) Identify the action force and reaction force in the balloon-powered car activity. (3 marks)

- Action force: The balloon pushes the escaping air backwards. (1 mark)
- Reaction force: The escaping air exerts an equal force forwards on the balloon. (1 mark)
- The forward reaction force propels the car forwards. (1 mark)

b) Explain why the car moves forwards when air is expelled backwards. (2 marks)

- The balloon exerts a force on the air, accelerating it backwards. (1 mark)
- The air exerts an equal and opposite force on the balloon and car, causing the car to accelerate forwards. (1 mark)

c) State two other everyday applications of Newton's third law of motion. (2 marks)

Any two:

- Walking: the foot pushes the ground backwards while the ground pushes the person forwards.
- Swimming: the swimmer pushes water backwards while the water pushes the swimmer forwards.
- Rowing: the oar pushes water backwards while water pushes the boat forwards.
- Rocket propulsion.
- Recoil of a gun when a bullet is fired.
- A person jumping from a boat.

(1 mark each)

d) A learner claims that action and reaction forces cancel each other, so the balloon-powered car should not move. Explain the error in this reasoning. (3 marks)

- Action and reaction forces are equal in magnitude. (1 mark)
- They act in opposite directions. (1 mark)
- They act on different bodies, not on the same body. Therefore, they do not cancel each other on the car, and the car can accelerate forwards. (1 mark)

Total: 10 marks

QUESTION 35: IMPULSE, MOMENTUM AND SAFETY (10 MARKS)

Given:

- Mass of ball, $m = 0.4\,kg$
- Initial velocity,
- Final velocity,
- Time taken, $t = 0.5\,s$

a) Calculate the initial momentum of the ball. (2 marks)

Formula:

$$p = mv$$

Substitution:

$$p = 0.4 \times 20$$

Mark allocation:

- Correct formula (1 mark)
- Correct answer with unit (1 mark)

b) Calculate the change in momentum of the ball. (2 marks)

Formula:

$$\Delta p = mv - mu$$

Substitution:

$$\Delta p = (0.4 \times 0) - (0.4 \times 20)$$

$$\Delta p = 0 - 8$$

The negative sign indicates that the change in momentum is opposite to the initial direction of motion.

Mark allocation:

- Correct formula and substitution (1 mark)
- Correct answer, including direction or negative sign (1 mark)

c) Calculate the magnitude of the average force exerted on the ball by the goalkeeper. (3 marks)

Using the rate of change of momentum:

$$F = \frac{\Delta p}{t}$$

Substitution:

$$F = \frac{-8}{0.5}$$

$$F = -16\,N$$

Therefore, the magnitude is:

$$\boxed{F = 16\,N}$$

Mark allocation:

- Correct formula (1 mark)
- Correct substitution (1 mark)
- Correct magnitude with unit (1 mark)

d) Explain why the goalkeeper moves his hands backwards while catching the ball. (2 marks)

- Moving the hands backwards increases the time taken to bring the ball to rest. (1 mark)
- Increasing the stopping time reduces the average force acting on the goalkeeper's hands for the same change in momentum. (1 mark)

e) State one other safety application of increasing the time taken to stop a moving object. (1 mark)

Any one:

- Airbags in motor vehicles.
- Safety belts in vehicles.
- Crumple zones in motor vehicles.
- Protective helmets with cushioning.
- Padded landing surfaces used in sports.

(1 mark)

Total: 10 marks

SUMMARY OF MARK ALLOCATION

Question	Topic	Marks
31	Inertia and Newton's First Law	8

Question	Topic	Marks
32	Newton's Second Law and Road Transport	10
33	Conservation of Momentum and Collisions	12
34	Newton's Third Law and Applications	10
35	Impulse, Momentum and Safety	10
Total		**50**

Overall examination distribution

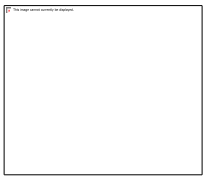
Section	Description	Marks
A	Multiple-choice questions	30
B	Structured questions	50
Total		**80**

Teacher's marking guidelines

1. Award marks for correct scientific explanations, even where learners use different but acceptable wording.
2. Award method marks for correct formulae and substitutions even when the final numerical answer is incorrect.
3. Accept equivalent SI units where appropriate.
4. Do not award full calculation marks for unsupported answers where working is required.
5. Accept other scientifically correct applications of Newton's laws.
6. For momentum questions, check that learners use consistent positive and negative directions.
7. Do not award more marks than indicated for any question.

TOPICAL REVISION QUESTIONS

1. Two masses of 3kg and 7kg are connected by a light string. The 3 kg mass rests on a smooth incline plane 300 to the horizontal. The 7 kg mass hangs freely from the frictionless pulley attached to the top of plane.
    i. Draw a diagram showing the bodies and identify the forces acting on the 3 kg mass.
    ii. Calculate the acceleration of the masses.
2. A rocket propelled upward with a constant thrust. Assuming friction due to air is negligible and the burning of the fuel is steady. Explain its motion.
3. A 2 kg body slides down a smooth slope from a height of 5m. As it reaches the horizontal, it strikes another body of mass 3 kg which is at rest. Both bodies stick together. Calculate the velocity of the bodies after collision.
4. A girl of mass 40 kg stands on a scale balance in a lift. The lift is accelerating upwards. At one instant the acceleration of the lift is 2 m/s. Calculate the reading on the scale at that instant.
5. The diagram below shows a tall measuring cylinder containing a viscous liquid. A very small steel ball is released from rest at the surface of the liquid as shown.



Sketch the velocity- time graph for the motion of the ball from the time it is released to the time just before it reaches the bottom of the cylinder.

6. A body of mass 5 kg is ejected vertically from the ground when a force of 600N acts on it for 0.1s. Calculate the velocity with which the body leaves the ground.
7.
    i.
        i. A body is initially in motion. If no external force acts on the body, describe the subsequent motion.
        ii. A car of mass 800 kg is initially moving at 25 m/s. Calculate the force needed to bring the car to the rest over a distance of 20 m.
    ii. Two trolleys of masses 2 kg and 1.5 kg are traveling towards each other at 0.25 m/s and 0.40 m/s respectively. Two trolleys combine on collision.
        i. Calculate the velocity of the combined trolleys.
        ii. In what direction do the trolleys move after collision?
8.
    i. The diagram below shows a block of mass 5 kg sliding down from rest on a plane incline at an angle of 300 to the horizontal. A frictional force of 6N acts between the block and the plane.



i. Copy the diagram and show the forces acting on the block.

ii. Calculate the resultant force on the block.

iii. Calculate the time taken by the block to cover the distance of 25cm.

ii. The table shows the value of the resultant force, F, and the time t for a bullet traveling inside the gun barrel after the trigger is pulled.

Force, F (N)	360	340	300	240	170	110
Time, (t) (milliseconds)	3	4	8	12	17	22

iii.

i. Plot a graph of Force, f against time t.

ii. Determine from the graph.

I. The time required for the bullet to travel the length of the barrel assuming that the force becomes zero just at the end of the barrel.

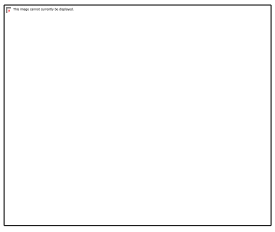
II. The impulse of the force.

III. Given that the bullet emerges from the muzzle of the gun with a velocity of 200 m/s, calculate the mass of the bullet.

9. The diagram below shows two identical strings A and B attached to a large mass M. String A is attached to the ceiling. State the reason why string B cuts when its free and is suddenly pulled downward.



10. The figure below shows a 2 kg block attached to 0.5 kg mass by a light inextensible string which passes over a pulley. The force of friction between the horizontal bench and block is 3N. The block is released from rest so that both masses move through a distance of 0.6m. Calculate the velocity of the string.



11. A trolley is moving at constant speed in a friction compensated track. Some plasticine is dropped on the trolley and sticks to it. State with a reason what is observed about the motion of the trolley.

12. The figure below shows a block of mass 30.0 kg being pulled up a slope by force P at a constant speed. The frictional force on the block is 20.0N



i.

i. On the same figure name and indicate other forces acting on the block.

ii. Determine the component of the weight acting on the trolley down the slope

iii. Determine the value of P.

ii. On reaching the top of the slope, the block is left to run freely down the slope.

i. Which one of the forces previously acting on the block would then act in the opposite direction?

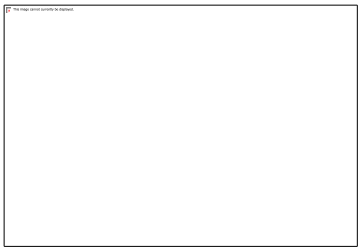
ii. Determine the acceleration of the block down slope.

iii. What is the effect of increasing the angle of slope on your answer in (ii) above?

13. A high jumper usually lands on a thick soft mattress. Explain how the mattress helps in reducing the force of impact.

14. A resultant force F acts on a body of mass m causing an acceleration a_1 on the body. When the same force acts on a body of mass 2m, it causes an acceleration a_2. Express a_2 in terms of a_1.

15.



The figure above shows two trolleys of mass 2.0 kg and 1.5 kg traveling towards each other at 0.25 m/s and 0.4 m/s respectively. The trolleys combine on collision. Calculate the velocity of the combined trolley and show the direction in which they move after collision.

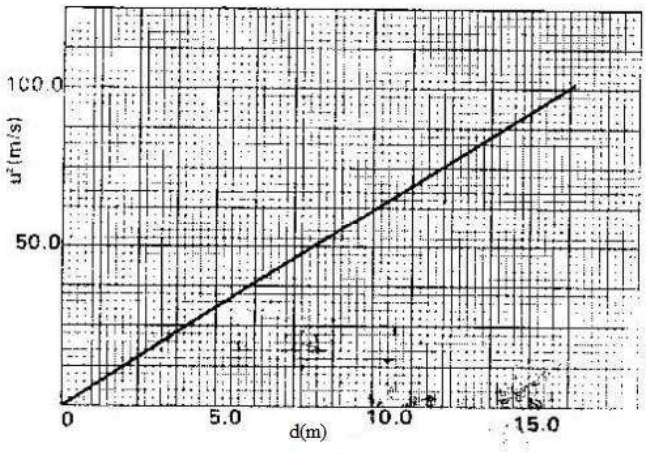
16. Two identical stones A and B are released from the same height above the ground. B falls through air while A falls through water. Sketch the graphs of kinetic energy (KE) against time (t) for each stone. Label the graph appropriately.

17. A trolley is moving at uniform speed along a track. A piece of plasticine is dropped on the trolley and sticks on it. Explain why the trolley slows down. (2 mks)

18.

i. State the Newtons law of motion. (1 mk)

ii. A wooden block resting on a horizontal bench is given an initial velocity, u, so that it slides on the bench surface for a distance, d, before coming to a stop. The values of d were measured and recorded for various values of initial velocity. The figure below shows the graph of u^2 against d.



i. Determine the slope, s, of the graph

ii. Given that u_2 = 20kd, where k is a constant for the bench surface, determine the value of k from the graph.

iii. State how the value of k would be affected by change in the roughness of the bench surface.

iii. A car of mass 800kg starts from the rest and accelerates at 1.2ms^{-2}. determine its momentum after it has moved 400m from the starting

19. A force of 6N acts on a 2kg trolley and accelerates at 2 m/s^2. Calculate the retarding force acting on the trolley.

20. A boulder is sliding down a slope, with a uniform acceleration of 3 ms^{-2}; calculate its velocity after it has slid 10m down the slope.

21. A man whose mass is 70 kg stands on a spring weighing machine. When the lift starts to ascend its acceleration is 2.45m/s^2. What is the reading on the scale?

22. A bullet of mass 22 g traveling at a velocity of 18 m/s penetrates a sand bag and is brought to rest in 0.6 seconds. Find:

i. The depth of penetration in metres

ii. The average retarding force of the sand

23. A bullet of mass 10g traveling horizontally with a velocity of 300 m/s strikes a block of wood of mass 290g which rests on rough horizontal floor. After impact they move together and come to rest after traveling a distance of 15m. Calculate

i. the common velocity of the bullet and the block.

ii. the acceleration of the bullet and the block.

iii. the coefficient of sliding friction between the block and the floor.

24.

i. A body of mass m initially at rest is acted on by a force F for a time t, as a result its velocity changes to a final value V. Use this information to show that the gain is kinetic energy E= ½ MV^2

ii. Calculate the kinetic energy of a car of mass 1000 kg traveling at 36 km/h

25. Under a driving force of 400N a car of mass 1250 kg has an acceleration of 2.5 m/s. Find the frictional force acting on the car.

26. An apple of mass 100g falls a distance of 2.5m to the ground from a branch of a tree.

i. Calculate the speed at which it hits the ground and the time taken for it to fall. (Ignore air resistance).

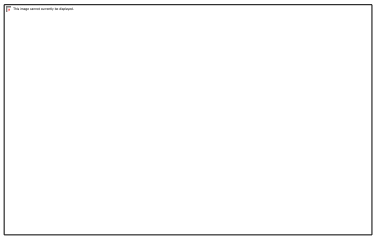
ii. Assuming the apple takes 100 milliseconds to come to rest. Calculate the average force experienced by the apple.

27. A helicopter of mass 3000 kg rises vertically at a constant speed of 25 ms^{-1} if the acceleration due to gravity is 10 ms^{-2}; determine the resultant force working on the helicopter

Answers

1.

i.



R - Reaction
W - Weight
T - Tension

ii. Net force= 70N – mgsinx= 70N- 30×sin 30
F= ma
55= (7 + 3) a
a= 5.5m/s^2

2. The rocket will accelerate due to 2 reasons

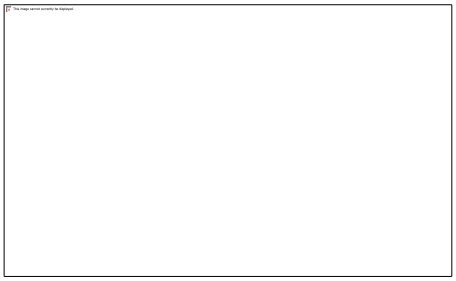
i. The total mass of the rocket decreases as the fuel burns but thrust force is constant

ii. The gravitational pull decreases with increase in distance from the centre of the earth so it will be less.

3. P.E = K.E
Mgh = ½ mv^2 therefore V= √(2gh) = √(20 x 5) = 10m/s
Momentum before collision = Momentum after collision
$M_1U_1 = (M_1 + M_2)20$
10 x 25 x 20
V= 4m/s

4. Total force downward = weight of the girl = 400N. Since the lift is moving upwards the upward force T, is greater than 400N therefore from F=ma
(T − 400) = 40 x 2
T = 480N = reading

5.



6. Force upward = 600N, Force downward = 50N (wt).Therefore Net force = 550N upwards.
F= ma = $^{m(v-u)}/_{t}$ = $^{m(v)}/_{t}$ since u= 0
550 = $^{(50 \times v)}/_{0.1}$
V = 11m/s

7.

i.

i. The body continues in its uniform state of motion velocity

ii. U= 25 m/s, V=0, S= 20m a=?
$V^2 = U^2 + 2as$
$0 = 625 + 40a$
$a = -15.625 m/s^2$
$F = ma = 800x - 15.625$
$= -12500N$
Therefore decelerating force= 12500N

ii. Since one is moving towards the other one is +ve while the other is –ve.
Momentum before collision = momentum after collision

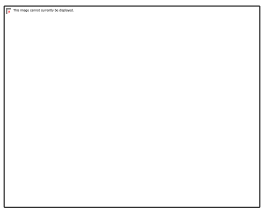
i. $M_1u_1 + m_2u_2 = (m_1+m_2)\ v$
$(2x\ 0.25) - (1.5 \times 0.4) = 3.5 \times v$
$0.5 - 0.6 = 3.5\ v$
$v = -0.02867 m/s$
$= -2.867 \times 10^{-2} m/s$

ii. The original direction of the 1.5kg mass

8.

i.

i.



Fr= Frictional force

ii. Force= mgsin 30 − 6
$= 5 \times 10 \times 0.5 - 6$
$= 19N$

iii. F= ma
$19 = 5a = a = 3.8 m/s^2$
U= 0 m/s
S= 0.25m
t =?
$s = ut + \frac{1}{2} at^2$
$0.25 = 0 + 1.9t^2$
$t^2 = 0.3627s$
$= 0.36s$

ii.

i. Plot the graph

ii. Let it touch y and x – axis

I. Time taken by bullet = x intercept (30ms)

II. Impuse = force x time = area bound between x – axis and the line of the graph (6Ns)

III. V= 200m/s m=?
Impulse = Ft = Mv – Mu
= 6Ns = M x 200-0 since u= 0
Therefore m= 0.03kg

9. M tends to remain in its state of uniform rest due to its inertia. This protects string A

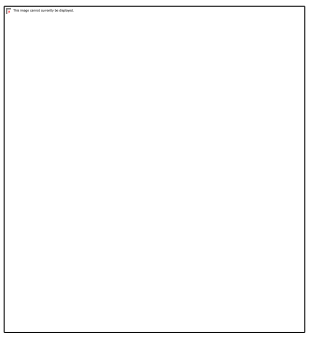
10. Propelling force= 0.5 x 10= 5N
Opposing force= frictional force = 3 N
Net Force = 5-3 = 2N
Using F= ma
2= (2+ 0.5)a
a= 0.8m/s^2
s= 0.6m
u=0
$V^2 = U^2 + 2as$
= 0+ 2+ 0.8 + 0.6
= 0.96
Therefore V= 0.9798
V= 0.098m/s

11. Speed decrease. Since momentum before collision is equal to momentum after collision i.e $M_1V_1 = M_2V_2$ then increase in mass implies/cause a decrease in velocity.

12.

i.

i. R=Reaction



ii. Mg sin 10 = 30 x 10 sin 10
= 52.1 + 20

iii. Since the velocity is constant then the net force = 0
p= mgsinθ + Fr
p= 52.1 + 20
= 72. 1N

ii.

i. Frictional force

ii. F= ma
(52.1 − 2.0) = 30a
32.1 = 30a
a = 1.07 m/s^2

13. The mattress increase time taken to land. Thus from
f= (Change in momentum)
Time taken
When time is more the force that will decelerate the jumper will be smaller (safer)

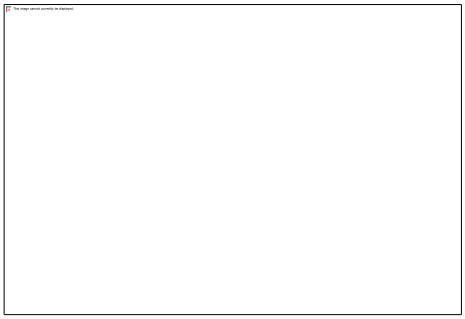
14. Fr= frictional force
F= ma
F= 2ma
Dividing
$1 = \frac{a_1}{2a_2}$
i.e. $a_2 = (½)a_1$ OR read the value of x- intercept i.e. when a=0 m=m_o and substitute in the equation to get m.

15. Since one is moving towards the other one has +ve vel while the other is –ve
Momentum before collision = momentum after collision

i. $m_1u1 + m_2u_2 = (m_1m_2)v$
$(2 \times 0.25) - (1.5 \times 0.4) = 3.5 \times v$
$0.5 - 0.6 = 3.5\ v$
V= 0.02867m/s
$= -2.867 \times 10^{-2}$ m/s

ii. The original direction of the 1.5 kg mass

16.



17. Speed decreases. Since momentum before collision is equal to momentum after collision i.e. $M_1V_1 = M_2V_2$ then increase in mass implies/cause a decrease in velocity.

18.

i. A body at rest or in motion at uniform velocity tends to stay in that state unless acted on by an unbalanced force.

ii.

i. Slope s= $\frac{97.5 - 0}{16 - 0}$ (m/s^2)
$20k = s = 6.09$

ii. $k = {}^{6.17}/_{20} = 0.304$

iii. Increase in roughness increase k and vice versa

iii. Applying equation
$V^2 - U^2 = 2as$
$V^2 - 0 = 2 \times 1.2 \times 400$
Momentum P = mv
$= 800 \times \sqrt{(2 \times 1.2 \times 400)}$
= 24787.09
= 24790 (table)

19. 2N

20. 7.75m/s

21. 2415N

22.

i. 5.4m

ii. 0.66N

23.

i. 10m/s,

ii. -3.33m/s,

iii. 0.333

24.

i.

ii. 50,000J

25. 875N

26.

i. 7.07 m/s, 0.71s,

ii. 0.071kgm/s (ii) 0.71N (iii) 0.71N

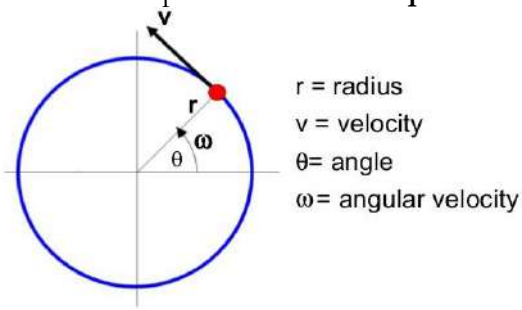
27. 30000N

STRAND: NATURAL PHYSICAL SCIENCE

SUBSTRAND 3.3: UNIFORM CIRCULAR MOTION

Introduction

- **Circular motion** is the motion of bodies travelling in circular paths.
- **Uniform circular motion** occurs when the speed of a body moving in a circular path is constant. This can be defined as *motion of an object at a constant speed along a curved path of constant radius.*
- When acceleration (variation of velocities) is directed towards the centre of the path of motion it is known as **centripetal acceleration** and the force producing this centripetal acceleration which is also directed towards the centre of the path is called **centripetal force**.



Angular Motion

- This motion can be described as the *motion of a body moving along a circular path by giving the angle covered in a certain time along the path of motion.*
- The angle covered in a certain time is proportional to the distance covered along the path of motion.

The Radian

- One radian is the angle subtended at the centre of the circle by an arc of length equal to the radius of the circle. Since one circle = 360° and has 2π radians therefore 1 radian = $360^\circ/_{2\pi r}$= 57.296° or 57.3°.

  Example

  A wheel of radius 50 cm is rolled through a quarter turn. Calculate

  i. The angle rotated in radians

  ii. The distance moved by a point on the circumference.

  Solution

  (i) A quarter turn = $360^\circ/_4$= 90° . Since 360° = 2π radians. Alternately since 1 radian = 57.3° hence 90° = 1.57 radii.

  (ii) A point on the circumference moves through an arc, Arc = radius × θ(θ in radians) = 50 cm × 1.57 = 78.5 cm.

Angular Velocity

- If a body moving in a circular path turns through an angle θ radians in time 't', we define angular velocity omega (ω), as the rate of change of the angular displacement ω = $^\theta/_t$,
- The **SI unit** of **angular velocity** is **radians per second (rads^{-1})**. Since the radian measure is a ratio we can write it as second^{-1} (s^{-1}).

Relation between linear velocity and angular velocity

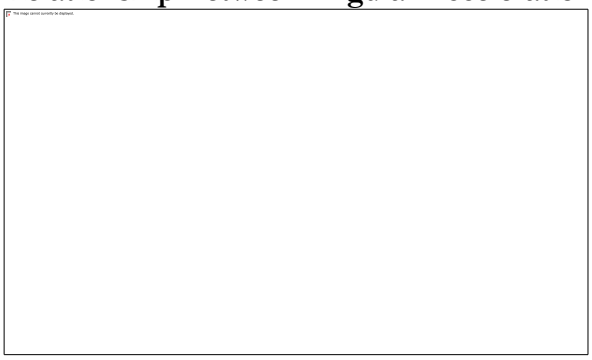
- Let us consider a body P moving along the circumference of a circle of radius r with linear velocity v and angular velocity ω as shown in the figure below
- Let it move from P to Q in time dt and dθ be the angle swept by the radius vector.

- Let PQ = ds, be the arc length covered by the particle moving along the circle, then the angular displacement dθ is expressed as $d\theta = {}^{ds}/_{r}$. But ds = vdt. ${}^{d\theta}/_{dt} = {}^{v}/_{r}$ (i.e) Angular velocity $\omega = {}^{v}/_{r}$ or $v = \omega r$

Angular Acceleration

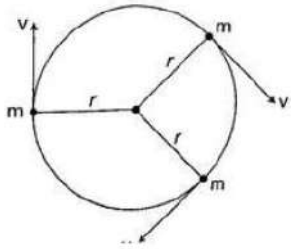
- If the angular velocity of a body changes from ω_1 to ω_2 in time t, then the angular acceleration, α can be expressed as;
  $\alpha = {}^{(\omega_2 - \omega_1)}/_{t}$
- Units for angular acceleration are radians per second squared (rad s^{-2}) or second^{-2} (s^{-2}).
- When α is constant with time, we say the body is moving with uniform angular acceleration.
  Note: In uniform circular motion α is equal to zero.

Relationship Between Angular Acceleration and Linear Acceleration



Centripetal Force

- This is a force which acts on a body by directing the body towards its centre. Since the direction is continuously changing, the velocity therefore cannot be constant.

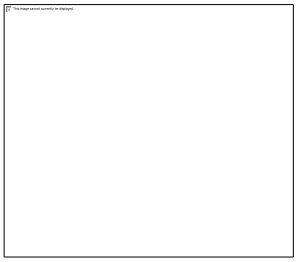


- Applying Newton's second law of motion(F=ma), centripetal force F_c is given by;
  $F_c = ma = {}^{mv^2}/_{r}$. Since $v = r\omega$,
  $F_c = {}^{mr^2\omega^2}/_{r} = m\omega^2 r$

- The centripetal acceleration in relation to angular velocity 'a', is given by $a=r\omega^2$,

Motion in a Vertical Circle

- Consider a mass 'm' tied to a string of length 'r' and moving in a vertical circle as shown below



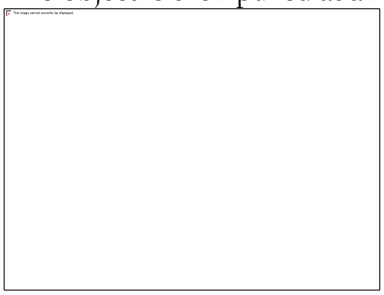
- **At position 1** –both weight (mg) and tension T are in the same direction and the centripetal force is provided by both, hence $T_1 + mg = mv^2/_r$.
  $T_1 = mv^2/_r - mg$ (The velocity decreases as T_1 decreases since mg is constant).
  T_1 will be zero when $mv^2/_r = mg$ and thus $v = \sqrt{rg}$ – this is the value of minimum speed at position 1 which keeps the body in a circle and at this time when T = 0 the string begins to slacken.
- **At position 2** – the 'mg' has no component towards the centre thus playing no part in providing the centripetal force but is provided by the string alone. $T_2 = mv^2/_r$
- **At position 3** – 'mg' and T arein opposite directions, therefore; $T_3 - mg = mv^2/_r$; $T_3 = mv^2/_r + mg$ – indicates that the greatest value of tension is at T_3 or at the bottom of the circular path.

Examples

1. A ball of mass 2.5×10^{-2} kg is tied to a string and whirled in a horizontal circular path at a speed of 5.0 ms^{-2}. If the string is 2.0 m long, what centripetal force does the string exert on the ball?
   Solution
   $F_c = mv^2/r = [(2.5 \times 10^{-2}) \times 5^2]/_{2.0} = 0.31$ N.
2. A car of mass 6.0×10^3 kg is driven around a horizontal curve of radius 250 m. if the force of friction between the tyres and the road is 21,000 N. What is the maximum speed that the car can be driven at on a bend without going off the road?
   Solution
   F_c = force of friction = 21,000, also $F_c = mv^2/_r$, hence $21{,}000 = [(6.0 \times 10^3) \times v^2]/_{250}$, $v^2 = {}^{(21{,}000 \times 250)}/_{6.0 \times 10^3}$
3. A stone attached to one end of a string is whirled in space in in a vertical plane. If the length of the string is 80 cm, determine the minimum speed at which the stone will describe a vertical circle. (Take g = 10 m/s^2).
   Solution
   Minimum speed $v = \sqrt{rg} = \sqrt{(0.8 \times 10)} = 2.83$ m/s.

The Conical Pendulum

- It consists of a small massive object tied to the end of a thin string tied to affixed rigid support.
- The object is then pulled at an angle then made to whirl in a horizontal circle.



- When speed of the object is constant the angle becomes θ constant also. If the speed is increased the angle increases, θ that is the object rises and describes a circle of bigger radius. Therefore as the angular velocity increases 'r' also increases.

The Centrifuge

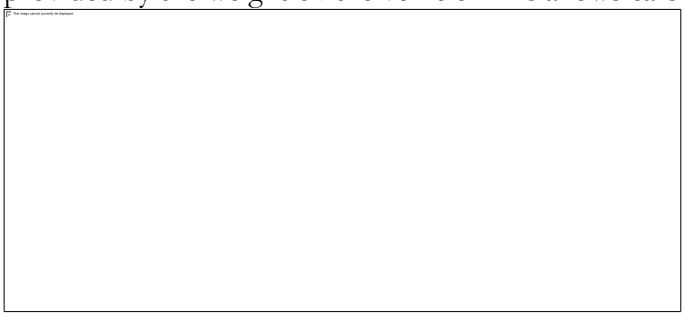
- It consists of a small metal container tubes which can be electrically or manually rotated in a circle.
- If we consider two particles of different masses m_1 and m_2 each of them requires a centripetal force to keep it in circular motion, the more massive particle require a greater force and so a greater radius and therefore it moves to the bottom of the tube.



- This method is used to separate solids and liquids faster than using a filter paper.

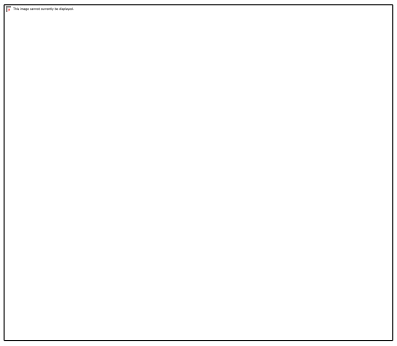
Banked Tracks

- As a vehicle moves round a bend, the centripetal force is provided by the sideways friction between the tyres and the surface, that is;
  Centripetal force = $mv^2/_r$ = frictional force
- To enable a vehicle to turn along a bend at high speed the road is raised on the outer edge to attain a saucer-like shape and this is known as banking, where part of the centripetal force necessary to keep the vehicle on track is provided by the weight of the vehicle. This allows cars to negotiate bends at critical speeds.



Applications of Uniform Circular Motion

1. *Centrifuges* - they are used to separate liquids of different densities i.e. cream and milk
2. *Drying clothes in spin dryer* - clothes are placed in a perforated drum rotated at high speed, water is expelled through the holes and this makes the clothes dry.
3. *Road banking* – especially for racing cars which enables them to move at critical speed along bends without going off the tracks.
4. *Speed governor* – the principle of conical pendulum is used here to regulate the speed by controlling the fuel intake in the combustion chamber. As the collar moves up and down through a system of levers it thereby connects to a device which controls the fuel intake.

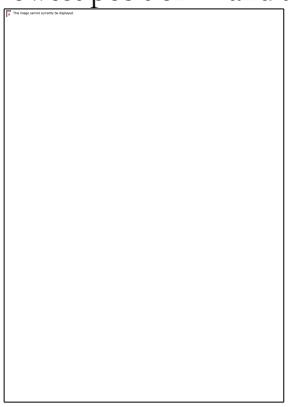


TOPICAL REVISION QUESTION

Questions

1. A light inextensible string of length L is fixed at its upper end and support a mass m at the other end. m is rotated at horizontal plane or radius r as shown. The maximum tension the string can withstand without breaking is 2N. Assuming the string breaks when the radius is maximum, calculate the velocity of the mass when the string breaks, given that L = 1.25m, and m= 0.1kg.

2. The diagram below shows a mass m, which is rotated in a vertical circle.
The speed of the mass is gradually increased until the string breaks. The string breaks when the mass is at its lowest position A and at a speed of $30ms^{-1}$. Point a is 5m above the ground.



   a. Show on the diagram.
      i. The initial direction of the mass at the point the string breaks.
      ii. The path of the mass from A until it strikes the ground at a point b.
   b. Calculate;
      i. The time the mass takes to reach the ground after breaking off.
      ii. The horizontal distance the mass travels before it strikes the ground.
      iii. The vertical velocity with which the mass strikes the ground.

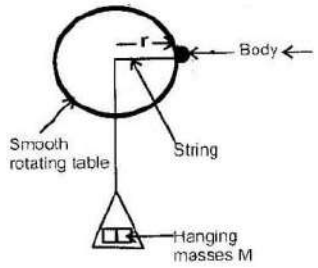
3. State the principle by which a speed governor limits the speed of a vehicle.

4. The rear wheel of a certain car has a diameter of 40cm. At a certain speed of the car, the wheel makes 7 revolutions per second. A small stone embedded in the tyre tread flies off initially at an angle of 450 to the ground. Determine the initial velocity of the pebble (take $\pi = {}^{22}/_{7}$)

5.
   a. Explain why a pail of water can be swung in a vertical circle without the water pouring out.
   b. A car of mass 1,200kg is moving with a velocity of 25m/s around a flat bend of radius 150m. Determine the minimum frictional force between the tyres and the road that will prevent the car from sliding off.

6.

a. The fig shows the diagram of a set up to investigate the variation of centripetal force with the radius r of the circle in which a body rotates. Describe how the set up can be used to carry out the investigation



b. The table shows results obtained from an investigation similar to the one in part (a)

Mass, m (g)	60	50	40	30	20
Radius, r(cm)	50	41	33	24	16

i. Plot a graph of force, F (y-axis) on the body against the radius r (in metre)

ii. Given that the mass of the body is 100g, use the graph to determine the angular velocity.

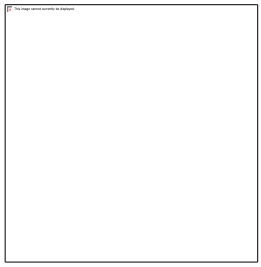
7. A small object moving in a horizontal circle of radius 0.2m makes 8 revolutions per second. Determine its centripetal acceleration.

8.

a. Define the term angular velocity. (1mk)

b. A body moving with uniform angular velocity found to have covered an angular distance 170 radians in t seconds. Thirteen seconds later it is found to have covered a total angular distance of 300 radians. Determine t (3mks)

c. The figure below shows a body of mass m attached to the centre of rotating table with a string whose tension can be measure. (This device for measuring the tension is not shown in the figure).



The tension, T, on the string was measured for various values of angular velocity,
The distance r of the body from the centre was maintained at 30cm. Table 1 shows the results obtained.

Table 1

Angular velocity ($rads^{-1}$)	2.0	3.0	4.0	5.0	6.0
Tension T (N)	0.04	0.34	0.76	1.30	1.96

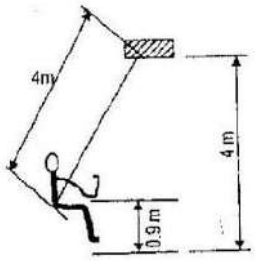
d. (5mks)

i. Plot the graph of T (y-axis) against ω^2

ii. From the graph, determine the mass, m, of the body given that $T= m\omega^2 r - C$ where C is a constant (4mks)

iii. Determine the constant C and suggest what it represents in the set up. (2mks)

9. A child of mass 20kg sits on a swing of length 4m and swings through a vertical height of 0.9m as shown in the figure below.



Determine the:

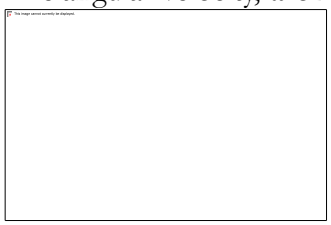
a. Speed of the child when passing through the lowest point.

b. Force exerted on the child by the seat of the swing when passing through the lowest point.

10.

a. State what is meant by centripetal acceleration?

b. The figure below shows masses A, B and C placed at different points on a rotating table. The angular velocity, ω of the table can be varied.



i. State two factors that determine whether a particular mass slides off the table or not. (2mks)

ii. It is found that masses slide off at angular velocities ω_A, ω_B, ω_C of in decreasing order. (1mk)

c. A block of mass 200g is placed on a frictionless rotating table while fixed to the centre of the table by a thin thread. The distance from the centre of the table to the block is 15cm. If the maximum tension the thread can withstand is 5.6N, determine the maximum angular velocity the table can attain before the thread cuts. (4mks)

11. Find the maximum speed with which a car of mass 100kg can take a corner of radius 20m if the coefficient of friction between the road and the tyres is 0.5.

12. An object of mass 0.5kg is rotated in a horizontal circle by a string 1m long. The maximum tension in the string before it breaks is 50N. Calculate the greatest number of revolutions per second the object can make.

13. An astronaut is trained in a centrifuge that has an arm length of 6m. If the astronaut can stand the acceleration of 9g. What is the maximum number of revolutions per second that the centrifuge can make?

14. A small body of 200g revolves uniformly on a horizontal frictionless surface attached by a cord 20cm long to a pin set on the surface. If the body makes two revolutions per second. Find the tension of the cord.

15. A circular highway curve on a level ground makes a turn $90^{0.}$ The highway carries traffic at 120 km/h. Knowing that the centripetal force on the vehicle is not to exceed $^{1}/_{10}$ of its weight, calculate the length of the curve

16. A turntable of record player makes 33 revolutions per minute. What is the linear velocity of a point 0.12m from the center?

17. An object 0.5kg on the end of a string is whirled around in a vertical circle of radius 2m, with a speed of 10m/s. What is the maximum tension in the string?

Answers

1. When tension is max then r= l

$T = F = \frac{MV^2}{r}$

$2 = \frac{0.1 \times V^2}{}$

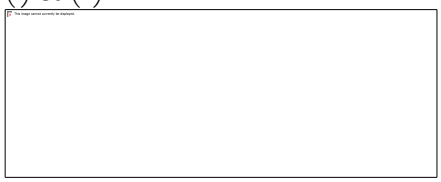
1.25

$\therefore V^2 = \frac{2 \times 1.25}{0.1}$

$V = 5$ m/s

2.

a. (i) & (ii)



b.

i. $S = Ut + \frac{1}{2} at^2$

$t = \frac{\sqrt{(2 \times 5)}}{10}$

$= 1$ seconds

ii. $S = Ut = 30 \times 1 = 30$m

iii. $V^2 = U^2 + 2as$

$V = \sqrt{(2 \times 10 \times 5)}$

$= 10$m

3. Principal of conical pendulum Or principle of circular motion

4. $V = \omega r$

But $\omega = \frac{\theta}{T} = \frac{2\pi \times 7}{1} = 14$ rads^{-1}

$\therefore V = 14\pi \times 0.20$

$= 8.8$ m/s

5. Centripetal acceleration of bucket is equal or higher than gravitational acceleration of the water.

6.

a. Keep angular velocity ω_1 constant; Centripetal force provided by mg; Fix the mass m and measure r; repeat for different values of m. Tabulate the values

b.

i. Force- Mg. Calculate and fill a column for force and another for radius in m
Plot the graph

ii. Gradient of the graph

$= \frac{0.625 - 0.1}{0.525 - 0.075} = 1.167$ N/m

Force F, on the body $= m_b\omega^2 r$

Where m_b = mass of the body

$M_b\omega^2$ = Gradient of the graph = 1.167

$\omega^2 = \frac{1.167}{0.1} = 11.67$

$\omega = \sqrt{11.67}$

$= 3.42$ rads^{-1}

7. $2\pi f = 2\pi \times 8$

$\alpha = r\omega^2 = 0.2\ (16\pi)^2$

$= 505.3$ m/s

8.

a. Angular displacement per second.

b. In 13s, angle turned = 300 − 170 = 130 rad
∴ $\omega = {}^{\theta}/_{t} = {}^{130}/_{13} = 10\ rads^{-1}$
So $\frac{300}{t+13} = 10$
$10t + 130 = 300$
$10t = 170$
$t = 17\ sec$

c.

i. Plot the graph which is a straight line.

ii. From $T = (mr)\omega^2 - C$ and $y = mx + c$
$Y = T$, grad = mr, y = intercept = -C
∴ Obtain gradient and equate it to mr.
Where r = 0.3m, to obtain m.

iii. The y-intercept should be equated to, -C.

9.

a. $Pe \rightarrow Ke$
∴ $mgh = \frac{1}{2}\ mv^2$
Or $v^2 = 2gh$.
$v = \sqrt{(2x\ 10x0.9)}$
$v = \sqrt{18} = 1.24m/s$

b. $F = mg + mv^2$
$= 200 + \frac{20 \times 18}{4}$
$= 290N$

10.

a. Acceleration directed towards the centre of the orbit.

b.

i. Roughness/smoothness of surface, radius of path, angular velocity/speed.

11. 10 m/s

12. 1.59 $rev.s^{-1}$

13. 0.61 $rev.s^{-1}$

14. 6.32N

15. 1744N

16. 0.41 m/s

17. 30N

TOPICAL REVISION QUESTIONS

Sub-strand: 3.3 Uniform Circular Motion
SECTION A: MULTIPLE-CHOICE QUESTIONS (30 MARKS)

Instructions: Answer all questions. Each question carries 1 mark. Choose the correct answer from the alternatives provided.

Question 1. Which of the following best describes uniform circular motion?

A. Motion in a straight line at constant speed.
B. Motion along a circular path at constant speed.
C. Motion along a circular path at increasing speed.
D. Motion along an elliptical path at constant velocity.

Question 2. The SI unit of angular displacement is the:

A. Metre.
B. Degree per second.
C. Radian.
D. Revolution per second.

Question 3. One complete revolution of a rotating object is equivalent to:

A. π radians.
B. 2π radians.
C. 3π radians.
D. 4π radians.

Question 4. Angular displacement refers to:

A. The distance travelled by an object along a circular path.
B. The angle swept through by the radius of a rotating object.
C. The speed of an object moving in a straight line.
D. The force acting towards the centre of a circle.

Question 5. A wheel rotates through an angle of $90°$. What is its angular displacement in radians?

A. $\frac{\pi}{2}$
B. π
C. 2π
D. $\frac{\pi}{4}$

Question 6. Which of the following is the SI unit of angular velocity?

A. m/s
B. rad/s

C. N/kg
D. m/s^2

Question 7. Angular velocity is defined as the:

A. Rate of change of linear speed.
B. Rate of change of angular displacement.
C. Distance travelled per unit time.
D. Force acting on a rotating object.

Question 8. An object completes 5 revolutions in 10 seconds. What is its frequency?

A. 0.2 Hz
B. 0.5 Hz
C. 2 Hz
D. 5 Hz

Question 9. Which of the following expressions correctly relates angular velocity and frequency?

A. $\omega = \frac{f}{2\pi}$
B. $\omega = 2\pi f$
C. $\omega = \frac{2\pi}{f}$
D. $\omega = 2f$

Question 10. The force that keeps an object moving in a circular path is known as:

A. Gravitational force.
B. Frictional force.
C. Centripetal force.
D. Centrifugal force.

Question 11. The direction of centripetal force acting on an object in uniform circular motion is:

A. Away from the centre.
B. Towards the centre.
C. Tangential to the circular path.
D. Vertically upwards.

Question 12. Which of the following is the correct expression for centripetal force?

A. $F = mv$
B. $F = \frac{mv^2}{r}$
C. $F = \frac{mr}{v^2}$
D. $F = mvr$

Question 13. The centripetal force acting on an object moving in a circular path depends on:

A. Mass, speed and radius of the circular path.
B. Temperature, mass and time.
C. Density, volume and pressure.
D. Distance, temperature and acceleration due to gravity.

Question 14. If the mass of an object moving in a circular path is doubled while its speed and radius remain constant, the centripetal force:

A. Halves.
B. Doubles.
C. Quadruples.
D. Remains constant.

Question 15. If the speed of an object moving in a circular path is doubled while its mass and radius remain constant, the centripetal force becomes:

A. Twice as large.
B. Three times as large.
C. Four times as large.
D. Half as large.

Question 16. When the radius of a circular path is doubled while the mass and speed remain constant, the centripetal force:

A. Doubles.
B. Halves.
C. Quadruples.
D. Remains unchanged.

Question 17. A stone tied to a string is whirled in a horizontal circle. Which force provides the centripetal force?

A. Air resistance.
B. Tension in the string.
C. Weight of the stone.
D. Centrifugal force.

Question 18. A vehicle moving around a level circular bend experiences centripetal force mainly due to:

A. Air resistance.
B. Normal reaction.
C. Friction between the tyres and the road.
D. Gravitational force alone.

Question 19. Why does a passenger tend to move sideways when a vehicle takes a sharp bend?

A. The passenger experiences an increase in mass.
B. The passenger tends to maintain the original direction of motion due to inertia.
C. The vehicle loses all its weight.
D. Centripetal force acts away from the centre.

Question 20. Which of the following is an application of uniform circular motion?

A. A stone falling freely.
B. A rotating centrifuge.
C. A stationary book on a table.
D. A person walking in a straight line.

Question 21. A centrifuge separates substances mainly by:

A. Heating them to different temperatures.
B. Spinning them rapidly to separate components according to their densities.
C. Freezing the substances.
D. Increasing atmospheric pressure.

Question 22. The main purpose of banking a road at a bend is to:

A. Increase the weight of vehicles.
B. Reduce the need for centripetal force.

C. Provide a component of the normal reaction towards the centre of the bend.
D. Prevent vehicles from moving forward.

Question 23. A satellite moving in a circular orbit around the Earth is kept in orbit by:

A. Magnetic force.
B. Gravitational force.
C. Air resistance.
D. Frictional force.

Question 24. The operation of a speed governor in a rotating machine is based on the principles of:

A. Uniform linear motion.
B. Circular motion.
C. Random motion.
D. Projectile motion.

Question 25. Which of the following provides the centripetal force for a satellite orbiting the Earth?

A. Gravitational attraction between the Earth and the satellite.
B. Friction between the satellite and space.
C. Air resistance.
D. Magnetic attraction from the Moon.

Question 26. An object moving in uniform circular motion has:

A. Constant velocity and constant acceleration.
B. Changing velocity and changing direction of acceleration.
C. Constant velocity and zero acceleration.
D. Changing speed but constant direction.

Question 27. A rotating fan completes 60 revolutions in one minute. What is its frequency?

A. 0.5 Hz
B. 1 Hz
C. 2 Hz
D. 60 Hz

Question 28. An object moves in a circle of radius 2 m with a linear speed of 4 m/s. What is its centripetal acceleration?

A. 2 m/s^2
B. 4 m/s^2
C. 8 m/s^2
D. 16 m/s^2

Question 29. A merry-go-round rotates at a constant angular velocity. A child sitting on it experiences:

A. No acceleration.
B. Centripetal acceleration directed towards the centre.
C. Acceleration directed away from the centre.
D. Linear acceleration in a straight line.

Question 30. Which safety precaution should be observed when carrying out an experiment involving a rotating mass attached to a string?

A. Use a damaged string.
B. Stand close to the rotating mass.

C. Ensure the rotating mass is securely attached and keep people away from its path.
D. Increase the speed without checking the equipment.

SECTION B: STRUCTURED QUESTIONS (50 MARKS)

Instructions: Answer all questions. Show all necessary working in numerical questions.

QUESTION 31: TERMS USED IN UNIFORM CIRCULAR MOTION (8 MARKS)

a) Define the following terms as used in uniform circular motion:

i. Angular displacement. (2 marks)

ii. Angular velocity. (2 marks)

iii. Radian. (1 mark)

b) State the SI unit of angular velocity. (1 mark)

c) A rotating wheel turns through an angle of $180°$.

Calculate its angular displacement in radians. (2 marks)

QUESTION 32: CENTRIPETAL FORCE AND ACCELERATION (10 MARKS)

a) Explain the meaning of centripetal force. (2 marks)

b) State two characteristics of centripetal force acting on an object moving in a circular path. (2 marks)

c) A stone of mass 0.5 kg is attached to a string and whirled in a horizontal circle of radius 2 m at a constant speed of 4 m/s.

Calculate:

i. The centripetal acceleration of the stone. (3 marks)

ii. The centripetal force acting on the stone. (3 marks)

QUESTION 33: FACTORS AFFECTING CENTRIPETAL FORCE (10 MARKS)

a) State the three factors that affect the centripetal force acting on an object moving in a circular path. (3 marks)

b) Explain how each of the following affects centripetal force when the other factors remain constant:

i. Mass of the rotating object. (2 marks)

ii. Speed of the rotating object. (2 marks)

iii. Radius of the circular path. (2 marks)

c) State one safety precaution to observe when investigating centripetal force experimentally. (1 mark)

QUESTION 34: APPLICATIONS OF UNIFORM CIRCULAR MOTION (10 MARKS)

a) Explain how centripetal force enables a vehicle to move around a circular bend on a level road. (2 marks)

b) Explain why roads are banked at sharp bends. (2 marks)

c) Describe how a centrifuge uses circular motion to separate substances. (2 marks)

d) Explain how gravitational force enables a satellite to remain in orbit around the Earth. (2 marks)

e) State two applications of circular motion in day-to-day life, apart from those mentioned in (a), (b), (c) and (d). (2 marks)

QUESTION 35: NUMERICAL PROBLEMS IN UNIFORM CIRCULAR MOTION (12 MARKS)

a) A rotating machine completes 120 revolutions in 60 seconds.

Calculate:

i. The frequency of rotation. (2 marks)

ii. The angular velocity of the machine. (2 marks)

b) A body of mass 2 kg moves in a circular path of radius 4 m at a constant speed of 6 m/s.

Calculate:

i. The centripetal acceleration of the body. (2 marks)

ii. The centripetal force acting on the body. (2 marks)

c) A wheel rotates with an angular velocity of 10 rad/s for 5 seconds.

Calculate the angular displacement of the wheel during this period. (2 marks)

d) Explain why an object moving at constant speed in a circular path is said to be accelerating. (2 marks)

TEACHER'S MARKING SCHEME

SECTION A: MULTIPLE-CHOICE ANSWERS (30 MARKS)

Award 1 mark for each correct answer.

Question	Answer	Question	Answer
1	B	16	B
2	C	17	B
3	B	18	C
4	B	19	B
5	A	20	B
6	B	21	B
7	B	22	C
8	B	23	B
9	B	24	B
10	C	25	A
11	B	26	B
12	B	27	B
13	A	28	C
14	B	29	B
15	C	30	C

SECTION B: STRUCTURED QUESTIONS (50 MARKS)

QUESTION 31: TERMS USED IN UNIFORM CIRCULAR MOTION (8 MARKS)

a) Definitions

i. Angular displacement (2 marks)

Angular displacement is the angle swept through by the radius of a rotating object about the centre of its circular path.

ii. Angular velocity (2 marks)

Angular velocity is the rate of change of angular displacement with time.

iii. Radian (1 mark)

A radian is the angle subtended at the centre of a circle by an arc whose length is equal to the radius of the circle.

b) SI unit of angular velocity (1 mark)

c) Calculate the angular displacement in radians (2 marks)

Given:

$$\theta = 180°$$

Conversion formula:

$$\theta(\text{rad}) = \theta(°) \times \frac{\pi}{180°}$$

Substituting:

$$\theta = 180° \times \frac{\pi}{180°}$$

$$\boxed{\theta = \pi \text{ rad}}$$

Mark allocation:

- Correct formula and substitution – 1 mark.
- Correct answer – 1 mark.

QUESTION 32: CENTRIPETAL FORCE AND ACCELERATION (10 MARKS)

a) Meaning of centripetal force (2 marks)

Centripetal force is the resultant force that acts towards the centre of a circular path, keeping an object moving along that circular path.

b) Characteristics of centripetal force (2 marks)

Any two of the following:

8. It acts towards the centre of the circular path.
9. It acts perpendicular to the instantaneous velocity of the object.
10. It continuously changes the direction of the object's velocity.
11. It is responsible for maintaining circular motion.

Award 1 mark for each correct characteristic.

c) Numerical calculations

Given:

- Mass, $m = 0.5$ kg
- Radius, $r = 2$ m
- Speed,

i. Calculate the centripetal acceleration (3 marks)

Formula:

$$a_c = \frac{v^2}{r}$$

Substituting:

$$a_c = \frac{4^2}{2}$$

$$a_c = \frac{16}{2}$$

Mark allocation:

- Correct formula – 1 mark.
- Correct substitution – 1 mark.
- Correct answer – 1 mark.

ii. Calculate the centripetal force (3 marks)

Formula:

$$F_c = \frac{mv^2}{r}$$

Substituting:

$$F_c = \frac{0.5 \times 4^2}{2}$$

$$F_c = \frac{0.5 \times 16}{2}$$

$$F_c = \frac{8}{2}$$

$$\boxed{F_c = 4\ \text{N}}$$

Mark allocation:

- Correct formula – 1 mark.
- Correct substitution – 1 mark.
- Correct answer – 1 mark.

QUESTION 33: FACTORS AFFECTING CENTRIPETAL FORCE (10 MARKS)

a) State the three factors affecting centripetal force (3 marks)

The three factors are:

1. Mass of the rotating object. (1 mark)
2. Speed of the rotating object. (1 mark)
3. Radius of the circular path. (1 mark)

b) Explain how each factor affects centripetal force.

i. Mass of the rotating object (2 marks)

Centripetal force is directly proportional to the mass of the rotating object when speed and radius remain constant.

Therefore, increasing the mass increases the centripetal force proportionally.

ii. Speed of the rotating object (2 marks)

Centripetal force is directly proportional to the square of the speed.

Therefore, increasing the speed increases the centripetal force.

For example, doubling the speed increases the centripetal force four times.

iii. Radius of the circular path (2 marks)

Centripetal force is inversely proportional to the radius when mass and speed remain constant.

Therefore, increasing the radius decreases the centripetal force.

c) Safety precaution (1 mark)

Any one of the following:

- Ensure that the rotating mass is securely attached.
- Use a strong string that is not damaged.
- Keep people away from the path of the rotating object.
- Avoid excessive rotational speed.
- Wear appropriate protective equipment.

QUESTION 34:

a) Vehicle moving around a circular bend on a level road (2 marks)

Friction between the tyres and the road provides the centripetal force directed towards the centre of the bend.

This force enables the vehicle to follow a circular path instead of moving in a straight line.

b) Banking of roads (2 marks)

Roads are banked at sharp bends so that the normal reaction force has a horizontal component directed towards the centre of the bend.

This component helps provide the required centripetal force and reduces dependence on friction.

c) Centrifuge (2 marks)

A centrifuge rotates substances rapidly in a circular path.

The components separate according to their densities, with denser components tending to collect towards the outer part of the rotating container relative to less dense components.

d) Satellites orbiting the Earth (2 marks)

The Earth's gravitational attraction provides the centripetal force required to keep a satellite in orbit.

This force continuously changes the direction of the satellite's velocity, maintaining its circular or nearly circular orbit.

e) Applications of circular motion (2 marks)

Any two valid examples:

1. Merry-go-round.
2. Rotating ceiling fan.
3. Washing machine spin cycle.
4. Electric motor.
5. Clock hands.
6. Bicycle wheels.
7. Rotating playground equipment.
8. Speed governor.
9. Electric drill.
10. Water wheels.

Award 1 mark for each correct example.

QUESTION 35:

a) A rotating machine completes 120 revolutions in 60 seconds.

Given:

- Number of revolutions = 120
- Time = 60 seconds

i. Calculate the frequency of rotation (2 marks)

Formula:

$$f = \frac{\text{Number of revolutions}}{\text{Time}}$$

Substituting:

$$f = \frac{120}{60}$$

$$\boxed{f = 2 \text{ Hz}}$$

Mark allocation:

- Formula and substitution – 1 mark.
- Correct answer – 1 mark.

ii. Calculate the angular velocity (2 marks)

Formula:

$$\omega = 2\pi f$$

Substituting:

$$\omega = 2 \times 3.14 \times 2$$

Mark allocation:

- Formula and substitution – 1 mark.
- Correct answer – 1 mark.

b) A body of mass 2 kg moves in a circular path of radius 4 m at a constant speed of 6 m/s.

Given:

- Mass, $m = 2$ kg
- Radius, $r = 4$ m
- Speed,

i. Calculate the centripetal acceleration (2 marks)

Formula:

$$a_c = \frac{v^2}{r}$$

Substituting:

$$a_c = \frac{6^2}{4}$$

$$a_c = \frac{36}{4}$$

Mark allocation:

- Formula and substitution – 1 mark.
- Correct answer – 1 mark.

ii. Calculate the centripetal force (2 marks)

Formula:

$$F_c = ma_c$$

Substituting:

$$F_c = 2 \times 9$$

$$\boxed{F_c = 18\ \text{N}}$$

Mark allocation:

- Formula and substitution – 1 mark.
- Correct answer – 1 mark.

c) A wheel rotates with an angular velocity of 10 rad/s for 5 seconds. Calculate its angular displacement (2 marks).

Given:

- Angular velocity,
- Time, $t = 5\ \text{s}$

Formula:

$$\theta = \omega t$$

Substituting:

$$\theta = 10 \times 5$$

$$\boxed{\theta = 50\ \text{rad}}$$

Mark allocation:

- Formula and substitution – 1 mark.
- Correct answer – 1 mark.

d) Explain why an object moving at constant speed in a circular path is said to be accelerating (2 marks).

An object moving in a circular path continuously changes its direction of motion even when its speed remains constant.

Since velocity depends on both magnitude and direction, its velocity changes continuously.

Therefore, the object experiences acceleration directed towards the centre of the circular path.

ASSESSMENT SUMMARY

Section	Questions	Marks
A: Multiple Choice	1–30	30
B: Structured Questions	31–35	50
TOTAL	**1–35**	**80**

TEACHER'S ASSESSMENT GUIDELINES

1. Award marks according to the marking points indicated.
2. Accept scientifically correct alternative responses.
3. In numerical questions, award method marks where the correct formula and substitution are shown, even if the final answer contains an arithmetic error.
4. Accept equivalent units where scientifically appropriate.
5. Do not award full marks for a numerical answer without the required working where working has been requested.
6. Award only the indicated number of marks for each question.

STRAND: NATURAL PHYSICAL SCIENCE

SUBSTRAND 3.7: HEATING EFFECT OF ELECTRIC CURRENT

Introduction

- When current flows through a conductor, heat energy is generated in the conductor. The heating effect of an electric current depends on three factors:
    - The resistance, R of the conductor. A higher resistance produces more heat.
    - The time, t for which current flows. The longer the time the larger the amount of heat produced
    - The amount of current, I. the higher the current the larger the amount of heat generated.
- Hence the heating effect produced by an electric current, I through a conductor of resistance, R for a time, t is given by $H = I^2Rt$. This equation is called the **Joule's equation of electrical heating.**

Electrical Energy and Power

- The work done in pushing a charge round an electrical circuit is given by w.d = VIt
  So that power, $P = {}^{w.d}/_{t} = VI$
- The electrical power consumed by an electrical appliance is given by $P = VI = I^2R = {}^{V^2}/_{R}$

Example 6.1

1. An electrical bulb is labeled 20W, 240V. Calculate:
    a. The current through the filament when the bulb works normally
    b. The resistance of the filament used in the bulb.{**ans. 0.437A, 575.04Ω**}
       Solution
        a. $I = {}^{P}/_{V} = {}^{20}/_{240} = 0.437A$
        b. $R = {}^{P}/_{I^2} = {}^{20}/_{0.437^2} = 575.04\Omega$ or $R = {}^{V^2}/_{P} = {}^{240^2}/_{20} = 576\Omega$
2. Find the energy dissipated in 5 minutes by an electric bulb with a filament of resistance of 500Ω connected to a 240V supply. {**ans. 34,560J**}
   Solution
   $E = Pt = {}^{V^2}/_{R} \times t = {}^{(240^2 \times 5 \times 60)}/_{500} = 34,560J$
3. A 5.5 kW immersion heater is used to heat water. Calculate:
    a. The operating voltage of the heater if its resistance is 24Ω
    b. The electrical energy converted to heat energy in 2 hours.
       {**ans. 241.9488V, 1.8×10^7 J** }
       Solution
        a. $P=VI=I^2R$
           $I = ({}^{2500}/_{24})^{½} = 5.2062A$
           $V=IR= 5.2062 \times 24 = 241.9488V$

b. $E = VIt = Pt = 2500 \times 2 \times 60 \times 60 = 1.8 \times 10^7$ J
OR $E = VIt = 241.9488 \times 5.2062 \times 2 \times 60 \times 60 = 1.8 \times 10^7$ J

4. An electric bulb is labeled 20W, 240V. Calculate:
   a. The current through the filament
   b. The resistance of the filament used in the bulb. {**ans. 0.437A, 575.95Ω**}
   Solution
      a. $P = VI$
      $I = {}^{P}/_{V} = {}^{20}/_{240} = 0.437A$
      b. From Ohm's law, $V = IR$
      $R = {}^{V}/_{I} = {}^{240}/_{0.437} = 575.95\Omega$

Applications of Heating Effect of Electric Current

- Most household electrical appliances convert electrical energy into heat by this means. These include filament lamps, electric heater, electric iron, electric kettle, etc.

In Lighting Appliances

a. Filament lamps- it is made of a tungsten wire enclosed in a glass bulb from which air has been removed. This is because air would oxidize the filament. The filament is heated up to a high temperature and becomes white hot. Tungsten is used due its high melting point; 3400 0 C. The bulb is filled with an inactive gas e.g. argon or nitrogen at low pressure which reduces evaporation of the tungsten wire. However, one disadvantage of the inert gas is that it causes convection currents which cool the filament. This problem is minimized by coiling the wire so that it occupies a smaller area which reduces heat loss through convection.

b. Fluorescent lamps- these lamps are more efficient compared to filament lamps and last much longer. They have mercury vapour in the glass tube which emits ultraviolet radiation when switched on. This radiation causes the powder in the tube to glow (fluoresce) i.e. emits visible light. Different powders produce different colours. Note that fluorescent lamps are expensive to install but their running cost is much less.

In Electrical Heating

a. Electric cookers- electric cookers turn red hot and the heat energy produced is absorbed by the cooking pot through conduction.

b. Electric heaters- radiant heaters turn red at about 900^{o} C and the radiation emitted is directed into the room by polished reflectors.

c. Electric kettles- the heating element is placed at the bottom of the kettle so that the liquid being heated covers it. The heat is then absorbed by water and distributed throughout the whole liquid by convection.

d. Electric irons- when current flows through the heating element, the heat energy developed is conducted to the heavy metal base raising its temperature. This energy is then used to press clothes. The temperature of the electric iron can be controlled using a thermostat (a bimetallic strip).

TOPICAL REVISION QUESTIONS

1. An electric bulb rated 40W is operating on 240V mains. Determine the resistance of its filament
2. When a current of 2A flows in a resistor for 10 minutes, 15 KJ of electrical energy is dissipated. Determine the voltage across the resistor.
3. How many 100W electric irons could be safely connected to a 240V moving circuit fitted with a 13A fuse?
4. A heater of resistance R_1 is rated P watts, V volts while another of resistance R_2 is rated 2P watts, $^{V}/_{2}$ volts. Determine $^{R1}/_{R2}$
5. State THREE factors which affect heating by an electric current.
6. What is power as it relates to electrical energy?
7. An electrical appliance is rated as 240V, 200W. What does this information mean?
8. An electrical heater is labelled 120W, 240V.
   Calculate;
   a. The current through the heating element when the heater is on.
   b. The resistance of the element used in the heater.
9. An electric toy is rated 100W, 240V. Calculate the resistance of the toy when operating normally.

Answers

1. $P = \frac{V^2}{R}$

   $40 = \frac{240^2}{R}$

   $R = 1440\ \Omega$

2. $P = VI$

   $\frac{W}{t} = VI$

   $\frac{15000}{10 \times 60} = V \times 2$

   $V = \frac{15000}{10 \times 60 \times 2}$

   $= \frac{150}{12}$

   $= 12.5V$

   Voltage across resistor is 12.5V

3. **Solution**

   (No. of ions) x 1000 = IV

   No. of ions $= \frac{13 \times 240}{1000}$

   = 3.12

   = 3A

4. **Solution**

   $R_1 = \frac{V^2}{P}$ …….. (i)

   $R_2 = (\frac{V}{2})^2 \div 2P$

   $= \frac{V^2}{4} \times \frac{1}{2P} = \frac{V^2}{8P}$ ……. (ii)

   $\frac{R_1}{R_2} = \frac{V^2}{P} \div \frac{V^2}{8P}$

   $\frac{R_1}{R_2} = \frac{V^2}{P} \times \frac{8P}{V^2}$

   = 8

5.
   - Amount of current, I
   - Resistance, R of the conductor
   - Time t for which the current flows

6. Is the rate at which electrical energy is converted to useful work per unit time?

7. That the appliance operates at a voltage of 240 volts. When it is operating normally, the electrical power outputs is 200 watts i.e. 200J of electrical energy is converted to other useful energy per unit time

8.
   - Electrical power P = VI

$120 = 240I$

$\therefore I = {}^{120}/_{240}$

$= 0.5A$

- From Ohm's law

  $V = IR$

  $R = {}^{V}/_{I}$

  $= {}^{240}/_{0.5}$

  $= 480\Omega$

  The resistance of element = 480Ω

9. **Solution**

   $P = {}^{V^2}/_{R}$

   $R = {}^{V^2}/_{P}$

   $= \frac{240 \times 240}{100}$

   $= 24 \times 24$

   $= 576\Omega$

COMPETENCE-BASED EDUCATION (CBE)

SUBJECT: General Science
STRAND: 3.0 Natural Physical Science
SUB-STRAND: 3.4 Heating Effect of Electric Current
TOTAL MARKS: 80 MARKS
TIME: 2 HOURS

INSTRUCTIONS TO LEARNERS

4. Answer all questions.
5. Section A consists of 30 multiple-choice questions. Choose the correct answer from the four alternatives provided.
6. Section B consists of structured questions totalling 50 marks.
7. Show all working in numerical calculations.
8. Use the appropriate SI units in your answers.
9. Take the necessary care when handling electrical apparatus during practical activities.

SECTION A: MULTIPLE-CHOICE QUESTIONS (30 MARKS)

Answer all questions. Each question carries 1 mark.

Question 1. The heating effect of an electric current refers to the:

A. Production of light when current flows through a conductor.
B. Production of heat when electric current flows through a conductor.
C. Production of sound when current flows through a circuit.
D. Conversion of heat energy into electrical energy.

Question 2. Which of the following is the main cause of heating in a conductor when electric current flows through it?

A. Collision of moving electrons with particles in the conductor.
B. Expansion of the conductor due to gravity.
C. Attraction between the conductor and the Earth.
D. Reflection of electrons from the surface of the conductor.

Question 3. Which of the following materials is commonly used to make heating elements in electric appliances?

A. Copper.
B. Aluminium.
C. Nichrome.
D. Silver.

Question 4. The SI unit of electrical resistance is the:

A. Ampere.
B. Volt.
C. Watt.
D. Ohm.

Question 5. Which instrument is used to measure electric current in a circuit?

A. Voltmeter.
B. Ammeter.

C. Thermometer.
D. Barometer.

Question 6. Which instrument is used to measure the potential difference across a heating element?

A. Ammeter.
B. Thermometer.
C. Voltmeter.
D. Galvanometer.

Question 7. Which of the following expressions represents the electrical energy converted into heat in a resistor?

A. $W = VIt$

B. $W = \frac{V}{I}$

C. $W = VI$

D. $W = \frac{I}{Vt}$

Question 8. The SI unit of electrical energy is the:

A. Watt.
B. Joule.
C. Ampere.
D. Volt.

Question 9. The electrical power consumed by an appliance is calculated using the expression:

A. $P = IR$

B. $P = I^2R$

C. $P = VI$

D. $P = \frac{V}{I}$

Question 10. Which of the following factors determines the amount of heat produced in a conductor?

A. Current, resistance and time.
B. Mass, density and volume only.
C. Temperature, pressure and humidity.
D. Length, colour and shape only.

Question 11. According to Joule's law of heating, the heat produced in a conductor is directly proportional to:

A. The current flowing through it.
B. The square of the current flowing through it.
C. The reciprocal of the current flowing through it.
D. The square root of the current flowing through it.

Question 12. If the current flowing through a resistor is doubled while resistance and time remain constant, the heat produced becomes:

A. Twice as much.
B. Three times as much.

C. Four times as much.
D. Half as much.

Question 13. If the resistance of a conductor is increased while current and time remain constant, the heat produced:

A. Increases.
B. Decreases.
C. Remains constant.
D. Becomes zero.

Question 14. If the time taken for current to flow through a resistor is doubled while current and resistance remain constant, the heat produced:

A. Halves.
B. Doubles.
C. Quadruples.
D. Remains constant.

Question 15. Which of the following appliances uses the heating effect of electric current to perform its main function?

A. Electric kettle.
B. Electric bell.
C. Loudspeaker.
D. Electric motor.

Question 16. The heating element in an electric iron is mainly responsible for:

A. Producing a magnetic field.
B. Converting electrical energy into heat energy.
C. Producing sound energy.
D. Reducing the resistance of the circuit to zero.

Question 17. The heating element of an electric kettle is designed to:

A. Convert electrical energy into sound energy.
B. Convert electrical energy into heat energy to boil water.
C. Convert heat energy into mechanical energy.
D. Prevent electric current from flowing.

Question 18. Which property makes nichrome suitable for use in heating elements?

A. Low resistance and low melting point.
B. High resistance and high melting point.
C. High electrical conductivity and low melting point.
D. Very low density and high thermal expansion.

Question 19. The filament of an ordinary incandescent electric bulb is commonly made of:

A. Copper.
B. Aluminium.
C. Tungsten.
D. Plastic.

Question 20. Why is tungsten suitable for making electric bulb filaments?

A. It has a very low melting point.
B. It has a high melting point and can withstand very high temperatures.
C. It does not allow electric current to pass through it.
D. It produces heat without becoming hot.

Question 21. Electric welding uses the heating effect of electric current mainly to:

A. Cool metals before joining them.
B. Melt metal surfaces so that they can be joined.
C. Increase the electrical resistance of metals.
D. Separate metals according to their densities.

Question 22. Which of the following is a major application of the heating effect of electric current in industries?

A. Electric arc welding.
B. Radio broadcasting.
C. Sound recording.
D. Magnetic navigation.

Question 23. An electric heater is rated 1,000 W. This means that it:

A. Uses 1,000 joules of electrical energy every second.
B. Uses 1,000 volts every second.
C. Allows 1,000 amperes to flow through it.
D. Has a resistance of 1,000 ohms.

Question 24. Which of the following is the correct unit of electrical power?

A. Joule.
B. Watt.
C. Coulomb.
D. Ohm.

Question 25. A heating appliance operates at a potential difference of 12 V and draws a current of 2 A. What is its power?

A. 6 W.
B. 10 W.
C. 14 W.
D. 24 W.

Question 26. An electric heater has a power rating of 500 W. How much electrical energy does it consume in 2 seconds?

A. 100 J.
B. 250 J.
C. 1,000 J.
D. 2,000 J.

Question 27. Which of the following safety measures should be observed when using an electric kettle?

A. Touch the heating element while the kettle is connected.
B. Operate the kettle with wet hands.
C. Keep the electrical plug and socket away from water.
D. Use a damaged power cable.

Question 28. Why should an electric iron be switched off when not in use?

A. To increase its electrical resistance.
B. To prevent unnecessary energy consumption and reduce the risk of fire.
C. To increase the current flowing through it.
D. To make the heating element melt faster.

Question 29. An electric appliance is rated 240 V, 1,200 W. What current does it draw when operating normally?

A. 2 A.
B. 3 A.
C. 5 A.
D. 10 A.

Question 30. Which of the following actions is unsafe when handling electrical appliances?

A. Switching off the power before cleaning an appliance.
B. Replacing damaged electrical cables.
C. Using appliances with wet hands.
D. Disconnecting an appliance by holding its plug.

SECTION B: STRUCTURED QUESTIONS (50 MARKS)

Answer all questions. Show all necessary working in numerical calculations.

QUESTION 31: HEATING EFFECT OF ELECTRIC CURRENT (10 MARKS)

a) Define the heating effect of an electric current. (2 marks)

b) Explain how heat is produced when electric current flows through a resistance wire. (2 marks)

c) Describe an experiment that can be carried out to demonstrate the heating effect of electric current using a resistance wire immersed in water. (4 marks)

d) State two observations that would be made during the experiment. (2 marks)

QUESTION 32: FACTORS AFFECTING THE HEATING EFFECT OF ELECTRIC CURRENT (10 MARKS)

a) State the three main factors that determine the amount of heat produced in a conductor carrying electric current. (3 marks)

b) State Joule's law of heating. (2 marks)

c) Explain how each of the following affects the amount of heat produced in a conductor:

i. The current flowing through the conductor. (2 marks)

ii. The resistance of the conductor. (1 mark)

iii. The time for which current flows through the conductor. (1 mark)

d) State one precaution to observe when investigating the heating effect of electric current experimentally. (1 mark)

QUESTION 33: ELECTRICAL ENERGY AND ELECTRICAL POWER (12 MARKS)

a) State the formula used to calculate:

i. Electrical energy consumed by an appliance. (1 mark)

ii. Electrical power consumed by an appliance. (1 mark)

b) An electric heater operates at a potential difference of 240 V and draws a current of 5 A.

Calculate:

i. The electrical power of the heater. (2 marks)

ii. The electrical energy consumed in 10 minutes. Give your answer in joules. (3 marks)

c) An electric kettle has a power rating of 2,000 W and operates for 5 minutes.

Calculate the electrical energy consumed by the kettle in joules. (3 marks)

e) State the SI unit of electrical energy and the SI unit of electrical power. (2 marks)

QUESTION 34: APPLICATIONS OF THE HEATING EFFECT OF ELECTRIC CURRENT (10 MARKS)

b) Explain how the heating effect of electric current is utilised in each of the following appliances:

iii. Electric kettle. (2 marks)

iv. Electric iron. (2 marks)

v. Incandescent electric bulb. (2 marks)

b) Explain how electric welding uses the heating effect of electric current. (2 marks)

c) State two properties of materials used to make heating elements in electrical appliances. (2 marks)

QUESTION 35: ELECTRICAL SAFETY AND PRACTICAL APPLICATIONS (8 MARKS)

a) State four safety precautions that should be observed when using electrical appliances at home or in school. (4 marks)

b) Explain why an electric kettle should not be operated without water. (2 marks)

c) State two ways in which the heating effect of electric current is useful in everyday life in your locality. (2 marks)

TEACHER'S MARKING SCHEME

SECTION A: MULTIPLE-CHOICE ANSWERS (30 MARKS)

Award 1 mark for each correct answer.

Question	Answer	Question	Answer
1	B	16	B
2	A	17	B
3	C	18	B
4	D	19	C
5	B	20	B
6	C	21	B
7	A	22	A
8	B	23	A
9	C	24	B
10	A	25	D
11	B	26	C
12	C	27	C
13	A	28	B
14	B	29	C
15	A	30	C

SECTION B: STRUCTURED QUESTIONS (50 MARKS)

QUESTION 31: HEATING EFFECT OF ELECTRIC CURRENT (10 MARKS)

a) The heating effect of electric current is the production of heat energy when an electric current flows through a conductor or resistance. (2 marks)

b) When electric current flows through a resistance wire, moving electrons collide with the particles in the conductor. These collisions transfer electrical energy to the particles, increasing their internal energy and temperature. (2 marks)

c) Experimental procedure

- Put some water into a suitable container, such as a beaker. (1 mark)
- Immerse a resistance wire in the water, ensuring that its connecting terminals are properly insulated. (1 mark)
- Connect the resistance wire to a low-voltage power supply through a switch and an ammeter. (1 mark)
- Record the initial temperature of the water, close the switch for a given period, then measure the final temperature. (1 mark)

d) Observations

Any two:

- The temperature of the water increases.
- The resistance wire becomes hot.
- The electrical energy supplied is converted into heat energy.
- The final temperature of the water is higher than its initial temperature.

(1 mark each)

QUESTION 32: FACTORS AFFECTING THE HEATING EFFECT OF ELECTRIC CURRENT (10 MARKS)

a) The three main factors are:

10. Magnitude of electric current flowing through the conductor. (1 mark)
11. Resistance of the conductor. (1 mark)
12. Time for which current flows through the conductor. (1 mark)

b) Joule's law of heating states that the heat produced in a conductor is directly proportional to the square of the current flowing through it, its resistance and the time for which the current flows, provided other conditions remain constant. (2 marks)

Mathematically:

$$\boxed{H = I^2Rt}$$

Where:

- H = heat energy produced in joules.
- I = current in amperes.
- R = resistance in ohms.
- t = time in seconds.

c)

i. Current flowing through the conductor

The heat produced is directly proportional to the square of the current. Increasing the current increases the heat produced. For example, doubling the current increases the heat produced four times, provided resistance and time remain constant. (2 marks)

ii. Resistance of the conductor

Increasing the resistance increases the amount of heat produced when current and time remain constant. (1 mark)

iii. Time for which current flows

Increasing the time for which current flows increases the heat produced. Heat is directly proportional to time. (1 mark)

d) Any one:

- Use a low-voltage power supply.
- Avoid touching the heating wire when the circuit is switched on.
- Switch off the power supply before making adjustments.
- Avoid using damaged connecting wires.
- Ensure the apparatus is properly insulated.

(1 mark)

QUESTION 33: ELECTRICAL ENERGY AND ELECTRICAL POWER (12 MARKS)

a)

i. Electrical energy:

$$\boxed{W = VIt}$$

(1 mark)

ii. Electrical power:

$$\boxed{P = VI}$$

(1 mark)

b) Given:

- Potential difference, $V = 240$ V
- Current, $I = 5$ A
- Time, $t = 10$ minutes

i. Electrical power

Formula:

$$P = VI$$

Substitution:

$$P = 240 \times 5$$

$$\boxed{P = 1{,}200 \text{ W}}$$

(2 marks: formula and substitution – 1 mark; correct answer – 1 mark)

ii. Electrical energy consumed

First convert time into seconds:

$$t = 10 \times 60 = 600 \text{ s}$$

Formula:

$$W = VIt$$

Substitution:

$$W = 240 \times 5 \times 600$$

$$W = 720{,}000 \text{ J}$$

$$\boxed{W = 720{,}000 \text{ J}}$$

(3 marks: time conversion – 1 mark; correct formula and substitution – 1 mark; correct answer – 1 mark)

c) Given:

- Power, $P = 2{,}000$ W
- Time, $t = 5$ minutes

Convert time into seconds:

$$t = 5 \times 60 = 300 \text{ s}$$

Formula:

$$W = Pt$$

Substitution:

$$W = 2{,}000 \times 300$$

$$\boxed{W = 600{,}000\ \text{J}}$$

(3 marks: time conversion – 1 mark; formula and substitution – 1 mark; correct answer – 1 mark)

d)

- SI unit of electrical energy: Joule (J). (1 mark)
- SI unit of electrical power: Watt (W). (1 mark)

QUESTION 34: APPLICATIONS OF THE HEATING EFFECT OF ELECTRIC CURRENT (10 MARKS)

a)

i. Electric kettle

An electric kettle contains a heating element with electrical resistance. When current flows through the element, electrical energy is converted into heat energy. The heat is transferred to the water, raising its temperature until it boils. (2 marks)

ii. Electric iron

An electric iron contains a resistance heating element. When current passes through the element, it becomes hot and transfers heat to the metal soleplate. The hot soleplate is used to remove wrinkles from clothes. (2 marks)

iii. Incandescent electric bulb

An incandescent bulb contains a thin tungsten filament. When electric current passes through the filament, its high resistance causes it to become extremely hot. It glows and produces visible light as well as heat. (2 marks)

b) Electric welding

Electric welding uses a large electric current to produce intense heat at the welding point. The heat melts the edges of the metal pieces, allowing them to fuse together when they cool. (2 marks)

c) Any two properties:

- High electrical resistance.
- High melting point.
- Ability to withstand high temperatures.
- Resistance to oxidation at high temperatures.
- Durability and ability to withstand repeated heating and cooling.

(1 mark each)

QUESTION 35: ELECTRICAL SAFETY AND PRACTICAL APPLICATIONS (8 MARKS)

a) Any four safety precautions:

13. Never operate electrical appliances with wet hands. (1 mark)
14. Keep electrical appliances and sockets away from water. (1 mark)
15. Switch off and unplug appliances before cleaning or repairing them. (1 mark)
16. Do not use appliances with damaged cables or exposed wires. (1 mark)
17. Avoid overloading electrical sockets.
18. Use the correct fuse rating for electrical appliances.
19. Do not insert metallic objects into electrical sockets.

20. Disconnect appliances by holding the plug rather than pulling the cable.
21. Keep hot electrical appliances away from flammable materials.

b) An electric kettle should not be operated without water because:

- The heating element may become excessively hot due to lack of water to absorb the heat. (1 mark)
- This may damage the heating element, cause overheating or create a fire hazard. (1 mark)

c) Any two valid examples:

- Boiling water using electric kettles.
- Cooking food using electric cookers.
- Ironing clothes using electric irons.
- Heating rooms using electric heaters.
- Welding metal structures.
- Producing light using incandescent bulbs.
- Heating water using electric water heaters.

(1 mark each)

ASSESSMENT SUMMARY

Section	Questions	Marks
A: Multiple Choice	1–30	30
B: Structured Questions	31–35	50
TOTAL	**1–35**	**80**

TEACHER'S ASSESSMENT GUIDELINES

1. Award marks according to the marking points provided.
2. Accept scientifically correct alternative answers.
3. In numerical questions, award method marks where the correct formula and substitution are shown.
4. Accept correct answers expressed in equivalent SI units.
5. Award marks for relevant practical observations and appropriate safety precautions.
6. Do not award full marks for numerical answers without the necessary working where working has been requested.

GRADE 11 GENERAL SCIENCE



