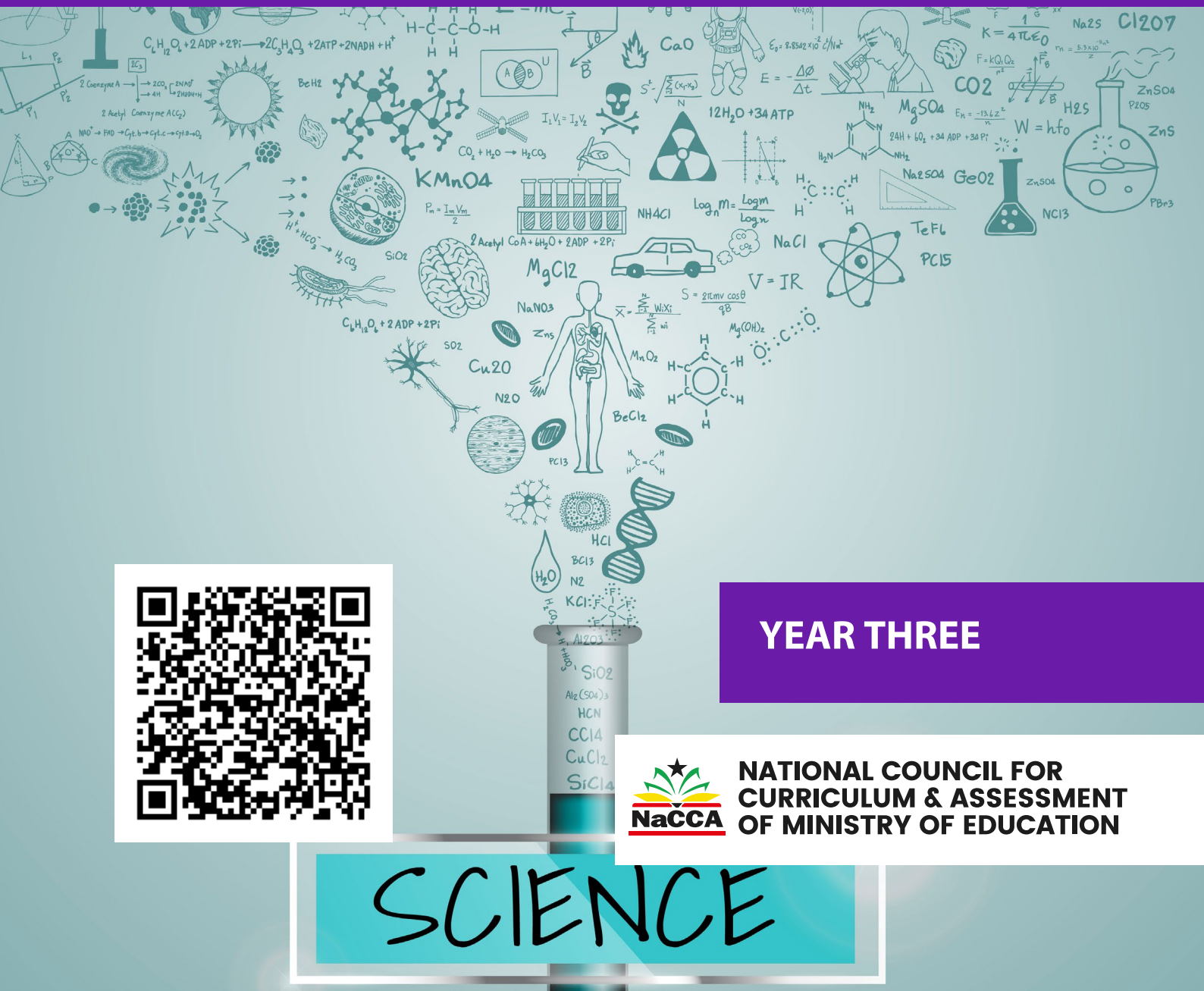
MINISTRY OF EDUCATION

GENERAL SCIENCE

For Senior High Schools

TEACHER MANUAL



YEAR THREE

NATIONAL COUNCIL FOR CURRICULUM & ASSESSMENT OF MINISTRY OF EDUCATION

MINISTRY OF EDUCATION

REPUBLIC OF GHANA

General Science

For Senior High Schools

Teacher Manual

Year Three

NaCCA NATIONAL COUNCIL FOR CURRICULUM & ASSESSMENT OF MINISTRY OF EDUCATION

GENERAL SCIENCE TEACHER MANUAL

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INTRODUCTION FOR THE YEAR THREE TEACHER MANUAL

The National Council for Curriculum and Assessment (NaCCA) has developed the third and final set of curriculum materials to support the implementation of the new Senior High School curriculum.

This Year Three Teacher Manual for covers all aspects of the content, pedagogy, teaching and learning resources and assessment required to effectively support learners in their final year of Senior High School. All the necessary information for the Student Assessment Portal has been included in the Year Three Teacher Manual to simplify the development of weekly learning plans, meaning that teachers have a single reference document.

The Year Three Teacher Manual has two main objectives:

- To support learners to consolidate and deepen their understanding of the content, pedagogy, and assessment across all three years of the new Senior High School curriculum in preparation for the West Africa Senior Secondary Certificate Examination (WASSCE).
- To equip teachers with the tools and resources needed to deliver revision-focused, assessment-led lessons that build on the knowledge learners have acquired from Year One to Year Three.

In this third year, teachers will be supporting learners to prepare for the WASSCE. Each section of the Teacher Manual is therefore structured around the highest Depth of Knowledge (DoK) levels, allowing learners to build progressively on knowledge acquired from Year One to Year Three. For each week, learning tasks and pedagogy are built around the assessment, ensuring that classroom activities directly prepare learners for the demands of the examination. Two sets of sample examination papers are also provided; one administered by Week 12 as a first semester practice examination, and one by Week 20 as a mock examination, to gauge learners' competencies and identify areas requiring remediation.

To further support teachers in delivering Year Three, NaCCA, working with the Ghana Education Service, has developed a subject specific App for each subject.

The Year Three PLC sessions have been revised in response to findings from the 2025 annual evaluation survey. The survey confirmed that teachers have made strong progress in lesson planning, use of varied instructional methods, ICT integration and modes of assessment. To address the identified gap in explaining concepts clearly using examples familiar to learners, each PLC session now includes a dedicated Content Exploration segment. This ten-minute segment brings the subject group together to work through one challenging problem or concept from the week's Teacher Manual content, not to plan how to teach it, but to ensure that every teacher in the group fully understands it.

The PLC sessions in Year Three also place particular emphasis on connecting the week's content to equivalent topics taught in Years One and Two. Teachers are encouraged to note the recap weeks signposted throughout the Teacher Manual and to use the App to explore how content across all three years links together.

As in previous years, teachers are expected to integrate National Values, Gender Equality and Social Inclusion (GESI), Social and Emotional Learning (SEL), and 21st-century skills into their learning activities, assessment tasks, and rubrics and mark schemes. The subject-specific App will support teachers in doing this throughout the year.

Ghana Education Service acknowledges the dedication of the teachers who have implemented the new curriculum across Years One and Two and recognises that Year Three represents both the culmination of that effort and a critical moment for learners. The Year Three Teacher Manual and its accompanying resources have been developed to ensure that every learner, regardless of background, ability, or school context, is fully prepared to demonstrate what they know and can do in the WASSCE and to progress confidently to further studies, the world of work, and adult life.

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SECTION 1: COMPOSITION OF AIR

STRAND: EXPLORING MATERIALS

Sub-Strand: Science and materials in nature

Learning Outcome: *Explore the composition of air and the laboratory preparation and uses of oxygen and carbon dioxide.*

Content Standard: *Explore the concept of 'Air' as a mixture of useful gases in nature and understand the preparation of oxygen and carbon dioxide and their uses in human life.*

INTRODUCTION AND SECTION SUMMARY

In this section, learners will explore air as a mixture of gases, identifying its major components and their uses in nature and everyday life. They will learn to prepare carbon dioxide and oxygen through simple laboratory experiments and explain the properties and applications of each gas.

By the end of the lesson, learners should be able to describe the composition of air, explain the roles of its components, and demonstrate the preparation and uses of carbon dioxide and oxygen.

The weeks and the indicators covered by the section are:

Week 1: Identify air as a mixture and explain the uses of the components of air.

Week 2

- Prepare carbon dioxide and discuss its uses.
- Prepare oxygen and discuss its uses.

SUMMARY OF Pedagogical Exemplars

This section outlines effective strategies for teaching the concept of air using learner-centred approaches. Learners work collaboratively to explore the meaning and properties of air, developing communication and problem-solving skills.

Inquiry-based learning encourages them to ask questions and investigate the composition of air, while experiential learning involves hands-on experiments to observe air's properties directly.

Demonstrations and simulations help visualise complex ideas like air pressure and composition, supported by visual and multimedia aids to enhance understanding. Through project-based learning, learners research and present real-world uses of air's components.

By the end of the lesson, learners should know the composition of air, understand its importance in nature, and be able to conduct investigations, ask scientific questions, and present their findings clearly.

Teachers act as facilitators, guiding learners through active discovery and practical application.

ASSESSMENT SUMMARY

This section employs varied assessment strategies aligned with appropriate Depth of Knowledge (DOK) levels to evaluate learners' understanding and application of key scientific concepts.

Learners will identify air as a mixture and explain the uses of its components through project work, assessed at DOK Level 4, requiring extended critical thinking and synthesis of information.

For the indicator 'prepare carbon dioxide and discuss its uses', learners will engage in practical demonstrations, allowing them to apply procedural knowledge and observe outcomes in real time.

Finally, learners will prepare oxygen and discuss its uses, also through practical demonstrations, assessed at DOK Level 3, focusing on strategic reasoning and the ability to link scientific procedures to real-world uses.

These assessments promote both collaborative and independent inquiry, hands-on exploration, and critical analysis.

Indicators	DOK Level	Assessment Strategy and/or Mode
Identify air as a mixture and explain the uses of the components of air.	Key Assessment Level 4: Extended critical thinking and reasoning	Project work
Prepare carbon dioxide and discuss its uses.	Key Assessment Level 3: Strategic reasoning	Test of practical
Prepare oxygen and discuss its uses.	Key Assessment Level 3: Strategic reasoning	Test of practical

WEEK 1

Learning Indicator: *Identify air as a mixture and explain the uses of the components of air*

Focal Area: Components of Air and their uses

Overview

Air is a substance that is inevitable in our lives. The earth is covered with a blanket of air called the atmosphere. Among the few fundamental elements, it is the most important because no life can exist for any length of time without it. It is needed by every single organism for their survival.

Air is a natural mixture of invisible gases that surround the Earth and is essential for sustaining life. Rather than being a single pure substance, air is made up of various gases in specific proportions, including nitrogen, oxygen, carbon dioxide, argon, water vapour, and trace gases such as neon and helium. Each of these components play a vital role in environmental processes and human activities.

Understanding air as a mixture helps us appreciate how these gases interact to support breathing, combustion, plant growth, industrial processes, and climate regulation. This topic explores the composition of air and highlights the practical uses of its key component.

Composition of Air and their Uses

Air is a mixture of various gases, each present in different proportions. These gases together support life, influence weather patterns, and drive numerous natural and industrial processes. The major components of clean, dry air near the Earth's surface include:

Nitrogen (N_2) – 78%

The most abundant, pure component of air is nitrogen, with a concentration of 78%. It has the symbol N and atomic number 7. Nitrogen is produced through a process called nitrogen fixation, which is a continuous cycle between living organisms and the atmosphere.

It is also produced in industries by fractional distillation of air in its liquid form. Dinitrogen is a molecule of two nitrogen atoms bonded by a strong triple bond. Due to the triple bond, the decomposition of N_2 ($N \equiv N$) is difficult and hence the process of its decomposition, which includes processes like exploding, produces a huge amount of useful energy. Nitrogen is present in living organisms in compounds such as nucleic acids and amino acids.

Uses of Nitrogen

Nitrogen, which makes up about **78%** of the Earth's atmosphere, plays a crucial role in various natural and industrial processes. Here are some of its main uses:

1. **Agriculture (Fertilisers)**
   Nitrogen is a key component of fertilisers such as urea and ammonium nitrate. Plants need nitrogen for growth as it helps in the formation of proteins and chlorophyll.
2. **Biological importance**
   Nitrogen is found in all living organisms as part of amino acids, proteins, enzymes, and deoxyribonucleic acid (DNA). It is essential for cell development and reproduction.

3. **Food industry**
   Nitrogen gas is used to preserve packaged foods by displacing oxygen to prevent spoilage and bacterial growth. Liquid nitrogen is used to quick-freeze food items.
4. **Industrial applications**
   a. Used to create an inert atmosphere in chemical processes and electronics manufacturing to prevent oxidation.
   b. Used in the production of ammonia (NH_3) through the Haber process, which is the foundation of many nitrogen-based products.
5. **Medical uses**
   Liquid nitrogen is used for cryosurgery, which involves freezing and removing abnormal tissues, such as warts or precancerous cells.
6. **Tyre inflation (aircraft and car)**
   Nitrogen is preferred in tyres because it is less likely to cause pressure changes due to temperature fluctuations and reduces oxidation inside the tyre.

Oxygen (O_2) – 21%

Oxygen is one of the most vital chemical elements in the air, represented by the symbol O and atomic number 8. It is a highly reactive and combustible gas that forms compounds called oxides with other elements. Oxygen ranks third in abundance by mass in the universe, after hydrogen and helium. At standard temperature (273.15K) and pressure (1 atm), two atoms of oxygen form a molecule called dioxygen (O_2), essential for respiration in living organisms.

Uses of Oxygen

1. **Respiration**

   Oxygen is essential for aerobic respiration in humans and animals. It is the gas we breathe in to help break down food and release energy in cells. Without oxygen, most living organisms cannot survive, as it plays a key role in cellular energy production.

2. **Medical applications**

   Oxygen is widely used in hospitals and healthcare settings

   a. Oxygen therapy is provided to patients with breathing difficulties or respiratory conditions like asthma, pneumonia, and COVID-19.
   b. It is also used in anaesthesia machines during surgeries.

3. **Industrial Processes**

   Oxygen is used in a range of industrial applications

   a. Steel manufacturing: Oxygen is blown into molten iron to remove impurities like carbon, producing high-quality steel.
   b. Chemical production: It is used in making chemicals such as nitric acid and hydrogen peroxide.
   c. Welding and cutting: Oxygen is used in combination with gases like acetylene in oxy-acetylene torches for welding, cutting, and brazing metals.

4. **Aviation and space exploration**

   In high-altitude aviation and space missions, oxygen is supplied in tanks to pilots and astronauts since the atmospheric oxygen is too low or absent at those altitudes. It ensures proper breathing and life support.

5. **Water treatment**

   Oxygen is used in wastewater treatment plants to help break down pollutants by supporting the growth of aerobic bacteria. It improves the efficiency of the biological treatment process.

6. **Scuba diving and High-altitude sports**

   Scuba divers carry compressed oxygen tanks to breathe underwater. Similarly, mountaineers climbing high-altitude peaks use oxygen cylinders to prevent hypoxia (lack of oxygen in the body).

7. **Environmental and laboratory uses**

   a. In environmental studies, oxygen sensors measure water quality by checking dissolved oxygen levels.

   b. In laboratories, pure oxygen is used to facilitate controlled reactions or support combustion in experiments.

Carbon dioxide (CO_2) – 0.04%

Carbon dioxide is classified as a trace gas, making up approximately 0.04% of the Earth's atmosphere. Trace gases are present in very small quantities. Carbon dioxide is represented by the chemical symbol CO_2. Carbon dioxide is released during respiration and the decomposition of organic matter. It also occurs naturally from sources such as volcanoes, geysers, and hot springs. Additionally, the burning of fossil fuels like petroleum and natural gas produces significant amounts of carbon dioxide.

Uses of Carbon dioxide

1. **Photosynthesis:** Carbon dioxide plays a crucial role in the survival of plants through the process of photosynthesis. During this process, plants absorb carbon dioxide from the atmosphere and use it, along with sunlight and water, to produce glucose (a form of sugar) and oxygen. This is not only essential for plant growth but also vital for maintaining the oxygen balance in the atmosphere.

2. **Food and beverage industry**

   a. **Carbonation**: CO_2 is widely used to carbonate beverages such as soft drinks, soda water, and sparkling wine, giving them their characteristic fizz.

   b. **Preservation**: In packaged foods, carbon dioxide is used as a food preservative to inhibit the growth of bacteria and fungi. Modified atmosphere packaging (MAP) involves replacing the air in packaging with a mixture of gases, including CO_2, to extend shelf life.

3. **Fire extinguishers**

   Carbon dioxide is commonly used in fire extinguishers, especially for electrical fires and flammable liquids. It works by displacing oxygen around the fire and forming a blanket over the flames, thus cutting off the oxygen supply required for combustion.

4. **Refrigeration (Dry Ice)**

   In its solid form, carbon dioxide is known as dry ice. It is used as a cooling agent for the preservation of perishable goods such as meat, seafood, and medical supplies during storage and transport. Dry ice sublimates directly into gas without passing through a liquid phase, making it very convenient for refrigeration without mess.

5. **Welding and industrial Use**

   In industries, carbon dioxide is used as a shielding gas in gas metal arc welding (GMAW). It protects the weld area from atmospheric gases such as oxygen and nitrogen that could cause defects in the weld. CO_2 is also used in the production of certain chemicals and plastics.

6. **Greenhouses**

   A greenhouse is used to create a controlled warmer environment for growing plants. Carbon dioxide enrichment in greenhouses is a common practice used to promote faster and healthier plant growth. By increasing the concentration of CO_2 in the air within a greenhouse, plants can photosynthesise more efficiently, resulting in better yields.

7. **Fertiliser production**

   CO_2 is an important raw material in the manufacture of **urea**, a nitrogen-based fertiliser used globally in agriculture.

   Urea is formed when carbon dioxide reacts with ammonia under specific conditions. This fertiliser helps to increase crop yields and is vital for food production.

Water vapour – 0.01% to 4% (variable)

The amount varies depending on location and weather. It plays a vital role in cloud formation, rainfall, and temperature regulation through the greenhouse effect.

Water vapour content in the air varies from 0.01% to 4.24%, depending on temperature. It is released during respiration and produced in many chemical reactions.

1. **Regulates temperature (Greenhouse Effect)**: Water vapour is a natural greenhouse gas. It traps heat in the atmosphere by absorbing and re-emitting infrared radiation. This helps maintain Earth's temperature within a range that supports life.

2. **Helps in the water cycle:** Water vapour is essential in the water cycle.
   a. It evaporates from water bodies (lakes, rivers, oceans).
   b. It condenses to form clouds.
   c. Eventually, it returns to Earth as precipitation (rain, snow, etc.).

3. **Weather formation**
   a. Water vapour is a factor in weather systems. It contributes to cloud formation, storms, and rainfall.
   b. Humidity levels, which affect how hot or cold the weather feels

4. **Supports plant life**
   a. Water vapour in the air contributes to atmospheric humidity.
   b. When humidity is high, transpiration (loss of water through plant leaves) slows down, helping plants to conserve water.
   c. When humidity is low, transpiration increases, pulling more water and nutrients up from the roots; this is important for nutrient transport.

Trace gases

These include neon, helium, methane, krypton, and hydrogen, which are present in minute quantities but may have significant environmental and technological roles. Even though trace gases make up less than 1% of the atmosphere, they play critical roles in natural processes, industry, medicine, and technology.

1. **Uses of trace gases**
   Neon (Ne) – ~0.0018%

   a. **Neon lighting:** Neon is famous for its use in advertising signs. When electric current passes through neon gas in glass tubes, it emits a bright red-orange glow.

   b. **Indicators and detectors:** Neon is also used in **high-voltage indicators**, lightning arresters, and vacuum tubes because of its stability and light-emitting properties.

2. **Helium (He) – ~0.0005%**

   a. **Lighter-than-air gas:** Helium is **non-flammable** and lighter than air, making it safer than hydrogen for filling balloons, blimps, and airships.

   b. **Medical uses (MRI):** Helium is used as a **coolant** in MRI (Magnetic Resonance Imaging) machines to maintain the superconducting magnets at extremely low temperatures.

   c. **Welding:** Helium serves as a **shielding gas** in arc welding to prevent oxidation of hot metals.

3. **Methane (CH_4) – ~0.0002%**

   a. **Fuel source:** Methane is the main component of natural gas. It's burned for heating, cooking, and generating electricity.

   b. **Chemical industry:** Used to produce hydrogen gas, ammonia, and other chemicals. It is also studied as a renewable energy source through biogas.

   c. **Greenhouse gas:** Although a trace gas, methane is very effective at trapping heat and contributes to global warming.

4. **Krypton (Kr) – ~0.0001%**

   a. **Lighting and lasers:** Used in high-performance light bulbs, such as flash lamps in photography and some kinds of fluorescent bulbs.

   b. **Insulated glazing (windows):** Krypton is used in double-glazed windows to reduce heat transfer, improving energy efficiency in buildings.

5. **Hydrogen (H_2) – Trace amounts**

   a. **Rocket fuel:** Hydrogen, when combined with oxygen, produces water vapor and a large amount of energy; ideal for space rockets.

   b. **Clean energy source:** Hydrogen is used in fuel cells to generate electricity, emitting only water, making it a potential green energy alternative.

   c. **Industrial use:** Involved in making ammonia (for fertilisers) and refining petroleum.

6. **Ozone (O_3) – Very small amount (mostly in the upper atmosphere)**
    a. **Ozone layer protection:** In the stratosphere, ozone forms a layer that absorbs harmful ultraviolet (UV) rays from the sun, protecting living organisms from radiation damage.
    b. **Sterilisation and purification:** At ground level, ozone is used to disinfect water, purify air in medical facilities, and clean food-processing equipment.
    c. **Environmental role:** Though beneficial in the upper atmosphere, at ground level, high concentrations of ozone can be a pollutant that affects human lungs.
7. **Argon (Ar) – 0.93%**
    a. **Lighting:** Argon is used in fluorescent and incandescent light bulbs to prevent the filament from oxidising and to increase the bulb's lifespan. It also gives a bluish glow when used in gas discharge tubes.
    b. **Electronics manufacturing:** In the production of semiconductors and other electronic components, argon provides an inert atmosphere to avoid unwanted chemical reactions during manufacturing.
    c. **Medical applications:** Argon lasers are used in eye surgeries (like treating retinal detachment or glaucoma) and to destroy tumours or abnormal tissues with precision.
    d. **Preservation and packaging:** Argon is used to displace oxygen in containers or packaging to preserve the freshness of wine, pharmaceuticals, and sensitive chemicals.
    e. **Scientific research:** It is used in gas chromatography and as a carrier gas in other analytical instruments due to its inertness.

Table 1.0: Shows composition of air

Components of air	*Volume by %*	*Symbol of the Element*
Nitrogen	78.0	N_2
Oxygen	21.0	O_2
Argon	0.93	Ar
Carbon Dioxide	0.04	CO_2
Other gases (Trace gases)		
Neon	0.0018	Ne
Helium	0.0005	He
Krypton	0.0001	Kr
Hydrogen	0.00005	H_2
Xenon	8.7×10^{-6}	Xe

Activity 1.1: Oxygen a component of air

1. **Aim:** To show that oxygen is a component of air
2. **Materials**

- Two candles
- Matches
- Glass jar

3. **Procedures**
   - Light both candles.
   - Cover one of them with a glass jar.
   - Observe what happens after a few seconds.
4. **Observation**
   The covered candle goes out, while the open one keeps burning.
5. **Conclusion**
   This shows oxygen is part of air and is needed for burning. When oxygen runs out inside the jar, the flame goes out; proving that oxygen is one component of air.

Environmental impact of Changes in the Percentages in components of Air

Table 1.1. Shows environmental impact of changes in the percentages of components of air**.**

Gas Component	% in Air	Role	If increased	If decreased
Nitrogen (N_2)	78%	- Provides inert balance - Dilutes oxygen - Supports nitrogen fixation	- Further dilutes oxygen, affects respiration - Reduces combustion - Minor climate/ health impact	- Increases oxygen levels, fire risk - Disrupts nitrogen cycle - Affects soil fertility
Oxygen (O_2)	21%	- Essential for respiration - Supports combustion	- Higher fire risk - Increased metabolism, oxidative stress - May help breathing temporarily	- Breathing difficulties, fatigue - Risk of death at <15% - Collapse of aerobic life
Carbon Dioxide (CO_2)	0.04%	- Needed for photosynthesis Greenhouse gas	- Global warming - Ocean acidification - Disrupts ecosystems	- Reduced photosynthesis and plant growth - Global cooling
Argon (Ar)	0.93%	- Inert gas - Stabilises atmosphere	- No significant effect (inert)	- No significant effect (inert)

Water Vapour	0–4% (Variable)	- Affects climate - Part of water cycle	- Increased rainfall and clouds - Traps heat (greenhouse effect) - Floods and extreme weather	- Dry conditions - Reduced plant growth - Drought risk
Ozone (O_3)	Trace	- Absorbs UV rays - Protects life	- Ground-level ozone causes smog - Respiratory problems	- More UV exposure - Skin cancer, cataracts - Harm to plankton and crops

Learning tasks

1. Analyse the nature of air as a mixture and justify, using scientific reasoning, why it is not classified as a compound.
2. Develop a model or data table that accurately represents the components of air, including their percentages, and evaluate how changes in these percentages could impact living organisms and the environment.
3. Investigate and evaluate the roles of different components of air in sustaining life and ecological balance, using real-world examples and current environmental data.
4. Design and conduct a comprehensive experiment to identify and test the presence of different components of air, including procedures for data collection, analysis, and error evaluation. Present your findings in a scientific report.

Pedagogical Exemplars

1. **Collaborative Learning**
   a. Foster group activities where learners can work together to explore the meaning of air.
   b. Encourages peer interaction, discussion, and shared problem-solving, allowing learners to benefit from diverse perspectives.
2. **Inquiry-Based Learning**

   Encourages learners to ask questions and investigate the concept of air through guided inquiry. This approach involves posing thought-provoking questions about composition of air, guiding research, and facilitating discussions to deepen understanding.
3. **Experiential Learning**

   Engage learners in hands-on experiments and activities to explore the properties of air firsthand. This can include conducting experiments to demonstrate the presence of gases in the air, exploring air pressure, or showcasing the effects of air on different objects.
4. **Demonstrations and Simulations**

   Conduct live demonstrations or use virtual simulations to show how air behaves and its impact on the environment. By visually demonstrating concepts like air pressure, buoyancy, and air composition, learners can gain a clearer understanding of the meaning of air.

5. **Visual and Multimedia Aids**

   Utilise visual aids such as diagrams, videos, and interactive simulations to illustrate complex concepts related to air. Visual and multimedia resources can help reinforce learning and make abstract ideas more concrete.

6. **Project-Based Learning:**

   Assign projects that require learners to research, analyse, and present information about the uses of components of air in nature. Projects could include creating visual representations of the uses of components of air in nature, designing experiments, or developing educational materials.

Key Assessment Level 4: Project Work

1. Evaluate the impact of changes in the concentration of air components (e.g., increased carbon dioxide) on natural processes such as photosynthesis, respiration, and global climate. Support your analysis with scientific evidence and propose two solutions to mitigate any negative effects. (**20 marks**)

2. Design a poster to show the uses of the major components of air in nature (such as nitrogen, oxygen, carbon dioxide, etc.) that has a critical analysis of how changes in the balance of these components due to natural or human-induced factors have impacted the ecosystems and biodiversity. Include real-world examples, scientific reasoning, and propose sustainable actions to mitigate negative impacts. **(20 marks)**

HINT

Assign a group project to learners and give them a reasonable time to complete it. Use the SS App to generate the project and the rubric. Learners' projects should be marked immediately and scores entered into the SAP.

PLC Session 1

45 minutes | **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous session, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to
   a. explain the week's concepts in a practical way that will make it easier for learners to understand.
   b. identify three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners (NTS 3a, 3g and 3m).
3. Use your subject specific app to plan your lesson. Ask the app to
   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
   b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q).
   c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).

Note

- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Use your app to plan and administer the mode of assessment for the Student Assessment Portal (SAP)

   a. The key assessment for the week is ***group project***. Chat with your app to plan this assessment by reviewing or developing the assessment items/tasks and marking schemes/rubrics for the project (NTS 3k-3q).

10 minutes **Content Exploration**

5. As a subject group, select one problem or topic/idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

   a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)

   b. all teachers in the group work through the problem individually for 3–4 minutes

   c. the group then works through it together the problem, step by step

   d. highlight the most common errors made at each step (NTS 1c, 1e, 2c, 2e, 3e-3j).

Note

- *This part is not 'How do I teach this?' but how do I teach it for learners to understand?*
- *If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.*
- *Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.*

30 minutes **Enactment**

6. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).

   a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.

   b. After the enactment, ask for structured feedback from the group

      i. was the concept explained in a way that a learner with no prior knowledge could follow?

      ii. were the examples grounded in contexts familiar to Ghanaian learners?

      iii. did any misconceptions surface and if so, how were they addressed?

5 minutes **Reflection**

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).

8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
    a. transfer your chats into your learning planner template.
    b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
    c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 2

Learning Indicators

1. *Prepare carbon dioxide and discuss its uses*
2. *Prepare oxygen and discuss its uses*

Focal Area: Preparation of carbon dioxide and oxygen

Laboratory Procedures for Preparing Carbon Dioxide and Oxygen Gases

Carbon dioxide (CO_2) and oxygen (O_2) are fundamental gases with a wide array of applications across various scientific, industrial, and everyday contexts.

Carbon dioxide plays a vital role in the carbon cycle, is used in the production of carbonated beverages, fire extinguishers, and serves as a crucial reactant in various chemical processes.

Oxygen, essential for respiration in most living organisms, is also widely used in industrial processes such as steelmaking, welding, and medical applications.

This lesson details the procedures for the laboratory preparation of both carbon dioxide and oxygen, outlining the principles of the reactions involved, the necessary materials and apparatus, step-by-step methodologies, critical safety precautions, and the scientific rationale behind the selection of specific materials and methods.

Laboratory Preparation of Carbon Dioxide (CO_2)

Carbon dioxide is commonly synthesised in the laboratory through the reaction between a metal carbonate and a dilute acid. A widely used method involves the reaction of calcium carbonate ($CaCO_3$), often in the form of marble chips, chalk, or limestone, with dilute hydrochloric acid (HCl). The balanced chemical equation for this reaction is:

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

This equation indicates that one mole of solid calcium carbonate reacts with two moles of aqueous hydrochloric acid to produce one mole of aqueous calcium chloride, one mole of liquid water, and one mole of gaseous carbon dioxide. The precise molar ratios are essential for determining the required quantities of reactants and predicting the theoretical yield of the product.

This type of reaction is classified as an acid-carbonate reaction, and it proceeds spontaneously at room temperature. The fact that the reaction occurs readily without external heating simplifies the experimental setup and reduces the need for additional energy input, making it a practical choice for laboratory use. Carbon dioxide can also be prepared using other methods such as the combustion of hydrocarbons, the decomposition of carbonates upon heating, and the reaction between baking soda and vinegar.

Materials and apparatus for the laboratory preparation of carbon dioxide

To prepare carbon dioxide gas in the laboratory, the following materials and apparatus are required:

- A round-bottom flask with a gas-tight stopper
- Thistle funnel

- Delivery tube bent twice at right angles
- Gas jar with a lid
- Rubber corks with bores
- Cork borer (used to create holes in the rubber corks)
- Marble chips (calcium carbonate)
- Dilute hydrochloric acid (typically 2M or 6M)
- Lime water (optional, for testing the presence of carbon dioxide)

The Woulfe's bottle is particularly suitable for this setup because its multiple openings allow for the controlled addition of acid through the thistle funnel while simultaneously enabling the collection of gas through the delivery tube. This closed system minimises gas leakage and ensures efficient carbon dioxide collection.

The reaction rate depends on the concentration of hydrochloric acid; a higher concentration increases the reaction speed.

Procedure

The procedure for preparing carbon dioxide gas in the laboratory is as follows:

1. Set up the apparatus by placing some marble chips inside the flask.
2. Fit the round bottom flask with a rubber stopper that has two holes.
3. Insert the thistle funnel into one of the holes, ensuring that its lower end extends almost to the bottom of the bottle.
4. Insert one end of the delivery tube into the other hole of the rubber stopper, positioning it above the level of the marble chips.
5. Place the gas jar in an upright position, ready to collect the gas.
6. Carefully pour dilute hydrochloric acid through the thistle funnel, making sure that the marble chips are fully submerged in the acid.
7. Observe the reaction, which will manifest as effervescence (the production of bubbles), indicating the evolution of carbon dioxide gas.
8. Collect the carbon dioxide gas in the gas jar using the method of upward displacement of air. This method is employed because carbon dioxide is denser than air, approximately 1.5 times heavier. Due to this density difference, the carbon dioxide gas will settle at the bottom of the gas jar, effectively pushing the lighter air upwards and out of the jar. This collection technique is efficient and does not necessitate drying the gas.
9. Collect several gas jars filled with carbon dioxide.
10. Confirm the identity of the collected gas by introducing a small amount of lime water into one of the gas jars. If carbon dioxide is present, the lime water will turn milky due to the formation of a white precipitate of calcium carbonate, as shown by the reaction: $Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$. This reaction with lime water serves as a specific and sensitive test for the presence of carbon dioxide gas.

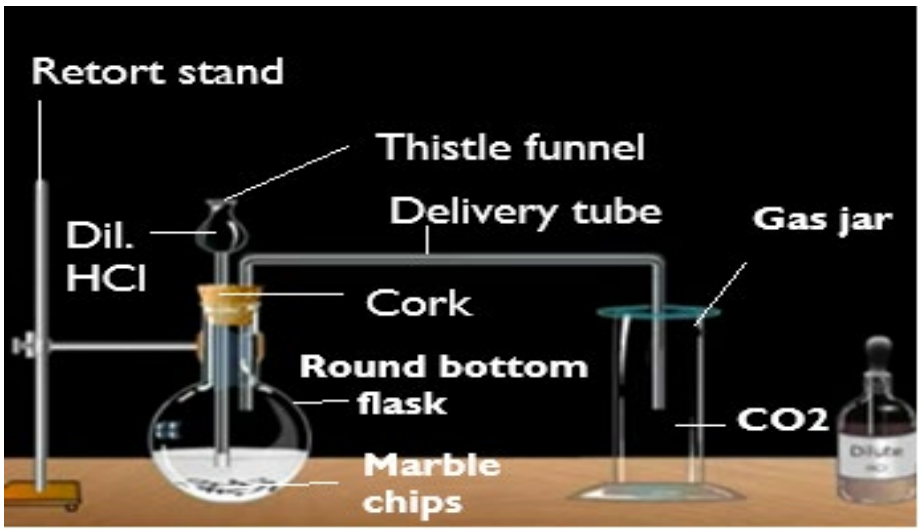


Figure 1.0: *Setup of laboratory preparation of carbon dioxide*

Activity 2: Test for Carbon Dioxide (CO_2)

Materials

- Test tube containing CO_2
- Delivery tube
- Rubber cork
- Lime water

Procedure

1. Prepare limewater. This is a clear solution of calcium hydroxide ($Ca(OH)_2$) in water.
2. Bubble the gas through the limewater. You can use a straw, tubing, or a delivery system to gently pass the gas through the limewater.
3. Observe the reaction. If carbon dioxide is present, the limewater will turn milky or cloudy. This happens because CO_2 reacts with calcium hydroxide to form calcium carbonate ($CaCO_3$), which is insoluble and makes the solution appear cloudy.

Chemical Equation

$CO_{2\,(g)} + Ca(OH)_{2\,(aq)} \rightarrow CaCO_{3\,(s)} + H_2O_{\,(l)}$

This is a standard and reliable test for detecting carbon dioxide gas.

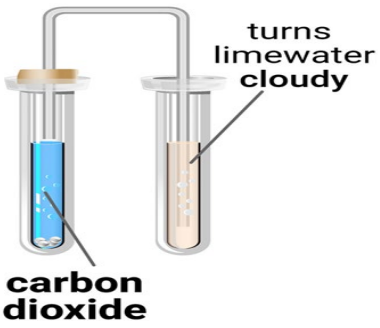


Figure 1.1: Diagram set-up for test for carbon dioxide

Safety Precautions

1. Always wear safety goggles to protect the eyes from any accidental splashes of hydrochloric acid.
2. Ensure that the entire apparatus is airtight to prevent the leakage of carbon dioxide gas and to ensure efficient collection. An airtight setup also prevents the escape of any potentially irritating acid fumes into the laboratory.
3. The thistle funnel must be inserted such that its lower end is always below the surface of the hydrochloric acid in the flask. This creates a liquid seal that prevents the carbon dioxide gas from escaping through the thistle funnel.
4. Add the dilute hydrochloric acid slowly and gradually through the thistle funnel. This controlled addition helps to regulate the rate of the reaction and prevents excessive frothing or a rapid release of gas that could lead to overflow.
5. Handle hydrochloric acid with care as it is corrosive. In case of any contact with the skin, immediately wash the affected area with plenty of water.
6. Use smaller pieces of marble chips in the flask. Smaller pieces provide a larger surface area for the reaction with the acid, leading to a more consistent and manageable rate of gas production. Larger pieces might also obstruct the opening of the flask.

Why these Materials and Methods?

1. Calcium carbonate, commonly available as marble chips, is an inexpensive and accessible reactant.
2. Hydrochloric acid is a strong acid that reacts readily with calcium carbonate at room temperature to produce carbon dioxide gas efficiently.
3. While other acids such as sulphuric acids can also react with calcium carbonate, hydrochloric acid is preferred because it does not produce insoluble by-products. For example, sulphuric acid forms calcium sulphate, which is poorly soluble and can form a coating around the marble chips, slowing or stopping the reaction.
4. The collection of carbon dioxide by upward displacement of air is chosen due to the gas's higher density compared to air. This method allows for:
5. Efficient collection without specialised drying equipment.
6. Avoidance of using water displacement, which is less suitable due to carbon dioxide's slight solubility in water.

Table 1.2: *Comparison of laboratory preparation methods for carbon dioxide*

Method	Reactants	Products (excluding CO_2)	Conditions	Advantages	Disadvantages
Reaction of Calcium Carbonate with HCl	$CaCO_3$, HCl	$CaCl_2$, H_2O	Room temperature	Readily available reactants, relatively safe	Requires airtight apparatus
Reaction of Baking Soda with Vinegar	$NaHCO_3$, CH_3COOH	CH_3COONa, H_2O	Room temperature	Simple and safe, readily available at home	May produce CO_2 mixed with air

Thermal Decomposition of Calcium Carbonate	$CaCO_3$	CaO	High temperature	Produces relatively pure CO_2 if done correctly	Requires high temperature, energy intensive

Table 1.3: *Properties of Carbon Dioxide (CO2)*

Property Category	Experiment	Observation	Inference
Physical Properties			
1. Colour	Observe the colour of the gas.	The gas is colourless.	CO_2 gas is colourless.
2. Odour	Observe the odour of the gas.	The gas has no odour.	CO_2 gas is odourless.
3. Combustibility	Introduce a burning matchstick /jute stick into a test tube containing CO_2 gas.	The matchstick get extinguished.	CO_2 gas is neither combustible nor a supporter of combustion, rather it extinguishes the flame.
4. Density & Combustion Support	Invert a test tube filled with the gas over another empty test tube. Then insert a burning matchstick into the lower test tube.	The burning matchstick gets extinguished showing the presence of CO_2 in the lower test tube.	The gas is heavier than air and it is neither combustible nor a supporter of combustion.
5. Solubility in Water	Collect CO_2 gas in a test tube, put your thumb at its mouth and invert it into a trough of water.	Water level inside the test tube rises slowly.	Carbon Dioxide (CO_2) gas is sparingly soluble in water.
Chemical Properties			
1. Acidity (Litmus with Solution)	Introduce a blue litmus paper into the CO_2 dissolved in water solution present in the test tube (likely referring to CO_2 dissolved in water from previous step).	Blue litmus papers turned red.	Carbon Dioxide (CO_2) gas is acidic in nature.
2. Acidity (Litmus with Gas)	Show a moist blue litmus paper to the evolved gas.	Blue litmus papers turned red.	Carbon Dioxide (CO_2) gas is acidic in nature.

3. Reaction with Lime Water	Pass the evolved gas into a test tube containing lime water ($Ca(OH)_2$).		
(a) Limited CO_2	At first slowly in a smaller amount.	Lime water turned milky.	Milkiness is due to the formation of insoluble $CaCO_3$ ppt.
(b) Excess CO_2	Then pass CO_2 gas in excess.	Milkiness disappeared.	This is due to the formation of soluble $Ca(HCO_3)_2$ solution.
(c) Heating Solution	Now heat the above solution (containing $Ca(HCO_3)_2$).	Milkiness again reappeared.	This is due to the expulsion of excess CO_2 gas on heating, reforming $CaCO_3$.
4. Reaction with Burning Magnesium	Introduce a burning magnesium ribbon into a test tube containing CO_2 gas.	The magnesium ribbon burns vigorously, producing white fumes and black residue.	Black residue is due to the formation of carbon black and white powder is due to the formation of MgO.
6. Reaction with Alkaline Phenolphthalein	Pass the gas through alkaline phenolphthalein solution.	The pink colour of solution becomes colourless.	Carbon dioxide (CO_2) gas is acidic in nature. (It neutralises the alkali causing the indicator to change)
7. Reaction with Methyl Orange	Add methyl orange indicator to the aqueous solution of CO_2 gas.	Orange colour of solution changes to red.	CO_2 gas is acidic in nature. (Methyl orange turns red in acidic solutions.)

Laboratory Preparation of Oxygen (O_2)

Oxygen is commonly prepared in the laboratory through the catalytic decomposition of hydrogen peroxide (H_2O_2). In this reaction, hydrogen peroxide breaks down into water and oxygen gas in the presence of manganese (IV) oxide (MnO_2) as a catalyst.

The balanced chemical equation for this reaction is:

$$2H_2O_{2(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$$

This equation shows that two moles of aqueous hydrogen peroxide decompose to yield two moles of liquid water and one mole of gaseous oxygen.

Manganese (IV) oxide acts as a catalyst by providing an alternative reaction pathway with a lower activation energy, thereby accelerating the rate of the decomposition of hydrogen peroxide without itself undergoing any permanent chemical change.

The catalyst can be recovered chemically unchanged at the end of the reaction. While other methods exist for preparing oxygen, such as the thermal decomposition of potassium chlorate and the electrolysis of water, the catalytic decomposition of hydrogen peroxide is often preferred due to its relative safety and convenience, as it typically does not require high temperatures and utilises readily available chemicals.

Laboratory preparation, collection and test for oxygen gas

Laboratory preparation of Oxygen gas

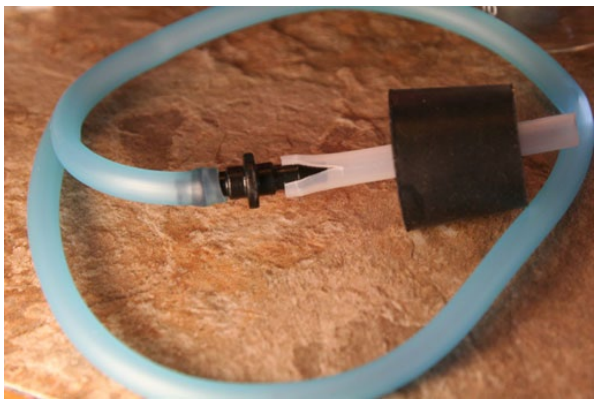
Description and procedures

1. **Apparatus:** Make sure all materials are ready and organised before beginning the experiment
   a. Hydrogen Peroxide
   b. Test Tube
   c. Rubber stopper with a hole
   d. Blue flexible tubing.
   e. Conical flask
   f. Scissors

   Manganese Dioxide: This will be used as the catalyst to speed up the decomposition of hydrogen peroxide.

2. **Assembling the gas delivery tubing setup using provided materials**
   a. **Materials Needed**
      i. White stiff tubing
      ii. Blue flexible tubing
      iii. Rubber stopper with a hole
      iv. Black plastic connector
      v. Scissors
   b. **Procedure**
      i. Inspect the white tubing for any damage, especially splitting at the ends.
      ii. Trim off any split or cracked portion of the white tubing using scissors.
      iii. Insert the white tubing carefully through the hole in the rubber stopper.
      iv. Attach the black plastic connector to the end of the white tubing.
      v. Connect the blue flexible tubing to the other end of the black connector.
      vi. Check that all connections are tight and secure to prevent leaks.

   Test the assembled system by running air or water through it to ensure proper flow.



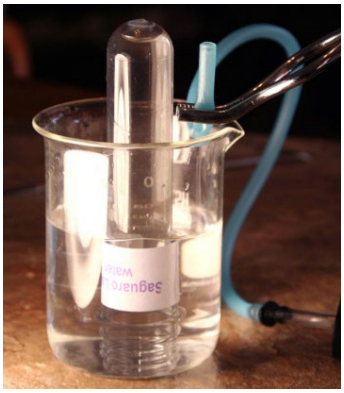
3. **Measure and pour 150 ml of tap water into the 250 ml beaker**

4. **Filling of the test tube**
   a. Fill the plastic test tube to the brim with tap water and securely put on the cap.
   b. Carefully turn the test tube upside down, ensuring there is minimal air bubbles inside.

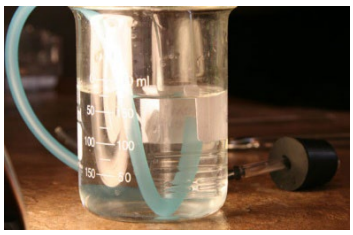
   Slowly lower the test tube into the beaker of water, ensuring that the cap is fully submerged.

5. Unscrew the cap of the test tube while keeping the mouth submerged under the water. If the mouth of the test tube rises above the water surface and water spills into the beaker, carefully pour the water back into the test tube.

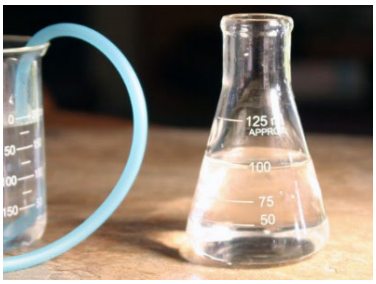
6. Using the metal tongs, carefully position the blue tubing so that it goes into the upside-down test tube. Angle the tubing so that it points upward.



7. Ensure that the blue tubing is sticking up inside the test tube by a couple of inches.

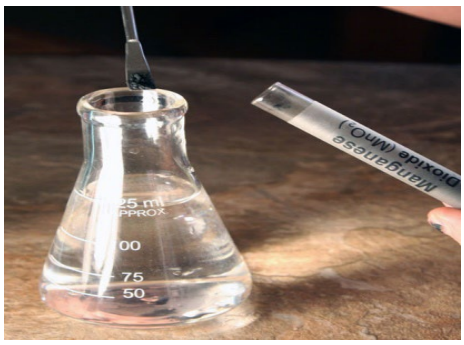


8. Fill the conical flask with 100 ml of tap water. This will reduce the amount of air in the flask, making it easier to displace when oxygen is being generated.



9. Add 25 ml of hydrogen peroxide to the 100 ml of water in the conical flask, bringing the total liquid level up to 125 ml.

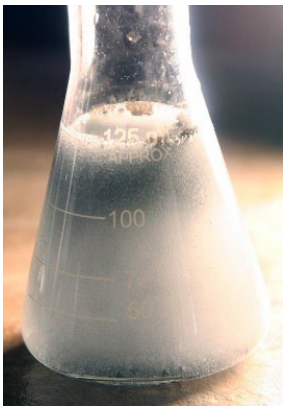
10. Now add a scoop of the manganese dioxide.



11. Mixing Hydrogen peroxide with the manganese dioxide
    a. Observe the formation of small bubbles as the manganese dioxide mixes with the hydrogen peroxide and water. Some of the manganese dioxide may settle at the bottom, while others may float near the surface.
    b. Do not place the stopper on the flask immediately. Allow the bubbles of oxygen to displace the air (which consists of about 25 ml of 80% nitrogen and 20% oxygen) by pushing it out of the flask.
    c. Wait for about 2 minutes to give the oxygen enough time to push most of the air out of the flask.
    d. Once the air has been displaced, place the stopper on the flask.

Note

The manganese dioxide acts as a catalyst, speeding up the decomposition of hydrogen peroxide into water and oxygen $2H_2O_2 \rightarrow 2H_2O + O_2$. It is not consumed or chemically altered during the reaction, so it can be filtered and reused after the experiment.



12. Two minutes after adding the manganese dioxide, firmly place the stopper on the conical flask.

13. Check for bubbles rising from the tubing inside the test tube; this indicates that oxygen is being produced and displacing the water, causing the water level to drop.
    a. If no bubbles appear:

i. Check that the rubber stopper is securely fitted in the flask.

Inspect the tubing and connector to ensure they are not split or cracked.

Collection of the Prepared Oxygen gas

1. **Removing the delivery tubing**
   a. Carefully remove the blue tubing from the test tube when you notice bubbles escaping from the bottom (open end) of the test tube.
   b. Once the tubing is removed, put the cap back onto the test tube.
   c. To keep your work area neat and avoid accidents, move the flask, rubber stopper, and tubing out of the way.

   Observation: This indicates that the test tube is full of oxygen

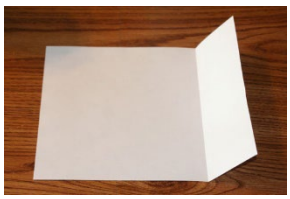
2. Use your fingers or the metal tongs to push the cap to the bottom of the beaker, as it will tend to float. Once the cap is at the bottom, carefully position the test tube so that it sits on the cap.

3. Carefully screw the cap back onto the test tube while keeping the mouth of the test tube submerged under the water. This will require some dexterity to ensure the test tube remains positioned correctly.

4. Stand the test tube with the oxygen in it in the small beaker. Alternatively, pour out the water from the large beaker and use instead.
5. To test if you have oxygen, perform a standard test by using a piece of paper (typically, laboratories use a wooden splint for this test.).

Test for the Prepared Oxygen Gas

1. Take a sheet of paper, fold or mark it to a width of about 2 inches. Then, cut off the 2-inch-wide strip of paper.



2. Start folding the paper in 1/2-inch strips, making neat folds. Continue folding until the entire 2-inch-wide strip is folded up into one long, compact strip.

3. Once the sheet of paper is folded into one long strip, try folding it one more time to create a narrower strip. Ensure that the final folded strip will fit easily into the test tube.

4. Light one end of the paper strip with your lighter.

5. Light the folded paper and let it burn for about 5 seconds. Then, blow it out, but ensure that the paper is still smoldering. You should see some smoke and notice parts of the paper glowing red.

6. While the paper is still smoldering, carefully remove the cap from the test tube. Insert the smoldering paper into the test tube with the oxygen gas.
7. Observe carefully, and you should notice the paper reignites into a flame for about a second before it begins to produce smoke and eventually extinguishes.

Observation

The reaction you observed when you inserted the smouldering paper into the test tube was a brief reignition of the paper into a flame. This occurred because the concentrated oxygen in the test tube (close to 100%) accelerated the combustion process. The oxygen fuelled the burning, causing the smouldering embers of the paper to become hot enough to ignite into a flame, but the flame only lasted briefly as the oxygen was quickly consumed by the combustion.

Table 1.4: *Comparison of laboratory preparation methods for oxygen*

Method	Reactants/ Conditions	Products (excluding O_2)	Advantages	Disadvantages
Catalytic Decomposition of Hydrogen Peroxide	H_2O_2, MnO_2 catalyst	H_2O	Safe and convenient, produces relatively pure oxygen	Hydrogen peroxide can be irritating
Thermal Decomposition of Potassium Chlorate	$KClO_3$, heat	KCl	Produces relatively pure oxygen	Potassium chlorate can be hazardous if not handled properly
Electrolysis of Water	H_2O, electricity	H_2	Produces high-purity oxygen	Requires specialised equipment

Safety Precautions

1. Always wear safety goggles to protect the eyes.
2. Handle hydrogen peroxide with care as it can cause skin irritation and burns, especially at higher concentrations. Avoid contact with skin and eyes, and in case of contact, wash the affected area immediately with plenty of water. The concentration of hydrogen peroxide typically used in this laboratory preparation (e.g., 6% or 9%) is relatively low, but caution should still be exercised.
3. Ensure that the apparatus is set up on a stable surface to prevent any accidental spills or breakage.
4. Avoid contact between manganese (IV) oxide and organic materials as it is a strong oxidizing agent and can cause vigorous reactions.

Learning tasks

1. Plan and explain a procedure for preparing carbon dioxide and oxygen gases in the laboratory, including safety precautions and justification for the choice of materials and methods.
2. Compare and contrast the physical and chemical characteristics of carbon dioxide and oxygen gases, using experimental evidence and scientific reasoning.
3. Evaluate and explain the various uses of carbon dioxide and oxygen gases in industry, medicine, and the environment, providing real-life examples and their implications.

Pedagogical Exemplars

1. **Demonstrative and Experiential Learning**

   Use live demonstrations and hands-on experiments to help learners understand the production and properties of carbon dioxide and oxygen. Demonstrate methods such as chemical reactions, fermentation, and electrolysis. Allow learners to conduct experiments that show oxygen's role in combustion and carbon dioxide's behaviour in different reactions. Use visual aids, electrolysis kits, and plant-based experiments to support this approach.

2. **Case-Based and Real-Life Application**

   Present real-world case studies showcasing how carbon dioxide and oxygen are used in industries such as healthcare, aerospace, metallurgy, and water treatment. Discuss industrial processes and how these gases support everyday life. Invite resource persons from relevant industries to provide practical insights and enhance learners' connection to real-world applications.

3. **Project-Based and Interactive Learning**

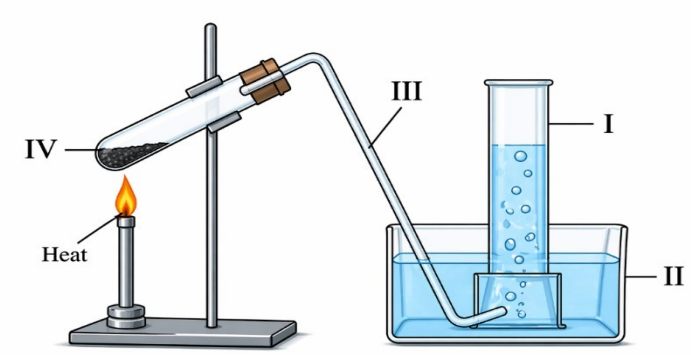
   Assign research and presentation projects where learners explore specific uses of oxygen and carbon dioxide in domestic and industrial settings. Use interactive group activities and discussions to simulate how these gases are applied in the real world. Encourage innovation through design of mock solutions or systems using these gases.

4. **Role-Playing and Simulation**

   Engage learners in role-playing exercises where they act as professionals (e.g., chemical engineers, medical staff) using oxygen and carbon dioxide in their work. Use simulations to show the impact and importance of these gases in different environments, fostering creativity and deeper understanding through active participation.

Key Assessment Level 3: Practical

1. The set-up below is an illustration of preparation of a gas in the laboratory. Study it carefully and answer the questions that follows



   Suppose the water level in the trough (II) is too low to fully submerge the mouth of the gas jar (I). Predict how this would affect the collection of gas and explain how you would modify the setup to ensure accurate results. **(6 marks)**.

2. Describe three real-world scenarios where knowledge of as preparation is crucial. **(6 marks)**
3. Design an experiment using the setup in the diagram above to test if the collected gas is oxygen and justify the choice of tests and observations. **(7 marks)**

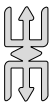
PLC Session 2

45 minutes | **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to
   a. explain the week's concepts in a practical way that will make it easier for learners to understand

b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).

3. Use your subject specific app to plan your lesson. Ask the app to
   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
   b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
   c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



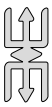
Note

- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Plan the week's key assessment with your app
   a. The key assessment for the week is ***practical***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the practical (NTS 3k-3q).

10 minutes **Content Exploration**

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
   a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
   b. all teachers in the group work through a similar problem individually for 3–4 minutes
   c. the group then works through the problem together step by step
   d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- *This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?*
- *If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.*
- *Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.*

30 minutes **Enactment**

6. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).

a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.

b. After the enactment, ask for structured feedback from the group

   i. was the concept explained in a way that a learner with no prior knowledge could follow?
   ii. were the examples grounded in contexts familiar to Ghanaian learners?
   iii. did any misconceptions surface and if so, how were they addressed?

5 minutes **Reflection**

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to

   a. transfer your chats into your learning planner template.

   b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).

   c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 1 Review

In **Week 1**, learners identified air as a mixture and examined its various components, such as nitrogen, oxygen, carbon dioxide, and noble gases. They discussed the role each component plays in nature and human life, including oxygen for respiration, carbon dioxide for photosynthesis, and nitrogen for plant growth.

In **Week 2**, the focus shifted to practical science. Learners prepared carbon dioxide through chemical reactions and discussed its uses in industries, food preservation, and fire extinguishers. They also prepared oxygen and explored its applications in respiration, combustion, and healthcare.

By the end of the section, each learner should have understood the composition and importance of air, developed practical skills in preparing gases, and gained confidence in discussing their uses in real-life.

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 1

Question 1

Concentration of CO_2 in air components in terms of its increase and decrease effect. **(Total of 4 marks)**

a. Description of one impact of increased and decreased carbon dioxide concentration (CO_2). **(4 marks)**

E.g., Increase

Enhance photosynthesis in plants, a process where plants convert CO_2 and water into glucose and oxygen using sunlight.

Decrease

CO_2 is essential for photosynthesis in plants. A drop in atmospheric CO_2 reduces the rate of photosynthesis, which can lead to lower crop yields and reduce forest growth

4 marks	1 mark	0 marks
Description of increase impact *Description of decrease impact*	*Identify one impact each without description*	*Incorrect answer*

Scientific evidence (8 marks)

Explains four scientific evidence using up-to-date reliable sources (8 marks)

E.g., Carbon dioxide (CO_2), while often viewed negatively due to its role in climate change, plays a crucial role in photosynthesis. According to *NASA's Earth Observatory* (2021), CO_2 is used by plants to produce glucose and oxygen, a process vital for plant growth and the oxygenation of the atmosphere.

8 marks (total)	2 marks	1 mark	0 marks
If a student explains four scientific evidence using up-to-date reliable sources (each 2 marks)	*If a student explains one scientific evidence using up-to-date reliable sources*	*If a student, identify only the scientific evidence without explaining with reliable sources*	*Incorrect answer*

Solutions to mitigate any negative effect (4 marks)

Explanation of any two solutions. (4 marks)

E.g., Reforestation and afforestation: Planting more trees increases CO_2 absorption and oxygen production.

a.

b. I

c.

4 marks	2 marks	1 mark	0 marks
If a student explains two solutions. (2 marks for each)	*If a student explains only one solution*	*If a student identifies solutions without explanation*	*Incorrect answer*

Organisation and structure (4 marks)

4 marks	3 marks	2 marks	1 mark	0 marks
If a student sequential logical flow of ideas containing content, scientific evidence and solutions of carbon dioxide and oxygen.	*If a student sequential logical flow of ideas containing content, scientific evidence without solutions*	*If a student sequential logical flow of ideas containing content, but without scientific evidence and solutions*	*If a student sequential logical flow of ideas but without containing content, scientific evidence and solutions*	*If a student doe not have sequential logical flow of ideas, without containing content, scientific evidence and solutions*

Question 2 (20 marks)

Criteria	Description	Mark allocation
Title (1 mark)	**Air or** **The invisible lifeline of nature**	**1 mark**
Main components of air and their uses in nature. (6 marks)	*Nitrogen (78%)* *Use in nature: Helps in plant growth through the nitrogen cycle. Nitrogen-fixing bacteria in the soil convert nitrogen gas into forms plants can absorb.* *Example: Leguminous plants like beans and peas have root nodules with nitrogen-fixing bacteria*	*Description of three components of air, their uses in nature with examples (6 marks)* *Description of two components of air, their uses in nature without examples. (4 marks)* *Description of two components of air without their uses in nature and examples. (2 marks)* *Identification of only the components. (1 mark)*
Analysis of changes in air composition and effects on ecosystems. (6 marks)	*For example,* *Increased carbon dioxide* o *Cause: Burning fossil fuels, deforestation.* o *Effect: Global warming, melting glaciers, shifting weather patterns, ocean acidification, coral bleaching.* *Example: Australia's Great Barrier Reef is suffering due to ocean warming and acidification*	*Description of changes in air composition, their effects on ecosystems and supporting examples. (6 marks)* *Description of changes in air composition and their effects without supporting examples. (4 marks)* *Description of changes in air composition without their effects on ecosystems and examples. (2 marks)* *States changes in air composition without a description and without their effects on ecosystems and examples. (1 mark)*
Sustainable actions. (4 marks)	*Reforestation to absorb CO_2.*	*Description of two sustainable actions (4 marks)* *Description one sustainable action. (2 marks)* *Identification of sustainable action without explanation. (1 mark)*

Organisation and structure. (3 marks)	*The visual shows a logical and coherent sequence with headings, subheadings, and labels for sections.*	*Visual shows a logical and coherent sequence with headings, subheadings, and labels for sections. (3 marks)* *Visual shows a logical and coherent sequence with headings without subheadings, and labels for sections. (2 marks)* *Visual shows logical and coherent sequence without headings, subheadings, and labels for sections. (1 marks)* *Visual does not show logical and coherent sequence without headings, subheadings, and labels for sections. (0 marks)*

WEEK 2

Question 1

1. Prediction of what happens when jar is not submerged: The gas would escape into the air instead of being collected in the gas jar. **(1 mark)**
2. Explanation of gas displacement not occurring: This is because the mouth of the gas jar is not under water, so gas cannot displace water to fill the jar. **(1 mark)**
3. Shows understanding of displacement and pressure: The water creates a seal that allows gas to push the water out and take its place in the jar. **(1 mark)**
4. Practical modification suggestion: To fix this, increase the amount of water in the trough so that the mouth of the jar is fully submerged. **(1 mark)**
5. Offers a second viable solution: Alternatively, a shorter gas jar or lower the gas jar to ensure it fits below the water level. **(1 mark)**
6. Summarises with understanding of accuracy and setup integrity:
7. These changes ensure that the setup works properly, and gas is accurately collected with minimal loss. **(1 mark)**

(Total of 6 marks)

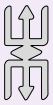
Note

1 mark each for any other similar point with clear understanding.

Question 2

1. **Medical use (2 marks)**
   Hospitals and emergency care centres rely on pure oxygen for patients with respiratory problems, during surgery, and in intensive care units. Knowledge of oxygen preparation ensures a reliable supply of medical-grade oxygen for safe breathing support.
2. **Industrial use (2 marks)**
   In welding and metal cutting, oxygen is used to support combustion in oxy-acetylene torches. Proper preparation of oxygen is essential for maintaining the high purity and pressure needed for efficient and safe operation.

3. **Space exploration and diving (2 mark)**
   Astronauts and scuba divers depend on pure oxygen or oxygen-enriched air to breathe in environments where the natural atmosphere is unavailable. Understanding oxygen preparation helps in providing safe and controlled breathing gas mixtures.



Note

2 marks each for any other real-world scenarios.

Question 3

- A glowing splint test. **(½ mark)**
- After collecting the gas in the jar **(I mark)**, remove the jar and keep it sealed using a glass plate or rubber cork to avoid losing the gas. Insert a glowing wooden splint into the gas jar **(2 marks)**
- If the gas is oxygen, the glowing splint will relight or burst into flame. **(1 mark)**
- This is because oxygen is needed to support combustion and causes substances to burn more readily. **(1 mark)**
- The test is specific to oxygen, as other gases like carbon dioxide or nitrogen would extinguish the glowing splint instead. **(1 mark)**

Therefore, this test confirms the presence of oxygen by using its reactive property to support combustion. **(½ mark)**

SECTION 2: OIL AND NATURAL GAS

STRAND: EXPLORING MATERIALS

Sub-Strand: Science and materials in nature

Learning Outcome: *Describe and analyse the origin and composition of natural gas.*

Content Standard: *Know, understand and identify the origin and composition of natural gas*

INTRODUCTION AND SECTION SUMMARY

Oil and natural gas are vital fossil fuels formed from ancient organic matter under high pressure and heat over millions of years. In this section, learners will explore their composition mainly hydrocarbons, such as methane in natural gas, and a mixture of alkanes and other compounds in crude oil. They will examine how these resources are formed, extracted, and used in everyday life, including their use in fuel, electricity, cooking, plastics, and fertilisers.

By the end of this section, learners should be able to identify the composition of oil and natural gas, explain their formation and uses, discuss their economic importance; especially in countries like Ghana; and evaluate the environmental impact of their use.

The week and the indicator covered by the section are:

Week 3: Discuss the composition and uses of oil and natural gas.

SUMMARY OF Pedagogical Exemplars

This section outlines engaging strategies for teaching the composition and impact of oil and natural gas through real-world and interactive methods.

Teachers use multimedia presentations to visually explain oil and gas composition, while case studies explore extraction methods and Ghana's economic developments. Hands-on activities such as simulating refining and combustion processes help learners apply knowledge practically.

Talks or presentations from people who work in the oil and gas sector to offer real-life insights into economic significance and sustainability challenges. Debates and discussions promote critical thinking on environmental impacts and ethical considerations.

By the end of this section, learners will explore the composition and uses of oil and gas, understand their role in industry and the economy, and be able to analyse case studies, conduct practical investigations, and evaluate impacts through discussion. Teachers facilitate learning by linking scientific content to national context and encouraging active participation.

ASSESSMENT SUMMARY

Learners will discuss the composition and uses of oil and natural gas through an essay, assessed at DOK Level 4, which requires extended critical thinking and reasoning. This task challenges learners to synthesise scientific knowledge with real-world applications, examining the chemical makeup of these fossil fuels and evaluating their diverse uses in energy production, transportation, industry, and domestic settings.

The debate format encourages in-depth exploration, evidence-based analysis, and clear communication of complex ideas, promoting higher-order thinking and a deeper understanding of the subject.

Indicator	DOK Level	Assessment Strategy and/or Mode
Discuss the composition and uses of oil and natural gas.	Key Assessment Level 4: Extending critical thinking and reasoning	Debate

WEEK 3

Learning Indicator: *Discuss the composition and uses of oil and natural gas*

Focal Area: Composition and uses of oil and natural gas

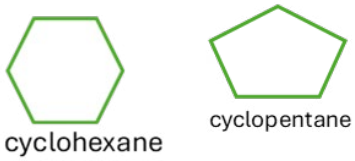
Composition of Oil and Gas
Crude Oil Composition: A Complex Mixture

Crude oil is a naturally occurring, unrefined petroleum product composed of a complex mixture of hydrocarbons and other organic compounds. Its exact composition varies significantly depending on the geological location, age of the deposit, and the conditions under which it was formed.

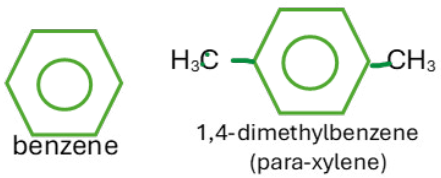
1. Hydrocarbons

a. Alkanes (Paraffins): These are saturated hydrocarbons with single carbon-carbon bonds, having the general formula $C_nH_{2n}+_2$. They can be straight-chain (normal alkanes) or branched (isoalkanes). Examples include methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), and heavier, liquid alkanes found in gasoline, kerosene, and lubricating oils. Paraffins are generally the most abundant type of hydrocarbon in crude oil.

b. Cycloalkanes (Naphthenes or Cycloparaffins): These are saturated hydrocarbons containing one or more carbon rings, with the general formula C_nH_{2n}. Common examples include cyclopentane and cyclohexane. They are significant components of gasoline and other refinery products.



c. Aromatic Hydrocarbons (Arenes): These contain one or more benzene rings (a six-carbon ring with alternating double bonds). The simplest aromatic is benzene (C_6H_6), followed by toluene, xylene, and more complex polycyclic aromatic hydrocarbons (PAHs). Aromatics are important for gasoline octane rating and are also valuable petrochemical feedstocks.



d. Asphaltenes: These are large, complex, high molecular weight polycyclic hydrocarbons containing heteroatoms like nitrogen, sulphur, and oxygen, as well as some metals (e.g., vanadium, nickel). They are soluble in carbon disulfide but insoluble in low-boiling aliphatic hydrocarbons like propane or butane. Asphaltenes contribute to the viscosity and density of crude oil and are a significant component of bitumen and heavy oils.

Typical Elemental Composition of Crude Oil (by weight)

1. Carbon (C): 82-87%
2. Hydrogen (H): 10-14%
3. Sulphur (S): 0.05-6.0%
4. Nitrogen (N): 0.1-2.0%
5. Oxygen (O): 0.05-1.5%
6. Metals (e.g., Ni, V, Fe, Cu): < 0.1%

2. Non-Hydrocarbon Compounds

Crude oil also contains smaller amounts of organic compounds that include elements other than just carbon and hydrogen. These heteroatoms can significantly impact the properties and refining processes of crude oil.

a. Sulphur compounds: These can range from simple hydrogen sulfide (H_2S) to more complex organic sulphur compounds like mercaptans (thiols), sulfides, disulfides, and thiophenes. Sulphur content is a key factor in crude oil quality, with "sweet crude" having low sulphur content and "sour crude" having high sulphur content. High sulphur content can lead to corrosion and environmental issues during refining and combustion.

b. Nitrogen compounds: These are typically basic or neutral organic compounds containing nitrogen atoms within their molecular structures (e.g., pyridines, quinolines, porphyrins). Nitrogen compounds can poison catalysts used in refining processes.

c. Oxygen compounds: These include organic acids (naphthenic acids), phenols, ketones, ethers, and esters. The presence of organic acids can contribute to corrosion.

d. Organometallic compounds: These contain metal atoms (like nickel and vanadium) chemically bonded to organic molecules, often associated with porphyrin structures. They can cause catalyst deactivation during refining and contribute to deposits.

3. Inorganic components

Crude oil can also contain trace amounts of dissolved inorganic salts (e.g., chlorides of sodium, calcium, and magnesium) and water. These need to be removed during processing to prevent corrosion and equipment damage.

Natural Gas Composition: Primarily Light Hydrocarbons

Natural gas is a naturally occurring gaseous hydrocarbon mixture consisting primarily of lighter alkanes. Its composition is generally simpler than that of crude oil.

Typical Composition of Natural Gas (by volume):

1. **Methane (CH_4):** The dominant component, typically ranging from 70% to 99%.
2. **Ethane (C_2H_6):** Usually present in smaller amounts than methane.
3. **Propane (C_3H_8) and Butane (C_4H_{10}):** These are often present in varying, but generally lower, concentrations. Natural gas rich in propane and butane is sometimes called "wet gas."
4. **Pentanes (C_5H_{12}) and heavier hydrocarbons:** These can be present in trace amounts and may condense out as natural gas liquids (NGLs) under certain conditions.
5. **Non-Hydrocarbon Gases:** Natural gas often contains varying amounts of other gases:

a. Carbon Dioxide (CO_2): Can range from trace amounts to significant percentages. It needs to be removed as it reduces the heating value and can cause corrosion.

b. Nitrogen (N_2): Another common non-hydrocarbon component that dilutes the gas and reduces its heating value.

c. Hydrogen Sulphide (H_2S): A toxic and corrosive gas that must be removed. Its presence makes the gas "sour."

d. Water Vapor (H_2O): Needs to be removed to prevent hydrate formation in pipelines and corrosion.

e. Helium (He): In some specific locations, natural gas can contain commercially viable amounts of helium.

f. Other trace gases like argon (Ar).

Differences in composition

1. State at surface conditions: Crude oil is liquid at standard temperature and pressure, while natural gas is gaseous.
2. Molecular weight: Crude oil contains a much wider range of hydrocarbon molecules, including very heavy and complex ones, while natural gas is dominated by light, low molecular weight hydrocarbons.
3. Non-Hydrocarbon content: Both contain non-hydrocarbons, but the types and proportions can differ. For instance, natural gas can have significant amounts of non-combustible gases like CO_2 and N_2.

Economic Benefits

1. Revenue generation: The oil and gas sector has become a major source of revenue for the Ghanaian government through royalties, taxes, and participating interests. These revenues are crucial for funding national development projects and balancing the budget. For instance, it was estimated that oil and gas fiscal revenues would reach $21 billion between 2015 and 2030.
2. GDP growth: The commencement of commercial oil production in 2011 led to a significant boost in Ghana's GDP growth, making it one of the fastest-growing economies in Sub-Saharan Africa at the time. Studies indicate that an increase in oil rents positively impacts GDP growth.
3. Export diversification: Crude oil has become a significant export commodity for Ghana, diversifying its exports beyond traditional products like gold and cocoa. These three commodities now account for a substantial portion of Ghana's total export earnings.
4. Foreign exchange earnings: The export of crude oil and potentially natural gas helps Ghana earn valuable foreign currency, which is essential for international trade and stabilising the national currency.
5. Job creation: The oil and gas industry create numerous jobs, ranging from skilled labour in exploration and production to support services, contributing to employment and local economic empowerment. It's estimated that the development of the oil and gas sector could create over 166,000 sustained full-time equivalent jobs.
6. Infrastructure development: Oil revenues have been earmarked for upgrading infrastructure, which can lead to increased labour productivity, economic competitiveness, and overall income growth. Investments in infrastructure driven by oil revenues are expected to be particularly effective in the medium term.

7. Attracting investment: The presence of oil and gas reserves has attracted significant foreign direct investment into Ghana, boosting the economy and bringing in technological expertise. The government has aimed to make the sector more attractive to international investors through transparent and good governance practices.

Energy Sector Transformation

1. **Power generation:** Natural gas associated with oil production is proving to be a vital feedstock for Ghana's power generation system. This has reduced the country's reliance on hydropower and expensive thermal plants fuelled by light crude oil and diesel, leading to a more reliable and potentially cheaper power supply.
2. **Fuelling industrial growth:** Natural gas is also supplied to the industrial sector at subsidised rates, enhancing the operations, increasing efficiency, and reducing production costs for industries such as ceramics, fertiliser production, and petrochemicals. There are plans to further extend the gas supply to fertiliser production and mining operations.
3. **Liquefied petroleum gas (LPG) Supply:** Natural gas processing produces LPG, which is supplied for domestic and commercial use, aligning with the government's cylinder recirculation policy and aiming to provide cleaner cooking fuel options.
4. **Potential for Gas Hub:** Ghana has ambitions to become a gas trading hub in the West African region, leveraging its gas infrastructure and potential LNG terminal.

Other Potential Benefits

1. **Local content development:** The government has emphasised local content and participation in the oil and gas industry, aiming to ensure that Ghanaian businesses and individuals benefit from the sector through contracts, employment, and capacity building.
2. **Social amenities:** In some instances, oil and gas production can lead to the development of social amenities like schools, roads, and hospitals in nearby communities, although the impact can be varied and sometimes overshadowed by negative consequences.

Impact of Oil and gas discoveries in Ghana

1. **Environmental damage (Spills, Pollution)**
    a. **Oil spills**
        i. Cause

        This is because of accidents caused during drilling, transportation (tanker accidents), or pipeline leaks.

        ii. Impact
            - Devastate marine ecosystems, harming or killing fish, seabirds, marine mammals, and coastal vegetation.
            - Pollute beaches and coastal areas, affecting tourism and fishing industries.
            - Long-term damage to ecosystems, as oil can persist in sediments for years.

2. **Water pollution**
    a. **Cause**
        - Wastewater discharge from drilling operations, containing drilling fluids, heavy metals, and other pollutants.
        - Contamination of groundwater from fracking operations (if applicable).
    b. **Impact**
        - Harm aquatic life.
        - Make water unsuitable for drinking or agriculture.
        - Damage local ecosystems.
3. **Air pollution**
    a. **Causes**
        - Emissions from drilling rigs, refineries, and associated transportation.
        - Release of methane (a potent greenhouse gas) during extraction and processing.
        - Flaring of natural gas (burning off excess gas), which releases pollutants.
    b. **Impact**
        - Contribute to respiratory problems and other health issues.
        - Worsen air quality.
        - Contribute to climate change.
4. **Habitat destruction**
    a. **Causes**
        - Construction of drilling platforms, pipelines, roads, and other infrastructure.
        - Deforestation and land clearing.
    b. **Impact**
        - Destroy natural habitats, displacing wildlife.
        - Fragmented ecosystems, reducing biodiversity.
        - Damage coastal ecosystems like mangroves, which are important for fisheries and coastal protection.
5. **Social Impacts:** The discovery of oil and gas can sometimes lead to increased costs of living and social disruptions in local communities.
6. **Revenue management:** Effective management and transparent use of oil and gas revenues are crucial to avoid the "resource curse" and ensure that the benefits are broadly distributed and contribute to long-term sustainable development.
7. **Declining production:** Recent reports indicate a decline in Ghana's crude oil production due to the aging of existing fields and a lack of new major discoveries, which could impact future revenue streams.

8. **Investment climate:** Regulatory inefficiencies, protracted licensing approvals, and fiscal uncertainties have been identified as challenges that could make Ghana less attractive for investment in the oil and gas sector compared to other nations.

Despite these challenges, the oil and gas sector remain a significant contributor to Ghana's economy and energy landscape, with the potential for further growth and development if managed effectively and sustainably.

Uses of Natural Gas (Expanded)

Natural gas is a crucial energy source with diverse applications, impacting various sectors of modern life.

1. **Energy Production (Electricity Generation)**
    a. Natural gas is a primary fuel for electricity generation in power plants. When burned, it heats water to produce steam, which drives large turbines connected to generators. Compared to other fossil fuels like coal and oil, natural gas combustion is generally cleaner, emitting fewer pollutants such as sulphur dioxide, nitrogen oxides, and particulate matter. This makes it a preferred option in many regions striving to improve air quality.
    b. Furthermore, natural gas power plants can often be brought online or taken offline more quickly than coal-fired plants, providing flexibility to meet fluctuating electricity demands throughout the day and to balance the intermittent nature of renewable energy sources like solar and wind power.
    c. As Ghana expands its electricity generation capacity to support industrial growth and household needs, natural gas plays a vital role. Ensuring a reliable and affordable supply of natural gas is essential for maintaining a stable and efficient power grid, which is crucial for economic development.
2. **Heating**
    a. Natural gas is a widely used source of heat for residential, commercial, and industrial purposes. In homes, it powers furnaces and boilers to provide space heating and water heaters to supply hot water. In commercial buildings, it's used for central heating systems, and in industries, it's employed in various heating processes, such as steam production for manufacturing. The efficiency and relatively lower cost of natural gas compared to other heating fuels contribute to its popularity in many parts of the world.
    b. While the direct use of natural gas for widespread residential heating may be less prevalent in Ghana's climate, it is still important for industrial applications that require high temperatures and process heat. As Ghana's industrial sector grows, the demand for natural gas in heating applications may increase. Additionally, Liquefied Petroleum Gas (LPG), a product derived from natural gas processing, is a primary cooking fuel in many Ghanaian households.
3. **Cooking**
    a. Natural gas is a preferred fuel for cooking in many households and restaurants due to its clean-burning nature and precise temperature control. Natural gas stoves and ovens offer instant heat, allowing for efficient cooking and baking. The ability to adjust the flame precisely enables chefs and home cooks to achieve desired cooking results.
    b. LPG, predominantly propane and butane, derived from natural gas processing, is a staple cooking fuel in Ghana. Ensuring a reliable supply of natural gas is therefore crucial to the availability and affordability of LPG for domestic use.

4. **Industrial uses:** Natural gas serves as a critical raw material, or feedstock, for numerous industrial processes, particularly in the chemical industry.

    a. **Chemicals:** It is used to produce a wide range of chemicals, including:

        - **Ammonia (NH_3):** A fundamental building block for nitrogen-based fertilisers, plastics, and other chemical products.
        - **Methanol (CH_3OH):** Used in the production of plastics, resins, solvents, and as a fuel additive.
        - **Hydrogen (H_2):** Essential for various industrial processes, including refining petroleum, producing ammonia, and in some emerging energy technologies.

    b. **Fertilisers:** The production of ammonia from natural gas is a crucial step in manufacturing nitrogen fertilisers, which are vital for increasing agricultural yields and supporting food production.

    Natural gas has the potential to support the development of Ghana's industrial sector by providing a feedstock for the production of fertilisers, chemicals, and other valuable products. This can contribute to economic diversification and growth.

5. **Transportation**

    a. Compressed Natural Gas (CNG) is an alternative fuel for vehicles that offers some environmental benefits compared to gasoline and diesel. CNG vehicles typically produce lower emissions of greenhouse gases and particulate matter. CNG is used in various types of vehicles, including buses, taxis, and trucks. However, the widespread adoption of CNG vehicles is often limited by the availability of refuelling infrastructure, as CNG requires specialised fuelling stations. The economic benefits of oil and gas discovery in Ghana are vast, contributing significantly to revenue generation, GDP growth, export diversification, foreign exchange earnings, and job creation.

    b. Ghana could explore the potential of CNG as a cleaner transportation fuel, particularly in urban areas where air pollution is a concern. However, significant investment in CNG fuelling infrastructure would be necessary to make it a viable alternative.

Processes Involved in Extraction of Oil and Gas

The extraction of oil and gas is a complex sequence of operations, each crucial to bringing these valuable resources to the surface.

1. **Exploration:** Exploration is the initial phase, focused on identifying potential underground reservoirs that may contain oil or gas.

    a. **Seismic Surveys:** These surveys involve generating sound waves that penetrate the earths subsurface. The reflected waves are recorded and analysed to create detailed images of geological structures. Geologists use these images to identify formations that are likely to trap oil or gas.

    b. **Exploratory Drilling:** If seismic surveys indicate the presence of a potential reservoir, exploratory wells are drilled to confirm the presence of oil or gas and to gather information about the reservoir's characteristics, such as its size, depth, and the quality of the hydrocarbons it contains. Exploratory drilling is a high-risk, high-cost activity.

Ghana has actively pursued oil and gas exploration in both its offshore and onshore regions. Advanced exploration technologies are employed to map subsurface structures and identify promising areas for drilling.

2. **Drilling:** Once a potential reservoir is confirmed, drilling is the process of creating a wellbore from the surface down to the oil or gas formation.
    a. **Drilling rigs:** These are large, complex structures that house the equipment needed to rotate a drill bit, circulate drilling fluids, and perform other drilling operations.
    b. **Drill bit:** A cutting tool attached to the end of a drill string that grinds or cuts through rock.
    c. **Drilling mud:** A fluid (typically a mixture of water, clay, and chemicals) that is pumped down the drill string to cool the drill bit, carry rock cuttings back to the surface, control pressure in the wellbore, and prevent the well from collapsing.
    d. **Directional drilling:** Techniques that allow wells to be drilled at angles or horizontally to reach specific targets within the reservoir, increasing the contact area between the wellbore and the productive formation.

    Oil and gas operations in Ghana involve both onshore and offshore drilling, requiring specialised drilling rigs and skilled personnel to operate them safely and efficiently.
3. **Well completion:** After drilling, the well must be prepared for production. This process is called well completion.
    a. **Casing:** Steel pipes (casing) are inserted into the wellbore and cemented in place to provide structural integrity, prevent the well from collapsing, and isolate different geological zones.
    b. **Cementing:** Cement is pumped into the annulus (the space between the casing and the wellbore) to create a seal that prevents fluids from migrating between formations and protects groundwater.
    c. **Perforation:** If the casing and cement are in place across the productive zone, small holes (perforations) are created in the casing to allow oil or gas to flow from the reservoir into the wellbore.
    d. **Hydraulic fracturing (Fracking):** In some cases, particularly in shale or tight sandstone formations, hydraulic fracturing is used to enhance the permeability of the rock and increase the flow of oil or gas to the wellbore.

    Proper well completion techniques are essential to ensure the safe and efficient production of oil and gas in Ghana's fields and to protect the environment.
4. **Production:** This is the stage where oil and gas are extracted from the reservoir and brought to the surface.
    a. **Primary Recovery:** This relies on the natural pressure of the reservoir to push oil and gas to the surface. Over time, this pressure declines, and production decreases.
    b. **Secondary Recovery:** Techniques such as water injection or gas injection are used to maintain reservoir pressure and displace more oil and gas towards the wellbore. Water or gas is pumped into the reservoir to push the hydrocarbons towards the production wells.
    c. **Enhanced Oil Recovery (EOR):** These are more advanced techniques used to extract oil that remains after primary and secondary recovery. EOR methods can involve injecting chemicals, gases, or heat into the reservoir to change the properties of the oil and make it flow more easily.

    Ghana's oil fields utilise various production methods to optimise the extraction of oil and gas, depending on the characteristics of the specific reservoirs.

5. **Transportation:** Once extracted, oil and gas must be transported from the production site to refineries, processing plants, and consumers.
    a. **Pipelines:** These are the most common and efficient way to transport large volumes of oil and gas over long distances, both onshore and offshore.
    b. **Tankers:** Ships are used to transport oil and liquefied natural gas (LNG) across oceans. LNG is natural gas that has been cooled to a liquid state to reduce its volume for transportation.
    c. **Trucks:** Tank trucks are used to transport smaller volumes of oil and gas over shorter distances.

    Ghana utilises pipelines to transport oil and gas within the country and tankers for exporting oil to international markets.
6. **Processing:** Raw oil and gas need to be processed to make them usable.
    a. Refining: Crude oil is refined in refineries to separate it into various petroleum products, such as gasoline, diesel fuel, jet fuel, heating oil, and asphalt.
    b. Natural gas processing: Natural gas is processed to remove impurities such as water vapor, carbon dioxide, hydrogen sulfide, and other gases. It may also be separated into its components, such as methane (the main component of natural gas), ethane, propane, and butane.

    Ghana has refineries such as Tema oil refinery to process crude oil and gas processing plants to prepare natural gas for distribution and use in the country.
7. **Decommissioning:** When an oil or gas well or production facility is no longer productive, it must be safely decommissioned to minimise environmental impact.
    a. Well plugging and abandonment: The wellbore is sealed with cement plugs to prevent the migration of fluids between formations and to protect groundwater. The wellhead and surface equipment are removed.
    b. Site Restoration: The surface area is cleaned up and restored to its original state as much as possible, including removing equipment and remediating any contamination.

    Proper decommissioning practices are essential to ensure that oil and gas operations do not leave a lasting negative impact on the environment in Ghana.

Fracturing (Fracking) of Fluids

Hydraulic fracturing, or fracking, is a technique used to extract oil and natural gas from low-permeability rock formations, primarily shale and tight sandstone.

Process involved in Fracking

1. **Drilling the well**
    a. Drilling is the process of creating a wellbore from the surface down to the oil or gas formation. This can be a vertical well, but increasingly, wells are drilled horizontally within the formation.
    b. Horizontal drilling exposes a much larger surface area of the formation to the wellbore, which significantly increases the potential for oil and gas production. The horizontal section of the well can extend for thousands of feet.
    c. Accurate drilling is crucial to ensure that the wellbore intersects the most productive zones of the formation.

    Important: Drilling is the foundation of the fracking process, creating the pathway to access the hydrocarbons.

2. **Casing and cementing:** After drilling, steel casing is inserted into the wellbore to provide structural integrity and prevent the well from collapsing. Cement is then pumped into the annular space between the casing and the wellbore to create a strong and impermeable seal. This casing and cementing process is essential for:
   a. Preventing the fracturing fluids from migrating into and contaminating underground water sources, particularly drinking water aquifers. This is a major environmental concern associated with fracking.
   b. Ensuring that the high-pressure fracturing fluids are directed into the target formation where the oil and gas are trapped, rather than escaping into other geological zones.

   Important: Casing and cementing are critical for well integrity and environmental protection.

3. **Injection of Fracturing Fluid:** The core of the fracking process involves injecting a large volume of fracturing fluid into the well at extremely high pressure. This pressure exceeds the tensile strength of the target rock formation, causing it to crack and fracture. A network of fractures is created, increasing the permeability of the rock.

   The fracturing fluid is typically composed of:
   a. Water: Makes up the vast majority (often 90% or more) of the fluid.
   b. Proppant: Solid materials, such as sand, ceramic beads, or resin-coated sand, which are carried by the fluid into the fractures.
   c. Chemical Additives: A small percentage of the fluid consists of various chemical additives that serve specific purposes, such as:
      - Friction reducers: To decrease friction in the pipes and allow the fluid to be pumped more efficiently.
      - Gelling agents: To increase the viscosity of the fluid, allowing it to carry proppant more effectively.
      - Biocides: To prevent the growth of bacteria, which can clog the fractures.
      - Corrosion inhibitors: To protect the well casing from corrosion.

   Important: This step creates pathways for oil and gas to flow from the rock formation to the wellbore.

4. **Sand proppants:** Proppants are essential to keep the fractures open after the injection pressure is released.
   a. The fracturing fluid carries the proppants deep into the created fractures.
   b. When the pumping pressure is reduced, the proppants become lodged within the fractures, preventing them from closing or collapsing.
   c. This ensures that enhanced permeability is maintained, allowing oil and gas to flow continuously to the wellbore.

   Important: Proppants are crucial for the long-term productivity of the well.

5. **Flowback and production:** After the fracturing process is complete, the pressure in the well is gradually reduced.
   a. Some of the injected fracturing fluid flows back to the surface. This is called flowback.

b. Flowback fluid can contain not only the injected components but also substances from the formation, such as:
    - Salts: Dissolved minerals from the rock.
    - Hydrocarbons: Oil and gas.
    - Naturally occurring radioactive materials (NORM): Radioactive elements that exist naturally in the subsurface.

c. Proper management and disposal or recycling of flowback fluid are essential to minimise environmental risks.

d. Oil and gas then flow through the network of fractures to the wellbore and are brought to the surface for processing and distribution.

Important: This is the production phase, where the extracted resources become available for use.

Advantages of Fracking of Fluids

Hydraulic fracturing offers several significant advantages, particularly in terms of accessing previously inaccessible resources and boosting energy production.

1. **Access to previously inaccessible resources**
    a. Fracking has revolutionised the oil and gas industry by enabling the economic extraction of resources from shale and tight sandstone formations that were previously considered too impermeable to produce using conventional drilling methods. These formations hold vast reserves of oil and natural gas that were locked away and inaccessible. This has dramatically increased global energy production and altered the energy landscape in some countries.

    b. While Ghana's current oil and gas production is primarily from conventional offshore fields, fracking technology could potentially become relevant if significant unconventional resources are discovered in the future. However, a thorough assessment of the geological conditions and potential environmental risks would be necessary before considering its implementation.

2. **Increased production from Wells**
    a. By creating a network of fractures in the rock, fracking significantly enhances the permeability of the formation, allowing oil and gas to flow more easily to the wellbore. This increased permeability leads to a higher rate of production and a greater ultimate recovery of resources from each well. Fracking can extend the productive life of a well and increase its overall economic viability.

    b. Enhanced production from existing or future wells can contribute to increased energy supply, revenue generation, and economic growth for Ghana.

3. **Increased domestic energy production**
    a. In countries with significant shale (a fine-grained sedimentary rock, often rich in organic matter) resources, fracking has led to a substantial increase in domestic oil and gas production. This increased domestic production can reduce reliance on energy imports, improve energy security, and lessen vulnerability to fluctuations in global energy prices and geopolitical events.

    b. Increasing domestic oil and gas production can strengthen Ghana's energy independence and reduce its dependence on external energy sources.

4. **Job creation and economic growth**
   a. The fracking industry creates a wide range of jobs in various sectors, including drilling, well servicing, transportation, manufacturing, and construction. Increased energy production can also stimulate economic activity in related industries and contribute to overall economic growth in the regions where fracking is practiced.
   b. Oil and gas activities, including any potential future fracking operations, can contribute to employment opportunities and economic development in Ghana.

Learning tasks

1. Identify the composition of oil and natural gas.
2. Critically analyse the multiple uses of oil and natural gas across different sectors and evaluate how these uses influence Ghana's industrial, domestic, and economic development.
3. Develop an evidence-based argument on the usefulness and economic necessity of oil and gas discovery in Ghana, using economic data, policy reports, and examples from oil-producing regions.
4. Design a comprehensive flowchart or model that illustrates the entire process of oil and gas extraction in Ghana, from exploration to refining, and evaluate its efficiency and sustainability.
5. Investigate and assess the environmental, social, and economic risks associated with oil and gas exploration in Ghana and propose actionable strategies to minimise these dangers.

Pedagogical Exemplars

1. **Experiential and Hands-on Learning**

   Engage learners in practical activities such as simulating oil refining, experimenting with natural gas combustion, or analysing oil and gas samples. These hands-on tasks help learners understand the physical and chemical properties of oil and gas, as well as their industrial processing.

2. **Case-Based and Contextual Learning**

   Use real-world case studies to deepen understanding of oil and natural gas. Explore extraction methods, industrial uses, and specific discoveries in Ghana. Highlight economic benefits, investment opportunities, infrastructure development, and socio-economic impacts in local contexts.

3. **Expert Engagement and Real-life Application**

   Invite industry professionals, policymakers, or experts from Ghana's oil and gas sector to share first-hand insights. Learners gain real-world knowledge about resource discovery, national economic implications, and sustainable development challenges and opportunities.

4. **Multimedia and Dialogic Learning**

   Use multimedia presentations (images, videos, interactive content) to visually explain oil and gas composition. Organise debates and group discussions to encourage critical thinking on issues such as environmental impact, extraction ethics, and sustainable use of fossil fuels.

Key Assessment Level 4: Debate

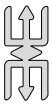
To what extent has the discovery of oil in Ghana been beneficial to the nation?"

Construct a well-reasoned written debate that explores both the advantages and disadvantages of oil discovery in Ghana. Support your arguments with evidence and address counterclaims to demonstrate deep understanding and critical evaluation. **(28 marks)**

PLC Session 3

45 minutes | **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to
   a. explain the week's concepts in a practical way that will make it easier for learners to understand
   b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject specific app to plan your lesson. Ask the app to
   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
   b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
   c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Plan the week's key assessment with your app
   a. The key assessment for the week is ***practical***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the practical (NTS 3k-3q).

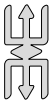
10 minutes | **Content Exploration**

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
   a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)

b. all teachers in the group work through a similar problem individually for 3–4 minutes

c. the group then works through the problem together step by step

d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- *This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?*
- *If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.*
- *Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.*

30 minutes Enactment

6. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).

   a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.

   b. After the enactment, ask for structured feedback from the group

      i. was the concept explained in a way that a learner with no prior knowledge could follow?

      ii. were the examples grounded in contexts familiar to Ghanaian learners?

      iii. did any misconceptions surface and if so, how were they addressed?

5 minutes Reflection

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).

8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).

9. Remember to

   a. transfer your chats into your learning planner template.

   b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).

   c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 2 Review

This section covers only **Week 3**. In this section, learners focused on the composition and uses of oil and natural gas. The lesson introduced them to the formation and components of these fossil fuels, including hydrocarbons such as methane, ethane, and propane. Through multimedia presentations, case studies, and hands-on simulations, learners explored the processes of extraction, refining, and distribution.

Emphasis was placed on how oil and natural gas are utilised in domestic, industrial, and economic settings; from powering vehicles and generating electricity to their use in the production of plastics, fertilisers, and other essential products. Learners also examined the relevance of Ghana's oil and gas discoveries and their socio-economic impacts.

By the end of the week, learners were expected to have understood the scientific composition of oil and natural gas, appreciated their practical uses, and developed the ability to analyse their importance in daily life and national development.

MARKING SCHEMES FOR THE KEY ASSESSMENTS

Total 28 marks

Criteria	Description	Mark Allocation
Introduces the topic and outlines both sides of the debate. (3 marks)	*Provides background on oil discovery in Ghana and outlines the scope of the debate, including benefits and challenges.*	*Introduction with context and purpose of the debate (3 marks)* *Introduction with only context of the debate (2 marks)* *Introduction without context and purpose of the debate (1 mark)*
Presents advantages of oil discovery with evidence. (5 marks)	*Discusses benefits such as economic growth, job creation, infrastructure, and energy security, supported by relevant data or examples.*	*Explains 3 benefits with 2 supporting evidence (5 marks)* *Explains 2 benefits with 1 evidence. (3 marks)* *Explains 1 benefits without evidence. (2 marks)*
Presents disadvantages of oil discovery with evidence (5 marks)	*Discusses drawbacks such as environmental harm, economic volatility, inequity, and corruption, supported by examples.*	*Explains 3 disadvantages with pieces 2 of evidence. (5 marks)* *Explains 2 disadvantages with piece of 1 evidence (3 marks)* *Explains 1 disadvantage without evidence (2 marks)*
Acknowledges counterarguments and provides rebuttals (5 marks)	*Identifies opposing viewpoints and responds with sound reasoning.*	*Identifies two counterclaims and responds with logical rebuttals (5 marks)* *Identifies one counterclaim and responds (3 marks)* *Identify 1 counterclaim without rebuttal (1 mark)*
Draws a conclusion and provides final evaluation (5 marks)	*Summarises key arguments and offers a reasoned judgment on the extent of benefits.*	*Balanced conclusion comparing both sides and making a justified judgment (5 marks)* *Summarises both sides without making a justified judgment (3 marks)* *One-sided conclusion (1 mark)*
Uses appropriate language, structure, and grammar. (5 marks)	*Organises content logically with coherent paragraphs and proper grammar.*	*Well-structured, clear language, proper grammar, logical flow (5 marks)* *Minor language or structure issues, but understandable (3 marks)* *Poor structure or grammar affecting clarity (1 mark)*

SECTION 3: NERVOUS SYSTEM

STRAND: PROCESSES FOR LIVING

Sub-Strand: Essentials for survival

Learning Outcome: *Model the structure of the nervous system and describe the functions of the parts of the nervous system*

Content Standard: *Model and demonstrate understanding of the nervous system, its parts and uses*

INTRODUCTION AND SECTION SUMMARY

The human nervous system is a complex network that controls and coordinates all body activities. In this section, learners will analyse the central nervous system (CNS), which is made up of the brain and spinal cord and understand its structure and control functions. They will also explain the role of the peripheral nervous system (PNS) in connecting the CNS to the rest of the body.

Learners will describe the autonomic nervous system, including its sympathetic and parasympathetic divisions that manage involuntary activities. Finally, they will explore how nerve impulses are generated and transmitted through neurons.

By the end of this section, learners should be able to identify and explain the structure and functions of the CNS, PNS, and autonomic nervous system, and describe how nerve impulses are produced and communicated throughout the body.

The weeks and the indicators covered by the section are:

- **Week 4:** Analyse the central nervous system.
- **Week 5:** Explain the peripheral nervous system.
- **Week 6:** Describe autonomic nervous system.
- **Week 7:** Discuss the generation and transmission of nerve impulses

SUMMARY OF Pedagogical Exemplars

This summary presents diverse, learner-centred strategies for teaching the structure and function of the central, peripheral, and autonomic nervous systems. Teachers facilitate active learning through simulations, collaboration, role-play, inquiry, and real-world case studies.

Interactive demonstrations and simulations, including 3D models and diagrams, help learners visualise brain regions, spinal cord, and neural pathways. Collaborative learning in mixed-ability groups encourages peer discussions on CNS and PNS functions, with presentations, gallery walks, and critiques enhancing engagement. Role-playing activities allow learners to act out signal transmission and nervous system interactions.

Nature walks and sensory activities link theory to real-life experiences, deepening understanding of sensory nerves. Learners also engage in research tasks on autonomic functions and reflex actions, supported by multimedia tools and guided inquiry.

By the end, learners should know nervous system structures, understand how they function and interact, and be able to investigate, analyse, model, and communicate key neurological concepts.

ASSESSMENT SUMMARY

Learners will engage in a variety of assessments aligned with different DOK levels to demonstrate their understanding of the nervous system.

To analyse the central nervous system (DOK Level 4), learners will complete a problem-based task requiring deep reasoning and application of knowledge to real-life scenarios. For the peripheral nervous system (DOK Level 2), a group discussion and multiple-choice questions will assess learners' conceptual understanding and ability to articulate ideas. The autonomic nervous system will be assessed using a case study, testing learners' higher-level thinking through carefully structured questions (DOK Level 4).

Finally, learners will discuss the generation and transmission of nerve impulses through classwork requiring strategic reasoning (DOK Level 3), enabling them to apply processes and explain mechanisms clearly.

Indicators	DOK Level	Assessment Strategy and/or Mode
Analyse the central nervous system.	Key Assessment Level 4: Extended critical thinking and reasoning	Group work
Explain the peripheral nervous system.	Key Assessment Level 2: Skills of conceptual understanding.	Group discussion
Describe the automatic nerve system	Key Assessment Level 4: Extended critical thinking and reasoning	Case study
Discuss the generation and transmission of nerve impulses	Key Assessment Level 3: Strategic Reasoning	Classwork

WEEK 4

Learning Indicator: *Analyse the central nervous system*

Focal Area: Structure of the nervous system

Nervous System

The nervous system is made of neurons or nerve cells. The nervous system is commonly divided into two parts: the central nervous system (CNS) and the peripheral nervous system (PNS).

The Central Nervous System (CNS)

The central nervous system (CNS) consists of the brain and the spinal cord. The brain tissue is protected by the bony skull, and the spinal cord is protected by the backbone or the vertebrae. The brain and spinal cord are linked to the rest of the body by nerves. Both parts of the central nervous system (the spinal cord and the brain) consist of white and grey matter. White matter represents areas with bundles of axons each coated with a sheath of myelin, while grey matter consists of masses of cell bodies and dendrites. In the spinal cord, the white matter is at the surface, with the grey matter inside, but this pattern is reversed in the brain of mammals.

Note

In the **brain***, grey matter lies on the outer surface, while white matter lies beneath it. In the* **spinal cord***, this pattern is reversed.*

Components of Central nervous System (CNS)
The Brain

It is a complex organ serving as the centre of the nervous system, located in the head to control thought, memory, emotions, motor skills and sensory processing. The human brain receives nerve impulses from the spinal cord and through cranial nerves. Some of the cranial nerves are "mixed", containing both sensory and motor axons; some (e.g., the optic and olfactory nerves) contain sensory axons only, while others (e.g., the one that controls eyeball muscles) contain motor axons only).

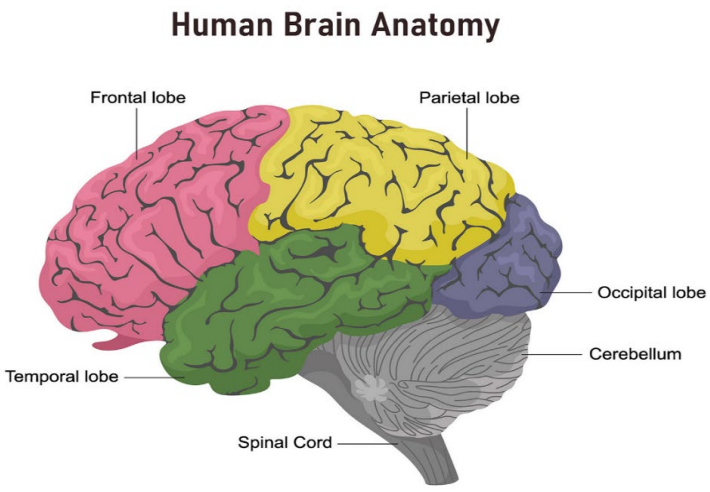


Figure. 3.1: *A well labelled diagram of the human brain*

The brain is made up of millions of neurons or nerve cells. The main parts of the brain are the:

1. Fore brain (Cerebrum)
2. Midbrain
3. Hindbrain (Cerebellum)
4. Medulla Oblongata

Cerebrum (fore Brain)

The cerebrum, the largest part of the human brain, is made up of two hemispheres, left and right cerebral hemispheres. The two hemispheres are separated by deep depression or fissure. The brain is the anterior part of the CNS. Its outer part is covered by thin grey matter and the inner part is covered by thick white matter. The grey matter forms the cerebral cortex, the outer part of the cerebrum. The grey matter or cerebral cortex is made up of non-myelinated axons. The white matter contains nerve cells that have myelinated axons. The cortex has grooves or sulci (infoldings) which gives it a large surface area. Each hemisphere of the cerebrum is subdivided into four lobes visible from the outside. The four lobes are the frontal, parietal, occipital, and temporal. It is believed that the larger the surface area of the brain, the more intelligent the person is. The other parts of the cerebrum are:

1. Hypothalamus:
2. Optic lobes
3. Pituitary gland

Functions of the Cerebral cortex or Cerebrum

1. Learning and information storage
2. Intelligence and problem-solving
3. Interpretation of sensory information
4. Voluntary muscle control
5. Thinking, imagination, and reasoning
6. Memory and emotion
7. Skill acquisition and coordination
8. Personality development
9. Speech, vision, taste, smell, and touch

Hypothalamus

The floor of the cerebrum forms the hypothalamus. It is the **control centre for involuntary activities** and forms part of the **autonomic nervous system.**

Functions of the Hypothalamus

1. Regulation of water and electrolyte balance
2. Monitoring carbon dioxide levels in the blood
3. Control of body temperature
4. Regulation of sleep and wake cycles

5. Appetite, thirst, and weight regulation
6. Heart rate and blood pressure control

Pituitary Gland

Often called the "master gland", it is located at the base of the brain beneath the hypothalamus. It secretes pituitary hormones that regulate various body functions and control other endocrine glands.

Functions of Pituitary Hormones

1. Promote physical growth
2. Regulate water balance
3. Stimulate and control other endocrine glands
4. Control sexual development and metabolism

Midbrain

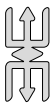
The midbrain is a small part of the brain located between the forebrain and hindbrain. It contains bundles of myelinated nerve fibres and visual and auditory reflex centres.

Functions of the Midbrain

1. Controls eye movement
2. Coordinates head turning in response to stimuli
3. Processes auditory information

Hindbrain – Cerebellum, Pon and Medulla Oblongata
Cerebellum

It is situated at the base of the skull just above the spinal cord. Receives input from the **inner ear** (semicircular canals) and **muscles** to help maintain balance and posture.



Note

Excessive alcohol disturbs the proper functioning of the cerebellum.

Functions of the cerebellum

1. Maintains posture and balance
2. Coordinates voluntary movements (e.g., walking, running, driving)
3. Maintains muscle tone

Medulla Oblongata

The cerebellum, pon and the medulla oblongata form the hindbrain. Medulla oblongata controls involuntary and reflex activities of the body. Located below the cerebellum; connects the brain to the spinal cord.

Functions

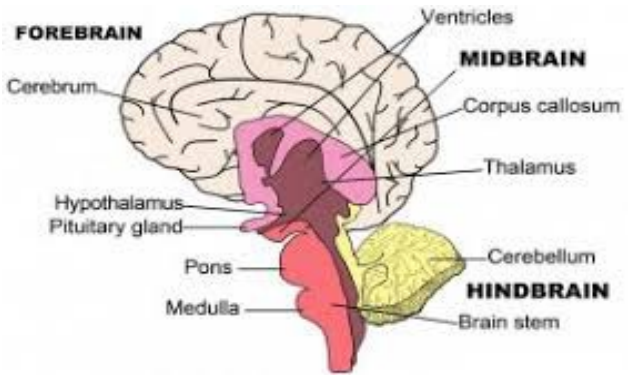
1. Controls heart rate and breathing
2. Regulates blood pressure
3. Manages reflex actions such as coughing, sneezing, yawning
4. Controls swallowing and vomiting

Pon

It is situated in front of the cerebellum and above the medulla oblongata. It acts as a bridge connecting cerebrum, cerebellum and spinal cord

Functions

1. Controls involuntary processes such as breathing
2. Regulates sleep
3. Facial expressions and movement
4. Relays signals between brain parts



Functions of the Central Nervous System

1. Controls the emotional behaviour of humans
2. Controls all reflex actions and conditioned reflexes
3. Co-ordinates the interactions of the body with external environment, e.g., the detection of changes in the external temperature and how the body structures involved with temperature regulation are all co-ordinated by the CNS.
4. The CNS receives information from all parts of the body through the sensory neurons, interprets the information and sends out correct responding information through motor neurones to the effectors and causes them to respond accordingly.

Factors that cause Damage to the Brain and Spinal cord

1. Psychological Conditions (e.g., Depression)

Mental health disorders such as depression and anxiety may not directly cause physical damage to the brain, but they can lead to changes in brain structure and function. Chronic stress and depression can reduce the production of neurotransmitters, shrink certain brain areas (for example the hippocampus, which is crucial for memory), and impair cognitive function. Long-term psychological distress can also increase the risk of neurodegenerative diseases such as Alzheimer's.

2. Substance Abuse (e.g., Indian Hemp, Heroin)

Drug and alcohol abuse can severely affect brain health. Prolonged use of substances such as marijuana (Indian hemp), heroin, cocaine, and methamphetamine alter brain chemistry, leading to impaired cognitive function, memory problems, and decreased impulse control. Some drugs reduce oxygen supply to the brain, causing cell death and increasing the likelihood of strokes. Alcohol abuse can lead to Wernicke-Korsakoff syndrome, a brain disorder resulting from severe thiamine deficiency.

3. Mental Illness and Sexually Transmitted Infections

Mental disorders such as schizophrenia and bipolar disorder are associated with structural and functional brain abnormalities. Additionally, sexually transmitted infections (STIs) such as syphilis and HIV can damage the nervous system. Neurosyphilis affects the brain and spinal cord, leading to cognitive decline and movement disorders. HIV-associated neurocognitive disorders (HAND) occur when the virus damages brain cells, leading to difficulties in memory, concentration, and coordination.

4. Physical Trauma (e.g., Motor Vehicle and Domestic Accidents)

Traumatic injuries from accidents or physical abuse can cause permanent damage to the brain and spinal cord. A traumatic brain injury (TBI) may result from falls, blows to the head, or car accidents, leading to loss of cognitive function, impaired speech, and personality changes. Spinal cord injuries from severe impacts can result in paralysis, loss of sensation, and difficulty in motor function. The severity of these injuries often depends on the location and extent of the damage.

Peripheral Nervous System

The peripheral nervous system (PNS) consists of nerves that branch out from the CNS and connect it to other body parts. The PNS includes the cranial nerves which arise from the brain and the spinal nerves which arise from the spinal cord.

Functions of the Peripheral Nervous System

1. Transmits sensory impulses (e.g., vision, smell, hearing)
2. Controls motor actions (e.g., tongue, eyes, jaw, and lips)
3. Relays information between the CNS and limbs/organs

The Spinal Cord

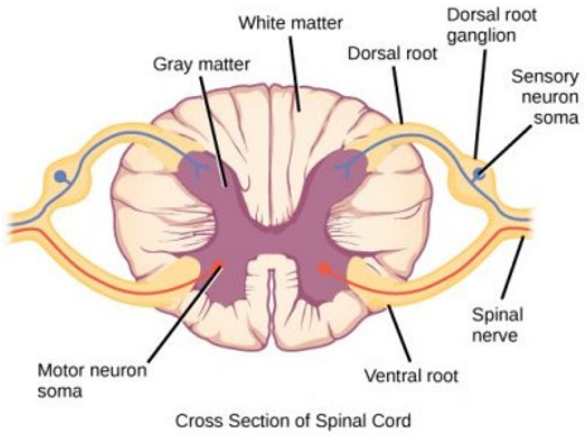


Figure.3.2: *A diagram of the cross section of the spinal cord*

The spinal cord is a white, soft and rope-like substance running through the backbone.

The spinal cord starts from the medulla oblongata and runs the whole length of the vertebral column. The vertebral column protects the spinal cord against mechanical injuries.

The central canal of the spinal cord is filled with cerebrospinal fluid. The inner layer of the spinal cord is made up of grey matter while the outer layer is made up of white matter. The white matter consists of nerve fibres which give it its colour, while the grey matter encloses the spinal canal and consists of neurones which give it the grey colour. There are two narrow grooves called the dorsal (anterior) fissure and the ventral (posterior) fissure situated at the dorsal and the ventral sides.

There are thirty-one pairs of peripheral spinal nerves connected to the spinal cord. The sensory spinal nerves are connected to the cord at the dorsal part; there are two (left and right) dorsal roots through which sensory information enters the spinal cord. The motor spinal nerves are connected to the cord ventrally. There are also two (left and right) ventral roots through which motor information goes out of the spinal cord. Sensory information goes towards the brain in the two dorsal columns of neurones, and motor information goes downward of the spinal cord in the two ventral columns of neurons. There are also two sets of lateral (side) columns of neurons whose function is both sensory and motor in nature. These are referred to as 'mixed' nerves.

Functions of the Spinal Cord

The spinal cord serves as a vital communication and coordination centre within the central nervous system.

Firstly, it receives sensory information from sensory receptors located throughout the body via afferent (sensory) nerve fibres. These afferent nerves transmit impulses into the dorsal (posterior) root of the spinal cord, where the information is then relayed to the brain for interpretation (e.g., recognising pain, temperature, pressure, or touch).

Secondly, the spinal cord also functions as a conduit for motor commands from the brain. Efferent (motor) nerve fibres carry instructions from the brain, down the spinal cord, and out through the ventral (anterior) root to muscles and glands, thereby initiating movement or stimulating glandular secretions.

In addition to these communicative roles, the spinal cord also performs a critical integrative function by coordinating reflex actions. Reflexes are automatic, rapid, and involuntary responses to specific stimuli (e.g., pulling the hand away from a hot surface) that are processed locally within the spinal cord, without the need for brain involvement. This makes reflex actions faster and efficient in protecting the body from harm.

Therefore, the spinal cord has both communicative and integrative functions:

1. It communicates between the peripheral nervous system and the brain by transmitting sensory inputs and motor outputs.
2. It integrates sensory input and generates motor output directly in reflex pathways, acting independently of the brain when necessary.

Learning tasks

1. Identify the components of the nervous system
2. Create a detailed and accurately labelled diagram of the central nervous system.
3. Analyse and explain the role of each part of the central nervous system.

Pedagogical Exemplars

1. **Demonstration/simulation:** Use interactive 3D models, animations, or virtual reality simulations discuss with learner the structure of the central nervous system, including the brain regions, spinal cord, and neural pathways.
2. **Collaborative learning:** Put learners in mixed ability groups to discuss the functions of different parts of the central nervous system, such as the role of the cerebral cortex in cognition, the spinal cord in reflexes, and the brainstem in regulating vital functions.

   Let learners present their finding for a gallery walk, whole class discuss and critique.
3. **Role-Playing Scenarios**: Ask learners to role-play the roles of different parts of the central nervous system (e.g., neurones, neurotransmitters) to understand how signals are processed within central nervous system.

Key Assessment Level 4: Case Study

Case Scenario

Emmanuel, a final-year learner, is giving a speech at a national science fair. As he walks onto the stage, his heart races, his palms sweat, and his breathing quickens. However, once he starts speaking and sees the audience reacting positively, his body begins to relax, and he feels more in control. Later that evening, while walking home, Emmanuel suddenly steps on a sharp object and instantly pulls his foot away before realising what happened.

1. Analyse the role of the autonomic nervous system in Emmanuel's physiological changes before, during, and after his speech. Support your answer with specific references to both the sympathetic and parasympathetic nervous systems. **(12 marks)**
2. Evaluate the importance of both voluntary and involuntary responses in ensuring survival in stressful or emergency situations like Emmanuel's. Justify with real-life examples. **(8 marks)**

PLC Session 4

45 minutes | **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to
   a. explain the week's concepts in a practical way that will make it easier for learners to understand
   b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject specific app to plan your lesson. Ask the app to
   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
   b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
   c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).

Note

- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Plan the week's key assessment with your app
    a. The key assessment for the week is ***case study***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the case study (NTS 3k-3q).

10 minutes **Content Exploration**

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
    a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
    b. all teachers in the group work through a similar problem individually for 3–4 minutes
    c. the group then works through the problem together step by step
    d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).

Note

- *This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?*
- *If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.*
- *Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.*

30 minutes **Enactment**

6. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).
    a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
    b. After the enactment, ask for structured feedback from the group
        i. was the concept explained in a way that a learner with no prior knowledge could follow?
        ii. were the examples grounded in contexts familiar to Ghanaian learners?
        iii. did any misconceptions surface and if so, how were they addressed?

5 minutes **Reflection**

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).

8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
    a. transfer your chats into your learning planner template.
    b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
    c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 5

Learning Indicator: *Explain the peripheral nervous system*

Focal Area: Peripheral Nervous System

The Peripheral Nervous System

The peripheral nervous system (PNS), aptly named, comprises all neural structures located outside the boundaries of the brain and the spinal cord; in essence, it's the portion of the nervous system external to the central nervous system (CNS). A key component of the PNS is its network of spinal nerves, which exist in pairs and serve as vital communication conduits, transmitting information both to and from the spinal cord. Complementing the spinal nerves are the cranial nerves, which offer a more direct route for information transfer between the brain and other parts of the body, bypassing the spinal cord. It consists of 12 pairs of cranial nerves and 31 pairs of spinal nerves.

Spinal nerves emerge bilaterally from the spinal cord. These points of exit are the dorsal and ventral horns of the spinal cord. The ventral portion of a spinal nerve is responsible for transmitting information away from the CNS to effector organs like muscles and glands; this is known as efferent function. Due to its role in controlling skeletal muscle movement, the ventral portion of the nerve is also commonly referred to as a "motor" nerve. Conversely, the dorsal portion of the spinal nerve is afferent, meaning it carries sensory information towards the CNS. In summary, afferent axons provide sensory input to the CNS, while efferent axons enable the CNS to send motor commands to muscles, internal organs, and glands.

Types of the Peripheral Nervous System (PNS)

Functionally, the peripheral nervous system (PNS) is organised into two main subdivisions: the somatic nervous system and the autonomic nervous system.

Somatic nervous system

The somatic nervous system, sometimes called the sensory-somatic nervous system, integrates both sensory and motor functions. Sensory nerves within this system are responsible for relaying information from the skin (such as sensations of pain and temperature changes) and muscles to the CNS, providing our conscious awareness of the external environment. Motor nerves, on the other hand, transmit commands from the CNS to skeletal muscles, enabling voluntary movements and our ability to interact with and respond to our surroundings. Therefore, all our conscious perception of the external world and all our volitional motor actions are mediated by the somatic division of the PNS.

Autonomic nervous system

The autonomic nervous system (ANS) is dedicated to the regulation of the body's internal environment. It achieves this through a network of sensory and motor neurones connecting the CNS (particularly the hypothalamus and medulla oblongata) to various internal organs, including the heart, lungs, and glands (both exocrine and endocrine). The ANS continuously monitors internal conditions and orchestrates necessary adjustments to maintain homeostasis. Motor neurones of the autonomic system exert control over the contraction of both smooth muscle (found in the walls of internal organs) and cardiac muscle (the heart muscle).

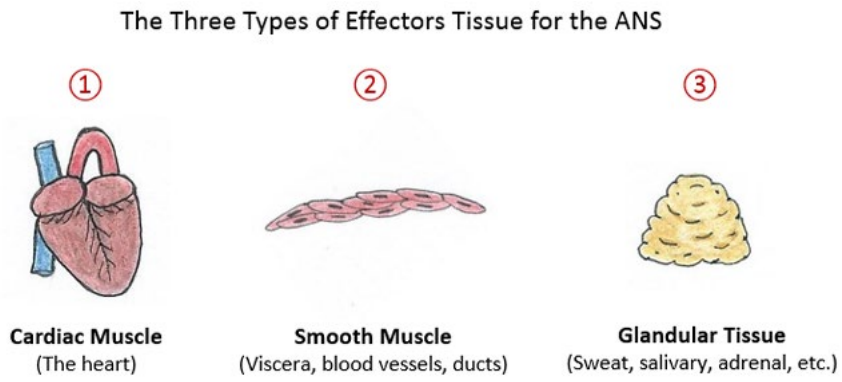


Figure. 3.3: *Types of effector tissues for ANS*

Essentially, the ANS governs involuntary bodily functions such as breathing, heart rate, and digestion. In contrast to the somatic system, the actions of the autonomic nervous system are largely involuntary. Another key difference lies in its use of a two-neurone chain to stimulate effector organs, rather than the single motor neurone used by the somatic system. Furthermore, the ANS is divided into the sympathetic nervous system and the parasympathetic nervous system.

Sympathetic and Parasympathetic Nervous Systems

The sympathetic and parasympathetic branches of the autonomic nervous system employ a two-neurone pathway to transmit signals from the central nervous system to peripheral organs. Both the parasympathetic and the sympathetic divisions act on the same effector tissue. This pathway includes two nerve fibres, the preganglionic and postganglionic neurones, connected by a ganglion. At the autonomic ganglia, acetylcholine typically functions as the neurotransmitter, facilitating signal transmission between preganglionic and postganglionic neurons. While postganglionic parasympathetic neurons also release acetylcholine, most postganglionic sympathetic neurons utilise norepinephrine as their primary neurotransmitter. Consequently, the effects of both sympathetic and parasympathetic stimulation are chemically mediated by the release of these neurotransmitters.

Preganglionic motor neurons of the sympathetic nervous system originate in the spinal cord and extend to sympathetic ganglia. These ganglia are organised into two chains, positioned parallel to and on either side of the spinal cord. The sympathetic nervous system is primarily responsible for the body's "fight-or-flight" response, preparing the organism to deal with perceived threats or stressful situations by mobilising its resources for action.

Norepinephrine, the neurotransmitter of the sympathetic system, can have diverse effects on target organs; its action may be excitatory in some cases, stimulating activity, or inhibitory in others, suppressing activity.

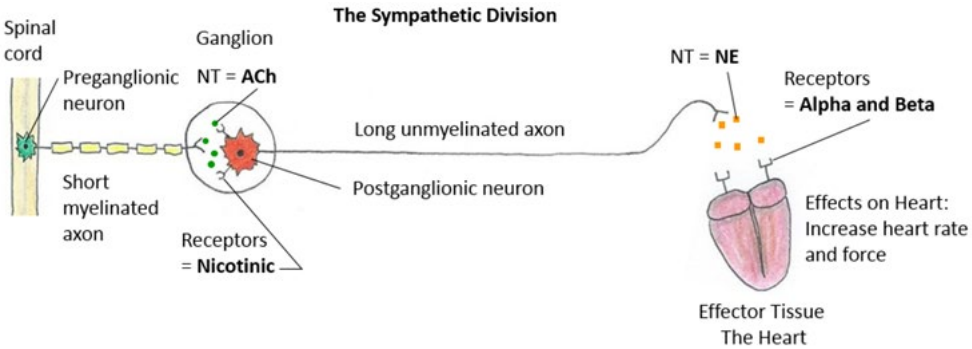


Figure. 3.4: *Shows Sympathetic division*

From the fig.3.4 the sympathetic division of the autonomic nervous system is characterised by having short preganglionic nerve fibres that extend from the central nervous system (CNS) to ganglia, which are typically located close to the spinal cord. At these ganglia, the preganglionic neuron releases acetylcholine (ACh), which then binds to nicotinic receptors on the cell body of the postganglionic neuron. This postganglionic neuron subsequently transmits a signal along its long, unmyelinated or lightly myelinated nerve fibre to the effector tissue (for example, the heart). Upon reaching the effector tissue, the postganglionic neuron releases norepinephrine (NE), and the receptors on the effector tissue are primarily alpha-adrenergic and beta-adrenergic receptors. The activation of these adrenergic receptors determines the specific response of the effector tissue.

The effects of norepinephrine release include:

1. Stimulation of heartbeat, increasing heart rate
2. Elevation of blood pressure
3. Dilation of the pupils of the eyes
4. Dilation of the trachea and bronchi, increasing airflow to the lungs
5. Stimulation of glycogenolysis, the breakdown of liver glycogen into glucose, providing energy
6. Shunting of blood away from the skin and viscera (internal organs) towards skeletal muscles, the brain, and the heart, prioritising oxygen delivery to these critical areas
7. Inhibition of peristalsis in the gastrointestinal (GI) tract, slowing down digestion
8. Inhibition of contraction of the bladder and rectum, delaying elimination

In essence, sympathetic nervous system activation orchestrates a coordinated physiological response that prepares the body to confront or escape danger ("fight or flight"). The widespread nature of sympathetic activation is facilitated by two mechanisms: a single preganglionic neuron typically synapses with numerous postganglionic neurons, allowing for broad activation of target organs. Additionally, the release of adrenaline (epinephrine) from the adrenal medulla into the bloodstream ensures that sympathetic stimulation reaches virtually all cells of the body, even those not directly innervated by postganglionic neurons.

The parasympathetic nervous system, in contrast, primarily utilises the vagus nerves (tenth cranial nerves), which originate in the medulla oblongata, as its main neural pathways. Other preganglionic parasympathetic neurons also emerge from the brain and the lower spinal cord.

Unlike the widespread divergence seen in the sympathetic system, each preganglionic parasympathetic neuron typically synapses with only a few postganglionic neurons, which are located close to or within the effector organ (muscle or gland) itself. Acetylcholine serves as the neurotransmitter at all preganglionic synapses and at many postganglionic synapses within the parasympathetic system.

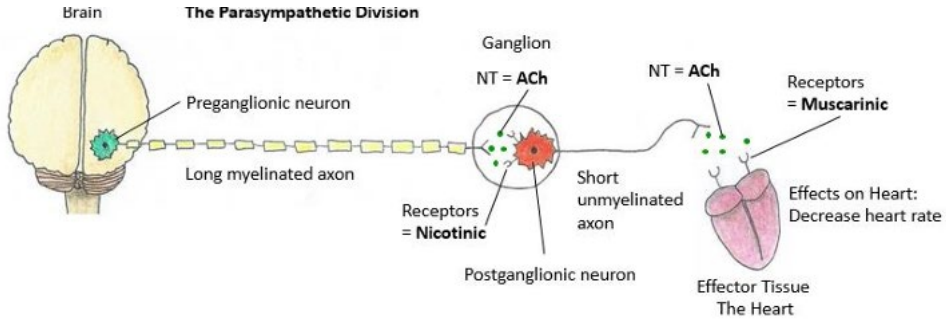


Figure. 3.5: *Shows parasympathetic division*

From the figure 3.5., the parasympathetic division of the autonomic nervous system is characterised by having long preganglionic nerve fibres that extend from the central nervous system (CNS) to ganglia located near or within the effector organs. At these ganglia, the preganglionic neuron releases acetylcholine (ACh), which then binds to nicotinic receptors on the cell body of the postganglionic neuron. This postganglionic neuron subsequently transmits a signal along its short, unmyelinated or lightly myelinated nerve fibre to the effector tissue (for example, the heart). Upon reaching the effector tissue, the postganglionic neuron again releases ACh. However, in this case, the receptors on the effector tissue are muscarinic receptors, and it is the activation of these muscarinic receptors that determines the specific response of the effector tissue.

Parasympathetic stimulation generally produces effects that are opposite to those of the sympathetic system, promoting a "rest-and-digest" state:

1. Slowing down of the heartbeat, decreasing heart rate
2. Lowering of blood pressure
3. Constriction of the pupils of the eyes
4. Increased blood flow to the skin and viscera, supporting digestion and other restorative processes
5. Stimulation of peristalsis in the gastrointestinal (GI) tract, promoting digestion

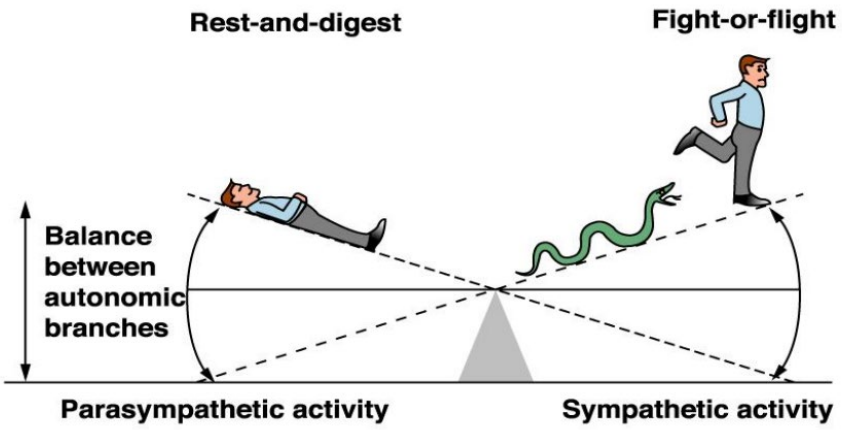


Figure.3.6: *Relationship between parasympathetic and sympathetic activity*

Table 3.1

Somatic	Autonomic
Voluntary	Involuntary
Skeletal muscle	Smooth, cardiac muscle; glands
Single efferent neuron	Multiple efferent neurons
Axon terminals release acetylcholine	Axon terminals release acetylcholine or norepinephrine
Always excitatory	Can be excitatory or inhibitory
Controlled by the cerebrum	Controlled by the homeostatic centres in the brain – pons, hypothalamus, medulla oblongata

Voluntary Action

It is any activity that can be started and stopped by an individual at any time. Voluntary actions are under the control of the brain, i.e., the will of an individual. One can choose to or not to do it, decide how long it must be done.

Examples of voluntary actions are walking, singing, shouting, eating, dancing, swimming, jumping, kicking a ball and throwing a stone.

Involuntary Actions

Involuntary actions include all actions that go on in the body that man has no will or control over. Involuntary actions happen unconsciously; they are not under the control of our will. Such actions occur without noticing. We cannot choose to do or stop them. Involuntary actions are less complex and involve the control of the spinal cord. Examples of involuntary actions are:

1. Dilation or constriction of pupil 6. Salivation upon smelling the aroma of food
2. Heartbeat 7. Constriction and dilation of the blood capillaries
3. Breathing 8. Regulation of the body temperature
4. Sleeping, 9. Blinking of the eye etc.
5. Regulation of water-salt balance of the blood

Comparison of Involuntary and Voluntary Actions

Table.3.2: *comparison of involuntary and voluntary action*

Spinal reflex (involuntary actions)	Voluntary action
1. Stimulus affect external or internal receptors	1.Initiated from the brain at the conscious level
2. Spinal cord involved-not under conscious control.	2. Forebrain involved under conscious control
3. The impulse travels only up or down the spinal cord	3. The impulse travels from the brain down the spinal cord
4. The path of the nerve impulse is by the shortest.	4. the path of the nerve impulse is much longer
5. The response is immediate	5. The response can be delayed
6. The response is in skeletal or an internal involuntary muscle.	6. The response is in skeletal muscles only

Learning tasks

1. Identify and describe the main types of the peripheral nervous system (somatic and autonomic) and their basic anatomy.
2. Explain the general functions of the somatic and autonomic nervous systems, including examples of voluntary and involuntary actions.

3. Compare the roles of the sympathetic and parasympathetic systems within the autonomic nervous system.
4. Describe how the peripheral nervous system interacts with other body systems, such as the muscular or endocrine system, using simple examples.

Pedagogical Exemplars

1. **Demonstration/Simulation**

   Use diagrams, charts, and illustrations to depict the structure of the peripheral nervous system, including the network of nerves, ganglia, and sensory receptors, to discuss with learners the various parts of the peripheral nervous system.

2. **Interactive Demonstrations:**

   Provide learners with diagrams, flowcharts, and images to help learners in mixed groups to discuss and present findings on functions of different types of peripheral nerves, such as motor nerves controlling muscle movement, and sensory nerves transmitting signals from the body to the brain, Learner peer critique each group work.

3. **Nature walk**

   Organise an outdoor activity for learners that involves sensory experiences, such as nature walks, to explore the sense of touch, sight, hearing, and smell. Relate these sensory perceptions to the functioning of sensory nerves in the peripheral nervous system.

4. **Role-Playing**

   Develop role-playing exercises where learners act out scenarios involving communication between the central and peripheral nervous systems.

5. **Research approach**

   In mixed ability groups, assign each group a specific aspect of the peripheral nervous system to research and present to their peers.

Key Assessment Level 2: Group discussion: Discuss how taste changes when the sense of smell is blocked with a nose peg. (20 marks)

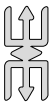
PLC Session 5

45 minutes | **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to
   a. explain the week's concepts in a practical way that will make it easier for learners to understand
   b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject specific app to plan your lesson. Ask the app to
   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.

b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)

c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Plan the week's key assessment with your app

   a. The key assessment for the week is ***Group discussion***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the discussion (NTS 3k-3q).

10 minutes **Content Exploration**

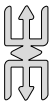
5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

   a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)

   b. all teachers in the group work through a similar problem individually for 3–4 minutes

   c. the group then works through the problem together step by step

   d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- *This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?*
- *If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.*
- *Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.*

30 minutes **Enactment**

6. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).

   a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.

   b. After the enactment, ask for structured feedback from the group

      i. was the concept explained in a way that a learner with no prior knowledge could follow?
      ii. were the examples grounded in contexts familiar to Ghanaian learners?

iii. did any misconceptions surface and if so, how were they addressed?

5 minutes **Reflection**

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
   a. transfer your chats into your learning planner template.
   b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
   c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 6

Learning Indicator: *Describe autonomic nervous system*

Focal area: Reflex Actions

Reflex

Reflexes are automatic, subconscious responses to changes within or outside the body.

Function of the reflexes

1. Reflexes maintain homeostasis (autonomic reflexes): heart rate, breathing rate, blood pressure, and digestion.
2. Reflexes also carry out the automatic action of swallowing, sneezing, coughing, and vomiting.
3. Reflexes maintain balance and posture, excluding Spinal reflexes that control trunk and limb muscles.
4. Brain reflexes which involve the reflex centre in the brain stem, excluding reflexes for eye movement.

Reflex action

There is one simple type of neural activity in which a stimulus results in an immediate action. This is a reflex action. Marshall Hall, a 19th-century English neurologist, coined the term reflex (from Latin reflexus, "reflection") to describe how muscles reflect a stimulus in the same way that a wall reflects a ball thrown against it. Hall defined reflex as the automatic response of a muscle or muscles to a stimulus that excites an afferent nerve. The term is now used to describe an action that is an inborn central nervous system activity that does not involve consciousness, in which a specific stimulus produces a stereotyped, immediate response of muscle or gland by exciting an afferent nerve. The reflex arc is the anatomical pathway of a reflex. It is made up of an afferent (or sensory) nerve, one or more interneurons from the central nervous system, and an efferent (motor, secretory, or secretory motor) nerve. The reflex arc of most reflexes contains several synapses. The stretch reflex is unique, in that it has only one synapse between the afferent nerve fibre and the motor neuron because there are no interneurons in the arc (see below Movement: The regulation of muscular contraction). There are at least two interneurons and three synapses in the flexor reflex, which removes a limb from a noxious stimulus. Reflex Action, also known as a reflex, is a nearly instantaneous involuntary movement in response to stimulus. When a person accidentally touches a hot object, they instinctively jerk their hand away. A reflex does not necessitate any mental effort.

Examples of Reflex Actions

1. When light is used as a stimulus, the pupil of the eye dilates.
2. When pricked by a pin, a jerky withdrawal of the hand or leg occurs.
3. Coughing or sneezing as a result of nasal passage irritants.
4. Knees jerk as a result of a blow or someone stamping on the leg.
5. The abrupt withdrawal of one's hand from a sharp object.
6. When an insect comes very close to the eyes, there is a sudden blinking.
7. Withdrawal of the hand from hot object.
8. Watering of the eye when an object falls on it
9. Flow of breast milk a baby puts mother's nipple into the mouth
10. Withdrawal of the leg when you step unto a sharp object
11. Sneezing when an irritating gas goes into the nose.

12. Dilation and constriction of the pupil when we go into light of different intensities.
13. Breast milk reflex: Milk flows when a baby sucks the nipple.

A reflex arc

A reflex arc is the path that nerve impulses take during a reflex. Most sensory neurons in the higher animals do not travel directly to the brain but instead synapse in the spinal cord. This property enables reflex actions to occur relatively quickly by activating spinal motor neurons without the delay of signal routing through the brain, even though the brain will receive sensory input while the reflex action occurs.

Some critical components are involved in the entire reflex action process. Receptor organs, sensory neurons, nerve centres, associated neurons, motor neurons, and effector neurons are all examples. The stimuli are perceived by the receptor organs. They are located in the organs of perception. Afferent neurons, also known as sensory neurons, transport stimuli from receptors to the spinal cord. The sensory neurons are found in the spinal cord's ganglion. The nerve centre, where synaptic connections are formed, is the spinal cord. The neurons involved are found in the spinal cord. Motor neurons are found in the ventral horn of the spinal cord. The glands and muscles that respond to stimuli are known as effector organs.

Neurons and Their Role in Reflexes

The majority of reflex arcs involve only three neurons. Neurons are specialised cells that are modified and adapted to transmit electrical impulses from one part of the body to another. They play a critical role in reflex actions, ensuring rapid communication between sensory organs, the spinal cord, and muscles. It is the main component of nervous tissue in all animals except sponges and placozoa. Plants and fungi do not have nerve cells. Each neuron has a cell body that contains a nucleus and processes information, dendrites that receive or collect information. The information received by the dendrites is passed to the cell body in the form of electrical impulses and is conducted along the axon and branch to the end plates of the axon. It has a fatty layer that insulates the axon and speeds up signal transmission called myelin sheath and Nodes of Ranvier which are the gaps in the myelin sheath that facilitate rapid impulse conduction.

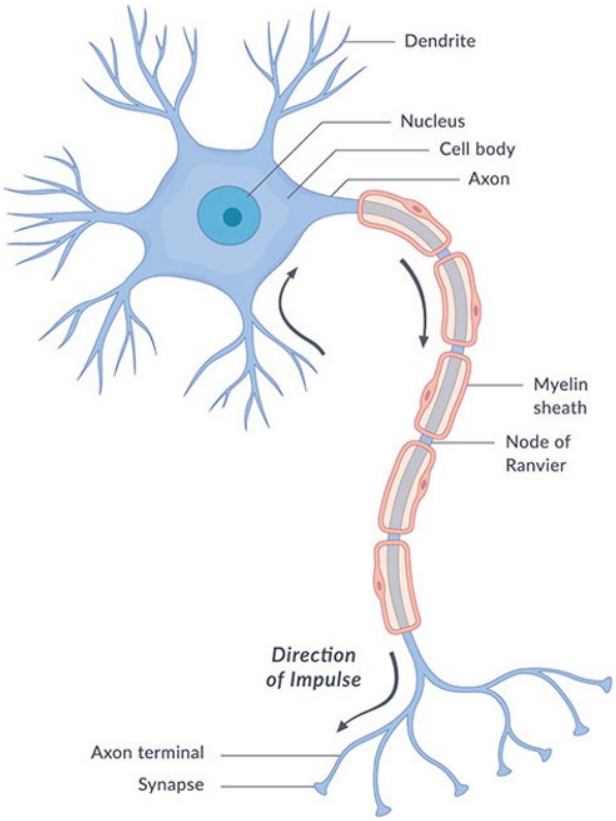


Figure. 3.6: *A Neuron*

Classification of Neurons

There are different types of neurons. Each type has different functions to perform. Neurons vary in size and shape. Neurons are also classified according to their structure and function. There are three kinds of neurons that are classified according to their structure namely, unipolar neurons, bipolar neurons and multipolar neurons. The classification is based on the number of processes (projections) emerging from the cell body.

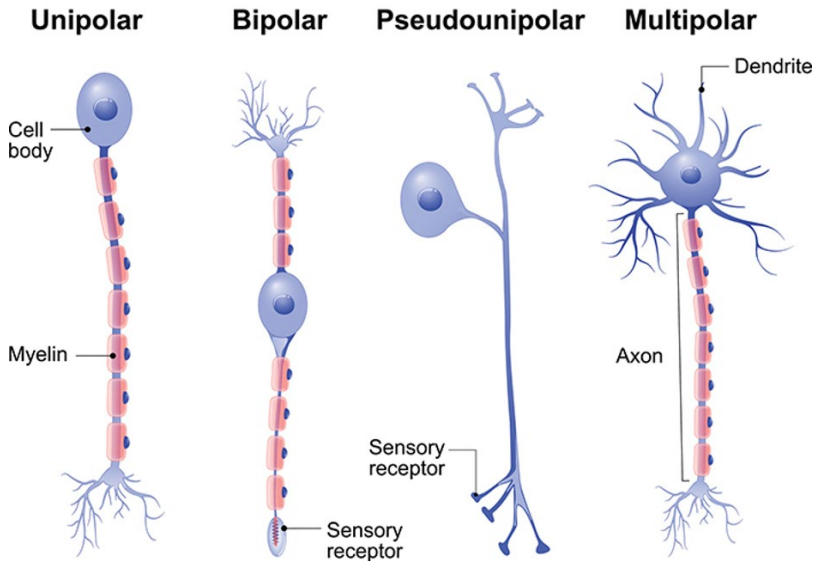


Figure. 3.7: *Classification of Neurons*

Types of Neurons

There are three main types of neurons. These are

1. Sensory neuron
2. Relay neuron/Interneuron
3. motor neuron

Sensory Neuron

The body branches at the junction of the Dendron and axon. It has Dendron with long fibre and axon. Sensory neurons have receptor cells. Receptors detect changes, stimuli or signals and pass them on as electrical impulses to the sensory neuron.

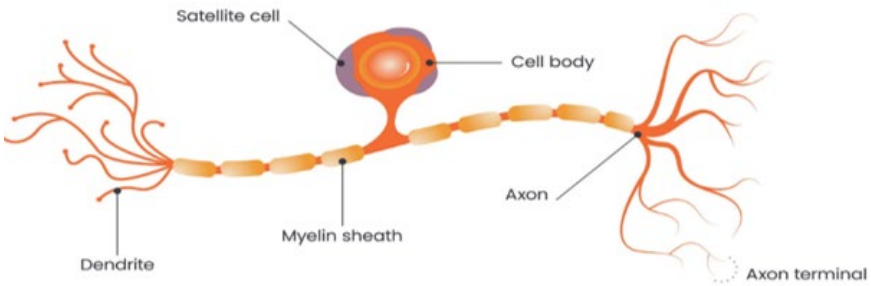


Figure 3.8: *A well labelled diagram of sensory neuron*

Function

It conducts impulses from receptors to the central nervous system.

Relay Neuron

Relay neurons are only found in the central nervous system (the brain and spinal cord). They are also referred to as associated neuron or intermediate neuron.

Function

It connects sensory neuron to a motor neuron.

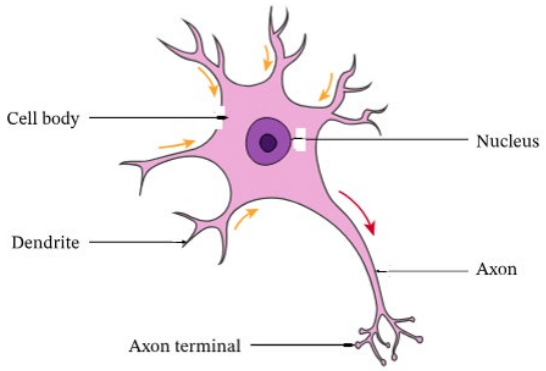


Figure 3.9: *A well labelled diagram of relay neuron*

Motor neuron

Some axons are covered with a thin sheath of a fat-like substance called myelin. Axons are covered with myelin are known as myelinated fibre and those without myelin are known as non-myelinated fibres. Myelin interrupted at short intervals to expose the nerve membrane. The exposed sites are called Nodes of Ranvier.

Function

It conducts/transmits electrical impulses from the central nervous system to effector organs, e.g., muscles and glands.

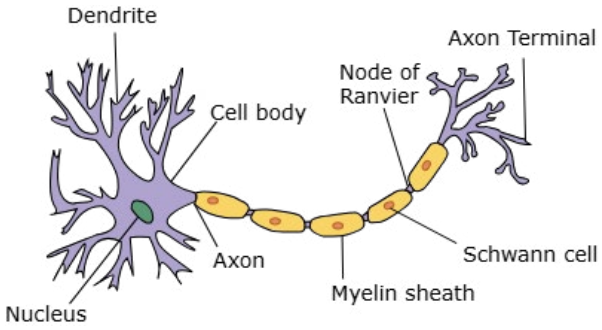


Figure .3.9.1: *A well labelled diagram of motor neuron*

Activity 3.1: Reflex Action

Objective

To observe and understand how reflex actions occur involuntarily and instantly in response to stimuli.

Materials

Reflex hammer (or use your hand)

- Chair or bench
- Stopwatch (optional)
- Volunteer

Procedure

1. Ask the volunteer to sit with their legs hanging freely.
2. Locate the patellar tendon below the kneecap.
3. Gently tap the tendon with the reflex hammer.
4. Observe the leg's automatic kick (knee-jerk reflex).
5. Repeat to compare reflex strength between both legs.

Observation

The leg moves involuntarily after the tendon is tapped, demonstrating the reflex arc's function.

Conclusion

The knee-jerk response is a spinal reflex that bypasses the brain, highlighting the speed and efficiency of reflex actions.

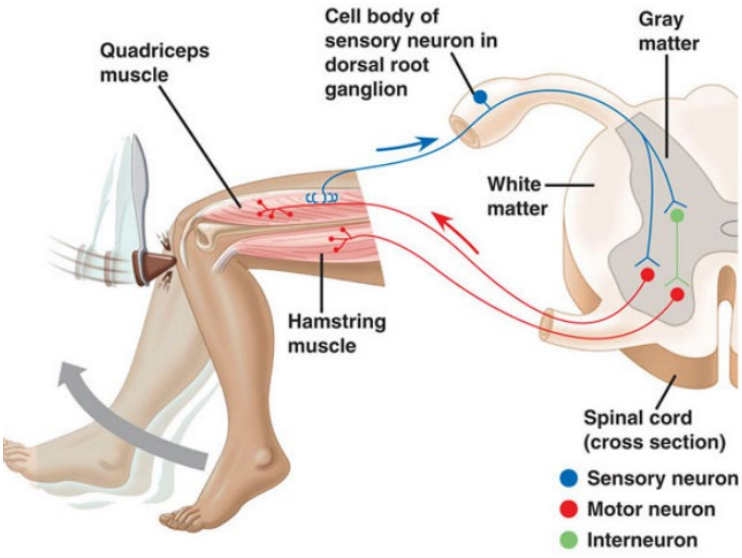


Figure. 3.9.2: A reflex action

Activity 3.2: Comparing Nerve Signal Speed and Diffusion

Objective

To illustrate the difference in speed between electrical signal transmission (action potential) and diffusion.

Materials: String or rope (10 meters), stopwatch, meter stick, spray bottle with coloured liquid, petri dish, safety goggles

Procedure

Part 1: Simulating Electrical Signals

1. Form a line with three learners, 1 meter apart.
2. Simulate a nerve impulse by flicking the string.
3. Measure the time it takes for the flick to reach the second and third learners.

Part 2: Simulating Diffusion

1. Pour coloured liquid into a Petri dish.
2. Measure how long it takes for the liquid to spread.

Calculations

- Speed of signal = Distance ÷ Time
- Compare the speed of electrical signals to diffusion.

Role of Reflexes in Daily Life

Reflex actions are crucial for survival, enabling the body to respond to:

- Sudden dangers (e.g., withdrawal from sharp objects).
- Environmental changes (e.g., pupil dilation in low light).
- Physiological needs (e.g., sneezing to expel irritants).

Neurons ensure the efficient coordination of sensory input and motor output, making reflexes instantaneous and protective. This rapid communication between the spinal cord and muscles allows the body to maintain homeostasis and adapt to its surroundings.

Learning tasks

1. Demonstrate how reflex actions occurs using videos
2. Create a concept map on the pathway of nerve impulses and explain how this mechanism protects the body.
3. Analyse the differences between voluntary and involuntary responses in a critical situation e.g., touching a hot object.

4. Compare and contrast the effects of the sympathetic and parasympathetic nervous systems on major organs during stress and rest. Using real-life scenarios e.g., emergency situations, digestion, sleep.
5. Evaluate how the body maintains internal balance (homeostasis).

Pedagogical Exemplars

1. **Collaborative learning and research method**

   In mixed ability groups, learners research the autonomic nervous system and present their findings to the whole class for discussion.

2. Use visual aids such as diagrams, charts, and illustrations to ask learners in mixed ability groups to discuss the effect of Sympathetic and Parasympathetic System and present their findings for whole class discussion.

3. **Collaborative learning:**

   Engage learners to utilise diagrams, animations, and videos to visually illustrate the structure of reflex action in mixed ability groups and present their findings for gallery walk.

4. **Case studies:**

   Present real-life case studies of neurological disorders to learners or conditions that involve abnormalities in neuron structure or function and ask learners to identify disorders associated with neuron function.

Key Assessment: Mid-Semester Examination

Case study

1. Fatima, a high school learner, was walking home from school when she heard the screech of car tires. Instinctively, she jumped back onto the sidewalk just in time to avoid being hit by a speeding motorcycle that had swerved out of control. She felt her heart racing, her hands trembling, and her breathing shallow. Later, she realised she had not consciously thought about moving; her body had reacted instantly.

   After the incident, her biology teacher asked the class to investigate what happened in her body during that moment. Learners were challenged to analyse her response as a reflex action, compare it to voluntary movement, and evaluate the importance of reflexes in survival.

   Analyse the sequence of events in Fatima's response, identifying the

   - Stimulus
   - Sensory neuron
   - Interneuron (relay neuron)
   - Motor neuron
   - Effector (muscle or gland) **(15 marks)**

2. Fatima, a high school learner, was walking home from school when she heard the screech of car tires. Instinctively, she jumped back onto the sidewalk just in time to avoid being hit by a speeding motorcycle that had swerved out of control. She felt her heart racing, her hands trembling, and her breathing shallow. Later, she realised she had not consciously thought about moving; her body had reacted instantly.

After the incident, her biology teacher asked the class to investigate what happened in her body during that moment. Learners were challenged to analyse her response as a reflex action, compare it to voluntary movement, and evaluate the importance of reflexes in survival.

Compare and contrast her reflex response with a voluntary action she might have taken if she had more time to think. **(10 marks)**

HINT

*Conduct **Mid-Semester Examination**. It should cover contents taught from Week 1 to 5. Refer to the **Table of Specification and Structure of the Paper**. Learners' papers should be marked immediately and scores entered into the SAP.*

Mid-Semester Examination

Structure

Section A: 25 Multiple-choice questions

Section B: 2 Essay Questions

Table of specification for item construction for section A and B

Week	Learning Indicator	Types of questions	DoK Levels				Total
			1	2	3	4	
1	Identify air as a mixture and explain the uses of the components of air	MCQs	2	2	–		4
		ESSAY	–	–	–		–
2	Prepare carbon dioxide and discuss its uses Prepare oxygen and discuss its uses	MCQs	2	2	2		6
		ESSAY	–	–	1		1
3	Discuss the composition and uses of oil and natural gas	MCQs	–	2	1		3
		ESSAY	–	–	–		
4	Analyse the central nervous system	MCQs	3	2	1		6
		ESSAY					
5	Explain the peripheral nervous system	MCQs	1	3	2		6
		ESSAY			1		1
		Total	**8**	**11**	**8**		**27**

PLC Session 6

45 minutes | **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous session, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to
   a. explain the week's concepts in a practical way that will make it easier for learners to understand.

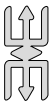
b. identify three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners (NTS 3a, 3g and 3m).

3. Use your subject specific app to plan your lesson. Ask the app to

   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.

   b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q).

   c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Use your app to plan and administer the mode of assessment for the Student Assessment Portal (SAP)

   a. The key assessment for the week is ***mid-semester examination***. Chat with your app to plan this assessment by reviewing or developing the assessment items/tasks and marking schemes/ rubrics for the mid-semester examination (NTS 3k-3q).

10 minutes **Content Exploration**

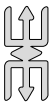
5. As a subject group, select one problem or topic/idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

   a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)

   b. all teachers in the group work through the problem individually for 3–4 minutes

   c. the group then works through it together the problem, step by step

   d. highlight the most common errors made at each step (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

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30 minutes **Enactment**

6. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).

a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.

b. After the enactment, ask for structured feedback from the group

   i. was the concept explained in a way that a learner with no prior knowledge could follow?

   ii. were the examples grounded in contexts familiar to Ghanaian learners?

   iii. did any misconceptions surface and if so, how were they addressed?

5 minutes **Reflection**

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).

8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).

9. Remember to

   a. transfer your chats into your learning planner template.

   b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).

   c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 7

Learning Indicator: *Discuss the generation and transmission of nerve impulses*

Focal Area: Generation and transmission of nerve impulses

The nervous system is composed of billions of neurons. Effective communication between these neurons is essential to maintaining homeostasis. These cells communicate via chemical synapses. The process by which this information is communicated is called synaptic transmission and can be broken down into four steps:

1. Synthesis and storage of neurotransmitters.
2. Neurotransmitter release.
3. Interaction of the neurotransmitter with the post synaptic receptor.
4. Inactivation of neurotransmitter

Synapse Structure

A synapse is the junction between two neurons or between a neuron and an effector cell. It consists of Presynaptic terminal/ synaptic knobs, Synaptic cleft and Postsynaptic membrane.

Presynaptic terminal/ synaptic knobs: The end of the axon of the transmitting neuron. It contains synaptic vesicles filled with neurotransmitters.

Synaptic cleft: The narrow gap (about 20-40 nm) between the presynaptic and postsynaptic membranes. It has a width of 200- 300 angstroms.

Postsynaptic membrane: The membrane of the receiving neuron or effector cell. It contains receptors for the neurotransmitter.

Synaptic Transmission

Synaptic transmission is the process by which a signal is transmitted from one neuron to another or to an effector cell across a synapse. It is a junction where the axon or some other portion of one cell (presynaptic cell) terminates on the dendrites, soma, or axon of another neuron (postsynaptic cell). The Central Nervous System (CNS) contains more than 100 billion neurons. The brain has 86 billion neurons. Some CNS neurons receive 20,000 synapses. Synaptic input is converted to a nerve impulse (AP) at the **Axon Hillock**. The output signal (AP) travels by way of a single axon leaving the neuron.

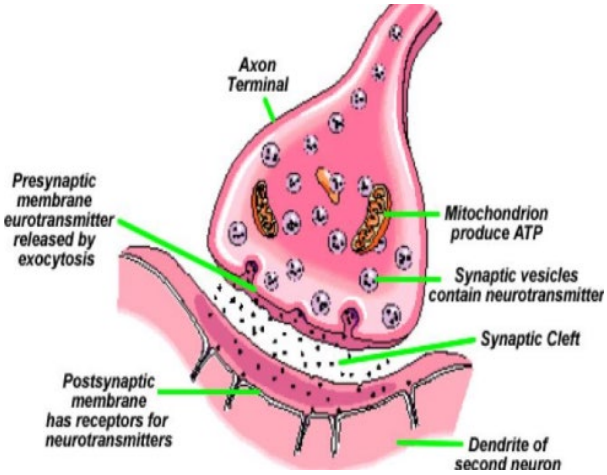


Figure 3.9.3: *Synaptic transmission*

Functions of synapse

1. In the central nervous system (CNS), the postsynaptic cell is typically another neuron.

   Synapses in the CNS are primarily neuron-to-neuron connections. These synapses facilitate communication between neurons in the brain and spinal cord, enabling complex processes such as learning, memory, and coordination of body functions.

2. In the peripheral nervous system (PNS), the postsynaptic cell may be either another neuron or an effector cell, such as a muscle or gland.

   In the PNS, synapses often occur at neuromuscular junction**s** (between motor neurons and muscle fibres) or **neuroglandular junctions** (between neurons and glands). These synapses are responsible for triggering specific actions like muscle contraction or secretion of hormones and other substances by glands.

3. Synapses determine the direction of signal transmission within the nervous system. Synaptic communication is unidirectional—nerve impulses always travel from the presynaptic neuron to the postsynaptic cell. This ensures orderly signal flow and organisation of neural pathways, allowing the nervous system to process inputs and coordinate responses accurately.

4. Synapses perform a selective filtering function by modulating the strength of signals that are transmitted.

   Synapses can amplify or inhibit nerve impulses. Weak or sub-threshold signals are often filtered out, preventing unnecessary or random activation of postsynaptic neurons. In contrast, strong signals that reach a sufficient threshold can be transmitted efficiently, sometimes even triggering action potentials in multiple downstream neurons. This selective capability plays a critical role in information processing, attention regulation, and sensory discrimination.

5. Synapses play a crucial role in connecting neurons together, allowing them to communicate through chemical signals. This communication occurs via neurotransmitters released at the synapse, enabling the transmission of information that ultimately regulates behavioural responses such as movement, emotion, perception, and cognition.

   If there is a dysfunction in synaptic activity, it can disrupt normal communication between neurons. This may lead to a variety of neurological and psychiatric disorders, including depression, anxiety, schizophrenia, epilepsy, and neurodegenerative diseases such as Alzheimer's disease.

6. Synapses ensure the one-way direction of nerve impulse transmission. This unidirectionality is maintained because neurotransmitters are stored only in the presynaptic neuron, while receptors for these neurotransmitters are located only on the postsynaptic neuron. As a result, the signal can only travel from the presynaptic to the postsynaptic cell, ensuring organised and effective communication in the nervous system.

7. Synapses assist in the integration of multiple neural signals. A single neuron may receive inputs from hundreds or thousands of other neurons. The synapse allows the neuron to process and integrate these incoming signals—some excitatory, some inhibitory—and determine whether to pass the signal along by generating an action potential. This is vital for complex decision-making processes in the brain.

8. Synapses help filter out weak or irrelevant stimuli. For a nerve impulse to cross a synaptic cleft and initiate a response in the postsynaptic neuron, it must reach a certain threshold—typically around +40 mV, which is the action potential. If the incoming signal is too weak and does not depolarise the membrane sufficiently, not enough neurotransmitter will be released, and the signal will not be passed on. This selective filtering mechanism prevents the nervous system from being overwhelmed by insignificant stimuli and allows us to focus on meaningful sensory information, such as a sudden loud sound or a bright light.

Process of Synaptic Transmission

When a nerve impulse, or action potential, reaches the terminal buttons (also known as synaptic terminals or axon terminals) of the presynaptic neuron, it triggers the opening of voltage-gated calcium (Ca^{2+}) channels in the presynaptic membrane. As a result, calcium ions rapidly enter the neuron from the extracellular fluid. This sudden influx of calcium ions initiates the movement of synaptic vesicles, small membrane-bound sacs containing chemical messengers known as neurotransmitters, toward the membrane of the synaptic knob. The vesicles then fuse with the presynaptic membrane through a process called exocytosis, releasing the neurotransmitters into the synaptic cleft, the small gap between the presynaptic and postsynaptic neurons. Once released, the neurotransmitters diffuse across the synaptic cleft and bind to specific receptor sites located on the postsynaptic membrane of the adjacent neuron. This binding initiates a local change in the membrane potential of the postsynaptic neuron, known as a postsynaptic potential. If the neurotransmitters are excitatory (e.g., glutamate), they cause sodium (Na^{+}) channels on the postsynaptic membrane to open. Sodium ions then rush into the neuron more rapidly than potassium (K^{+}) ions exit, resulting in a net positive charge inside the neuron. This depolarisation is referred to as an excitatory postsynaptic potential (EPSP). If the EPSP reaches a certain threshold level, an action potential is triggered in the postsynaptic neuron, allowing the signal to continue propagating. Conversely, inhibitory neurotransmitters (e.g., gamma-aminobutyric acid, or GABA) open potassium or chloride channels. When potassium ions (K^{+}) move out or chloride ions (Cl^{-}) move into the cell, the inside of the postsynaptic neuron becomes more negative than its resting potential. This hyperpolarisation is known as an inhibitory postsynaptic potential (IPSP) and reduces the likelihood that the neuron will fire an action potential. Not all neurotransmitters that are released into the synaptic cleft will bind to receptors. Those that remain unbound are typically cleared from the synapse through two main processes:

1. **Reuptake** – Neurotransmitters are reabsorbed into the presynaptic neuron for reuse. Specialised transporter proteins facilitate this process by returning the neurotransmitters to synaptic vesicles.
2. **Enzymatic degradation** – Specific enzymes present in the synaptic cleft break down the excess neurotransmitters. For example, the enzyme acetylcholinesterase breaks down acetylcholine.

These mechanisms ensure that the synapse is cleared and ready for the next round of neurotransmission, maintaining the fidelity and timing of neural communication. It is important to note that some drugs and substances can interfere with this finely tuned process. For instance, cocaine, a highly addictive stimulant, exerts its effects by blocking the reuptake of dopamine, a neurotransmitter associated with pleasure and reward. By preventing reuptake, cocaine leads to prolonged stimulation of dopamine receptors, which contributes to its euphoric effects and high potential for addiction.

Neurotransmitters

Neurotransmitters are specialised chemical messengers that are stored in synaptic vesicles within the terminal buttons of neurons. When a neuron fires an action potential, these neurotransmitters are released into the synaptic cleft, where they travel across to bind with receptor sites on the membrane of the next cell—either another neuron or an effector cell (such as a muscle or gland). This chemical signalling is fundamental to the communication between nerve cells, allowing the transmission of information throughout the nervous system.

As the term implies, neurotransmitters are substances that "transmit" messages across a synapse, and they operate entirely within the framework of neuronal communication. To date, researchers have identified more than 100 different neurotransmitter substances and more continue to be discovered as our understanding of the brain advances.

Classification of Neurotransmitters

Neurotransmitters are generally categorised into two broad groups based on their molecular structure.

Small-Molecule Neurotransmitters

These include

1. Amino acids (e.g., glutamate, gamma-aminobutyric acid [GABA], glycine, and aspartate)
2. Monoamines (e.g., dopamine, norepinephrine, epinephrine, and serotonin)
3. Acetylcholine (ACh) – the first neurotransmitter to be discovered
4. Unconventional neurotransmitters, such as nitric oxide and carbon monoxide, which do not follow the traditional packaging and release mechanisms

Large-Molecule Neurotransmitters

Known as neuropeptides, these include substances like endorphins, substance P, and oxytocin. They typically act more slowly than small-molecule neurotransmitters but have longer-lasting effects.

Functional Roles

1. Most neurotransmitters exhibit either an excitatory or inhibitory effect on the postsynaptic neuron:
2. Excitatory neurotransmitters increase the likelihood that the neuron will fire an action potential. Examples include:
3. Acetylcholine (ACh) – crucial for muscle activation, learning, memory, and REM sleep
4. Glutamate – the most abundant excitatory neurotransmitter in the brain, important for learning and neural plasticity
5. Catecholamines (e.g., dopamine, norepinephrine) – involved in alertness, mood regulation, attention, and movement
6. Serotonin – important for mood regulation, appetite, and sleep
7. Histamine – involved in wakefulness and immune responses
8. Inhibitory neurotransmitters reduce the likelihood of the neuron firing. The most notable example is GABA (gamma-aminobutyric acid), which calms neural activity and helps prevent overstimulation.

Interestingly, some neurotransmitters can act as either excitatory or inhibitory depending on the type of receptor they bind to and the physiological context. For example, dopamine can have varying effects depending on the receptor subtype (D1 vs. D2 family) it interacts with peptides.

Table 3.3: *Neurotransmitters and their functions*

Neurotransmitters	Functions
Acetylcholine (ACh)	Affects movement, learning, memory, REM sleep
Gaba-Aminobutyric Acid (GABA	Facilitates neural inhibition in the central nervous system (too much action potential)
Endorphins	Provide relief from pain and feelings of pleasure and well-being
Dopamine (DA)	Controls voluntary movements of the body and affects movement, attention, learning, reinforcement, pleasure

Norepihephrine (NE)	Affects eating, alertness, wakefulness
Epinephrine	Effects metabolism of glucose, energy release during exercise.
Serotonin (5HT)	Affects mood, sleep, appetite, impulsivity, aggression

Neurotransmitter release

When an action potential arrives at the presynaptic terminal, it depolarises the membrane, opening voltage-gated calcium channels. Calcium ions (Ca^{2+}) flow into the presynaptic terminal. The increase in intracellular Ca^{2+} triggers the fusion of synaptic vesicles with the presynaptic membrane. Neurotransmitter molecules are released into the synaptic cleft by exocytosis.

Neurotransmitter Binding: Neurotransmitter molecules diffuse across the synaptic cleft and bind to specific receptors on the postsynaptic membrane. These receptors are typically ligand-gated ion channels or G protein-coupled receptors.

Postsynaptic Effects: The binding of neurotransmitter to receptors causes a change in the permeability of the postsynaptic membrane to ions. If the receptors are ligand-gated ion channels, they open, allowing specific ions to flow across the membrane, causing either depolarisation (EPSP) or hyperpolarization (IPSP). If the receptors are G protein-coupled receptors, they activate intracellular signalling pathways that can have more complex and longer-lasting effects on the postsynaptic cell.

1. Neurotransmitter Inactivation: The neurotransmitter in the synaptic cleft is rapidly inactivated to terminate the signal. This can occur through:
2. Reuptake: The neurotransmitter is transported back into the presynaptic terminal or into glial cells by specific transporter proteins.
3. Enzymatic degradation: The neurotransmitter is broken down by enzymes in the synaptic cleft.
4. Diffusion: The neurotransmitter diffuses away from the synapse.

Neurotransmission

Neurotransmission is the fundamental process by which neurons communicate with each other and with effector cells (like muscle or gland cells) across synapses. It involves the generation and propagation of electrical signals within neurons and the conversion of these electrical signals into chemical signals that cross the synaptic gap.

Generation and Propagation of Nerve Impulses

Resting Membrane Potential:

Neurons, like other cells, maintain a resting membrane potential, an electrical potential difference across their cell membrane. This potential is typically negative inside the cell (around -70mV) relative to the outside. It is established and maintained by the unequal distribution of ions, mainly sodium (Na^+) and potassium (K^+), across the membrane. The sodium-potassium pump actively transports Na^+ out of the cell and K^+ into the cell, while the membrane is more permeable to K^+ at rest, allowing some K^+ to leak out.

Action Potential

Nerve impulses, also called action potentials, are rapid, transient changes in the membrane potential that propagate along the neuron's axon.

1. Depolarisation: An action potential is initiated when a stimulus (e.g., a neurotransmitter binding to receptors) causes the membrane potential to become less negative (depolarize). If this depolarisation reaches a threshold level, voltage-gated sodium channels in the membrane open rapidly, allowing a large influx of Na^+ into the cell. This influx further depolarises the membrane, causing more sodium channels to open in a positive feedback loop. The membrane potential quickly becomes positive (around +30mV).
2. Repolarisation: The rapid influx of Na^+ is short-lived. The sodium channels quickly inactivate, and voltage-gated potassium channels open more slowly. The efflux of K^+ from the cell repolarises the membrane, restoring the negative membrane potential.
3. Hyperpolarisation: The potassium channels remain open for a brief period, causing the membrane potential to become even more negative than the resting potential (hyperpolarisation). This is followed by a return to the resting potential.

Propagation

The action potential propagates along the axon like a wave. The depolarisation at one point on the axon triggers the opening of sodium channels in the adjacent region, initiating a new action potential. In myelinated axons, the action potential "jumps" between the Nodes of Ranvier (gaps in the myelin sheath), a process called saltatory conduction, which significantly increases the speed of propagation.

Regulation and Integration of Neural Signalling

Synaptic Integration: Neurons receive input from multiple other neurons at synapses on their dendrites and cell bodies. These inputs can be excitatory (depolarising) or inhibitory (hyperpolarising).

- Excitatory postsynaptic potentials (EPSPs): Depolarisations that increase the likelihood of the postsynaptic neuron firing an action potential.
- Inhibitory postsynaptic potentials (IPSPs): Hyperpolarisations that decrease the likelihood of the postsynaptic neuron firing.

Temporal and Spatial Summation

The postsynaptic neuron integrates these inputs through temporal summation (adding up EPSPs or IPSPs that occur close together in time) and spatial summation (adding up EPSPs or IPSPs that occur simultaneously at different locations on the neuron). If the combined effect of the inputs depolarizes the postsynaptic neuron to the threshold, an action potential is generated at the axon hillock and propagates along its axon.

Neuromodulation: In addition to fast synaptic transmission, neuromodulators can regulate neuronal activity. Neuromodulators are chemicals that don't directly excite or inhibit neurons but instead modify the strength of synaptic transmission or the excitability of neurons. They can act over longer distances and time scales than neurotransmitters.

Learning tasks

1. Explain the process of nerve impulse generation and propagation along a neuron, using scientific reasoning to describe the role of ions and the membrane potential.
2. Analyse how neural signalling is regulated and integrated within the nervous system, including how the body prioritises or modifies nerve signals in different situations.

3. Describe the steps involved in synaptic transmission at the synapse and explain how neurotransmitters influence the transmission of nerve impulses between neurons.
4. Use a labelled diagram or sequence chart to illustrate the process of synaptic transmission and explain what might happen if this process is disrupted.

Pedagogical Exemplars

1. **Interactive Demonstration**

   Using interactive demonstrations illustrates the process of neurotransmission at the synapse. Use props or models to represent neurons, neurotransmitter molecules, and receptors, allowing learners to visualise the steps involved in synaptic transmission.

2. **Inquiry-Based Activities**

   Learners in mixed ability groups are assigned to specific aspect of neurotransmission to investigate.

3. **Guided inquiry**

   Provide guided inquiry activities or lab investigations where learners explore neurotransmitter types, receptor subtypes, neurotransmitter release mechanisms, or the effects of drugs on synaptic transmission.

4. **Multimedia Resources and Virtual Simulations**

   a. Provide multimedia resources such as virtual neuron simulations, online tutorials, and interactive animations for learners to observe outcomes in real-time.

   b. Encourage learners to engage with multimedia resources independently to reinforce key concepts and explore topics of interest at their own pace.

Key Assessment Level 3: Homework

1. Illustrate the process of synaptic transmission using a labelled diagram. **(9 marks)**
2. Analyse how inhibitory and excitatory neurotransmitters affect the post-synaptic membrane. **(11 marks)**

PLC Session 7

45 minutes | **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to

   a. explain the week's concepts in a practical way that will make it easier for learners to understand

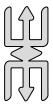
   b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).

3. Use your subject specific app to plan your lesson. Ask the app to

   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.

   b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)

c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



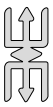
Note

- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Plan the week's key assessment with your app
   a. The key assessment for the week is ***homework***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the homework (NTS 3k-3q).

10 minutes **Content Exploration**

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
   a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
   b. all teachers in the group work through a similar problem individually for 3–4 minutes
   c. the group then works through the problem together step by step
   d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- *This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?*
- *If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.*
- *Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.*

30 minutes **Enactment**

6. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).
   a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
   b. After the enactment, ask for structured feedback from the group
      i. was the concept explained in a way that a learner with no prior knowledge could follow?
      ii. were the examples grounded in contexts familiar to Ghanaian learners?
      iii. did any misconceptions surface and if so, how were they addressed?

5 minutes **Reflection**

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
   a. transfer your chats into your learning planner template.
   b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
   c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 3 Review

In **Week 4**, they analysed the central nervous system (CNS), focusing on the brain and spinal cord, and their roles in processing and responding to information. By examining brain regions and neural pathways, learners developed critical thinking around coordination and control in the body.

In **Week 5**, attention shifted to the peripheral nervous system (PNS), where learners learned to identify its components and understand how sensory and motor nerves link the CNS to limbs and organs.

Week 6 covered the autonomic nervous system (ANS), with learners describing how the sympathetic and parasympathetic divisions regulate involuntary body functions.

Finally, in **Week 7**, learners discussed how nerve impulses are generated and transmitted. They examined synapses, neurotransmitters, and reflex actions.

By the end of this section, learners gained a comprehensive understanding of how the nervous system functions as a communication network within the body.

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 4

Question 1

Criteria	Description	Mark allocation
Identifies sympathetic response before/ during speech (4 marks)	*a. Before the Speech – Activation of the sympathetic nervous system* *For example,* *i. Increasing heart rate to pump more blood to muscles.* *ii. Stimulating sweat glands to cool the body.* *iii. Dilating airways for increased oxygen intake.* *b. During and After the Speech – Activation of the parasympathetic nervous system.* *For example,* *i. Heart rate slows down.* *ii. Breathing becomes regular.* *iii. Sweat production decreases.* *iv. Muscles relax, helping him feel calmer and in control.*	*Stating and explaining sympathetic response before and after/during speech (2 marks each)* *Stating without explaining sympathetic response before and after/during speech (1 mark)*
Explains the function of the sympathetic system ('fight or flight'). (3 marks)	*The 'fight or flight' response, preparing the body to face a stressful situation by increasing heart rate and breathing.*	*Explanation with a function and supporting examples. (3 marks)* *Explanation without supporting example (1 mark)*
Identifies parasympathetic response as Emmanuel calms down (1 mark)	*As Emmanuel notices the audience's positive reactions, the parasympathetic nervous system takes over.*	*Identification of parasympathetic response (I mark)*
Explains reflex action related to the sympathetic response when he steps on a sharp object. (2 marks)	*When Emmanuel steps on a sharp object, the sympathetic nervous system triggers a fast reflex, pulling his foot away before he feels pain.*	*Identification of reflex action in relation to the sympathetic response (2 marks)* *Identification of reflex action only. (1 mark)*
Demonstrates clear understanding of ANS roles in different contexts. (2 marks)	*This shows how the autonomic nervous system continuously adjusts the body's responses to emotional and physical changes using both branches.*	*Description of the role of ANS role different contexts. (2 mark)* *Stating without describing ANS role different contexts. (1 mark)*

(Total 12 marks)

Question 2

Criteria	Description	Mark allocation
Describes role of involuntary responses (with example) (3 marks)	*In emergency situations, involuntary responses are crucial for immediate survival. For instance, the fight-or-flight response, controlled by the nervous system, increases heart rate and redirects blood to muscles without conscious control.* *Example: during a car accident, a person might involuntarily brace for impact (reflex)*	*Explains reflexes/autonomic actions in emergencies with an example (3 marks).* *Explains reflexes/autonomic actions in emergencies without example. (1 mark).*
Describes role of involuntary responses (with example) (2 marks)	*Voluntary responses are controlled by conscious thought (like running or calling for help). Voluntary responses allow a person to make deliberate decisions, such as moving away from danger or helping someone else.* *Example: In Emmanuel's case, if he was approaching an accident, he would voluntarily steer the car to safety.*	*If a student:* *Explanation of conscious decision-making with a real-life or relevant example. (2 marks)* *Explains conscious decision-making without real-life examples (1 mark)* *Providing only a real-life or relevant example. (½ mark)*
Evaluates importance of both types of responses (3 marks)	*Both types of responses are essential for survival. Involuntary reactions prepare the body instantly for danger, while voluntary actions enable individuals to make life-saving decisions. Their combined function significantly increases the chances of surviving emergencies*	*If a student:* *Compares or highlights their complementary roles in survival. (3 marks)* *Highlights the role of only response. (1 mark)*

(Total 8 marks)

WEEK 5

Explanation of the relationship between taste and smell. (3 marks)

Description of relationship between taste and smell. (2 marks)

E.g., Taste and smell are closely connected because both senses work together to create a full experience of flavour.

Explains how smell enhances flavour perception beyond the basic tastes. (1 mark)

E.g., The tongue can detect basic tastes such as sweet, salty, sour, bitter, and umami. It is the sense of smell that allows us to identify more complex flavours such as chocolate, spices, or fruit. Without smell, food tastes much less flavourful.

Description of what happens when smell is blocked (e.g., with a nose peg) (5 marks)

States that blocking smell reduces input to the brain. (1 mark)

E.g., When the nose is blocked, such as by using a nose peg, the olfactory receptors cannot detect smells

Explains that flavour perception is weakened or altered. (2 marks)

E.g. the brain receives less sensory input about the food's aroma, and the overall flavour is perceived as weaker or different. Foods may taste bland or hard to identify because the smell component is missing.

Uses correct scientific terms. (2 marks)

E.g., olfactory receptors and flavour

Scientific explanation of sensory interaction (e.g., olfactory receptors, brain) (6 marks)

Describes the role of both taste and smell in flavour perception. (3 marks)

E.g., The brain creates the experience of flavour by combining signals from both the taste buds on the tongue and the olfactory receptors in the nose. While the taste buds detect basic tastes such as sweet or salty, the olfactory receptors send information about the food's aroma.

Explains that the brain integrates both signals to produce a unified experience. (3 marks)

E.g., These inputs are processed together in the brain, especially in areas like the gustatory cortex and olfactory bulb, to form a complete flavour perception.

Use of relevant examples or evidence (e.g., personal observation or known foods) (2 marks)

Gives a real-life example (having a cold or using a nose peg). (2 marks)

E.g., when someone has a cold and their nose is blocked, they often say that food tastes bland.

Supports the idea with specific observations (e.g., distinguishing apple from avocado). (4 marks)

E.g., A personal observation is that when I eat a fruit like an apple while wearing a nose peg, I can tell it's sweet, but I can't identify whether it's an apple or a pear because I can't smell the fruity aroma. This shows how important smell is in recognising flavours.

(Total 20 marks)

WEEK 6

Question 1

Scoring rubric and marking scheme

When Fatima heard the screech of car tires and saw the motorcycle approaching, her body initiated a reflex action to protect her from harm. The sequence of events in her reflex arc can be analysed as follows:

a. **Stimulus** ***(3 marks)***

3 marks	2 marks	1 mark
Identifies the stimulus (sound and sight of danger) and receptors. *E.g. The loud screeching of tires and the sight of the speeding motorcycle acted as stimuli. These signals were detected by receptors in her ears and eyes, alerting her to danger.*	*Identifies the stimulus (sound and sight of danger) and one of the receptors.* *E.g. The loud screeching of tires and the sight of the speeding motorcycle acted as stimuli. These signals were detected by receptors in her eyes, alerting her to danger.*	*Identifies the stimulus (sound and sight of danger) without receptors. E.g. The loud screeching of tires and the sight of the speeding motorcycle acted as stimuli*

b. **Sensory Neuron** ***(3 marks)***

3 marks	2 marks	1 mark
Describes function of sensory neuron and path to CNS. *E.g. sensory neurons carry electrical signals from sensory receptors such as those in the ears detecting sound to the spinal cord, initiating the reflex pathway*		*Describes only function of sensory neuron to CNS.* *E.g. sensory neurons carry electrical signals from sensory receptors*

c. **Interneuron (Relay Neuron)** ***(3 marks)***

3 marks	2 marks	1 mark
Describes the role of interneuron in CNS, fast processing, bypassing brain. (3 marks) *E.g. the interneuron (relay neuron) is located in the spinal cord, where it processes the incoming signal from the sensory neuron and relays it to the motor neuron, allowing for a rapid, reflexive response without requiring input from the brain.*		*Identifies the role of interneuron in CNS, fast processing, bypassing brain. (1 mark)* *E.g. the interneuron (relay neuron) is located in the spinal cord, where it processes the incoming signal from the sensory neuron and relays it to the motor neuron*

d. Motor Neuron ***(3 marks)***

3 marks	2 marks	1 mark
Describe the path and action of motor neuron to muscles. *E.g. The motor neuron carries impulses from the spinal cord to the effector (usually a muscle), which then responds by producing a movement such as Fatima stepping away from danger.*	*Describe the path of motor neuron to muscles.* *E.g. The motor neuron carries impulses from the spinal cord to the effector (usually a muscle).*	*States the path of motor neuron to muscles.* *E.g. The motor neuron carries impulses to the muscles.*

e. Effector (Muscle) ***(3 marks)***

3 marks	2 marks	1 mark
States which effector muscles acted and describes the response. *E.g. the effector, such as the leg muscles, and explains that it receives impulses from the motor neuron and carries out the appropriate response—for example, contracting making Fatima jump and move Fatima away from danger.*	*States which effector muscles acted and the response.* *E.g. the effector, such as the leg muscles receives impulses from the motor neuron and responds to move Fatima away from danger.*	*States which effector muscles acted without describing the response.* *E.g. the effector, such as the leg muscles, it receives impulses from the* *motor neuron.*

(Total 15 marks)

Question 2

Marking scheme and scoring rubric

a. Identification of reflex response (3 marks)

Explaining the nature of a reflex action (3 mark)

E.g., the nature of a reflex action as involuntary (1 mark), rapid (1 mark), and processed via the spinal cord without conscious thought (1 mark).

b. Description of voluntary action. (3 marks)

Describes a voluntary action (3 mark)

E.g. Fatima might have taken (e.g., looking for a safe path, stopping and assessing the

situation) (1 mark), noting that it is slower (1 mark) and involves conscious decision-making via the brain (1 mark).

c. Comparison (contrast/similarities) (4 marks)

4 marks	2 marks	1 mark
Compares the two types of actions, noting any four key differences (e.g., speed, control, neural pathway) and similarities (both aim to ensure safety).	*Compares the two types of actions, noting any two key differences (e.g., speed, control, neural pathway)*	*Compares the two types of actions, noting any 1 key differences (e.g., speed, control or neural pathway)*

(Total 10 marks)

WEEK 7

Question 1

Mark scheme and scoring rubric

Title (1 mark)

Award 1 mark for title

E.g., A well- labelled diagram of Synaptic Transmission

Diagram layout and structure (2 marks)

Award ½ mark for any 4 parts

E.g., Diagram representing the synapse between two neurons, showing the pre-synaptic

terminal, synaptic cleft, and post-synaptic membrane.

Correct labels (3 marks)

Award ½ mark for any 6

E.g., Labels such as: Pre-synaptic neuron. Synaptic vesicles, Synaptic cleft, Neurotransmitters, Receptors, Post-synaptic membrane/neuron

Direction of transmission. (2 marks)

Award 1 mark for any 2

E.g., Arrows correctly indicate the direction of:

a. Nerve impulse in pre-synaptic neuron

b. Neurotransmitter release across synaptic cleft

Functional explanation (4 marks)

i. Describes how neurotransmitters are released and bind to receptors (2 marks)

E.g**.,** Action Potential Arrival
The process begins when an action potential (an electrical signal) travels down the axon of a presynaptic neuron and reaches the axon terminal.

Describes how ion channels open to generate action potential in the post-synaptic neuron (2 marks)

E.g., Neurotransmitter Binding
When neurotransmitters released from the presynaptic neuron reach the post-synaptic membrane, they bind to specific receptors located on ligand-gated ion channels.

(Total 9 marks)

Question 2

General role of Neurotransmitters (3 marks)

Definition of neurotransmitters and description of their role at the synapse. (3 marks)

E.g., Neurotransmitters are chemical messengers that transmit signals across a synapse from one neuron (the presynaptic neuron) to another (the postsynaptic neuron). An action potential reaches the presynaptic terminal; it triggers the opening of voltage-gated calcium (Ca^{2+}) channels. Calcium ions enter the neuron and cause synaptic vesicles to release neurotransmitters into the synaptic cleft by exocytosis.

Excitatory neurotransmitters (4 marks)

Description of increasing action potential likelihood (2 marks)

E.g., The likelihood of an action potential increases when excitatory neurotransmitters (e.g., glutamate) bind to ligand-gated ion channels on the post-synaptic membrane. This causes sodium (Na^+) ions to enter the neuron, leading to depolarization.

Description of mechanism (depolarisation/Na^+ influx) (2 marks)

E.g., If this depolarisation reaches the threshold potential, it triggers an action potential. The more excitatory signals a neuron receives, the greater the chance it will reach this threshold and fire.

3.Inhibitory neurotransmitters (4 marks)

Description for decreasing action potential likelihood (2 marks)

E.g., The likelihood of an action potential decreases when inhibitory neurotransmitters (e.g., GABA) bind to ligand-gated ion channels on the post-synaptic membrane. This opens channels that allow chloride ions (Cl^-) to enter or potassium ions (K^+) to exit the neuron, causing hyperpolarisation.

Description for mechanism (hyperpolarisation/Cl^- or K^+ channels) (2 marks)

E.g., Hyperpolarisation makes the inside of the neuron more negative, moving it further from the threshold potential, and therefore reduces the chance of an action potential occurring.

(Total 11 marks)

SECTION 4: MOVEMENT OF VARIOUS PARTS OF THE HUMAN BODY

STRAND: PROCESSES FOR LIVING

Sub-Strand: Essentials for survival

Learning Outcome: *Demonstrate how movement occurs in parts of the human body*

Content Standard: *Develop an understanding of the relationships between bones, skeleton and muscles and the principles underlying the movement of various parts of the human body.*

INTRODUCTION AND SECTION SUMMARY

The human body relies on the skeleton and muscles to provide structure, support, and movement. In this section, learners will model and discuss the structure of the human skeleton and its connection with muscles to form the musculoskeletal system. They will also demonstrate and explain how different types of muscle tissues; skeletal, smooth, and cardiac—are structured and how they function to produce movement. Through observation, modelling, and discussion, learners will gain a deeper understanding of how muscles and bones work together to enable motion, maintain posture, and protect internal organs.

By the end of this section, learners should be able to model the skeletal and muscular structures, describe the types and roles of muscle tissues, and explain how muscle contractions cause body movements.

The weeks and the indicators covered by the section are:

Week 8: Model and discuss the structure of the skeleton and muscles

Week 9: Demonstrate and explain the structure and function of the movement of muscle tissues.

SUMMARY OF Pedagogical Exemplars

This summary highlights effective, learner-centred strategies for teaching the structure and function of the skeletal and muscular systems. Teachers guide learners through collaborative learning, demonstrations, and project-based tasks using visual and kinaesthetic tools.

In mixed-ability groups, learners explore skeletal models, videos, and diagrams to identify bones, joints, and muscles, and their functions in support, protection, and movement. Through simulations and multimedia, they investigate types of skeletons (exo-, endo-, and hydrostatic), the mammalian skeleton, and the vertebrae. Learners engage with anatomical charts and kinaesthetic activities to distinguish between skeletal, smooth, and cardiac muscles, experiencing their function first-hand.

Joint structure and movement are explored through models and group tasks, identifying components like cartilage, ligaments, and synovial fluid. Project-based learning encourages independent research and peer teaching.

By the end, learners should explore key structures, understand their roles, and be able to apply, model, and communicate their learning effectively.

ASSESSMENT SUMMARY

Learners will be assessed on their in-depth understanding of the skeletal and muscular systems through tasks that require extended critical thinking and reasoning. To model and discuss the structure of the skeleton and muscles (DOK Level 4), learners will complete homework assignments that involve constructing accurate models or diagrams and providing detailed explanations of each component's role. For the task to demonstrate and explain the structure and function of the movement of muscle tissues (also DOK Level 4), learners will engage in group project work.

This will require them to apply theoretical knowledge, communicate scientific concepts effectively, and reflect on how muscles coordinate to enable movement.

Indicators	DOK Level	*Assessment Strategy and/or Mode*
Model and discuss the structure of the skeleton and muscles	Key Assessment Level 4: Extended critical thinking and reasoning	Homework
Demonstrate and explain the structure and function of the movement of muscle tissues.	Key Assessment Level 4: Extended critical thinking and reasoning	Group project work

WEEK 8

Learning Indicator: *Model and discuss the structure of the skeleton and muscles*

Focal Area: Skeletal system

Skeletal material

The main types of skeletal materials of animal's skeleton are chitin, cartilage and bone.

Chitin: It is a tough, light, flexible material, and the major component of the skeleton of arthropods. Chitin is a carbohydrate that has a structural role similar to cellulose. It is strengthened by deposits of hardened proteins and minerals.

Cartilage

It consists of living cells (chondroblasts), carbohydrates and proteins fibres. It is a tough and flexible tissue that has great tensile strength. It acts as a shock absorber cushioning the effects of bones moving against bones when moved. Cartilage forms the entire system of sharks, rays and foetus.

There are three types of cartilage, hyaline cartilage, fibro-cartilage and elastic cartilage. Cartilage occurs in the ear, discs between (vertebrae) of the vertebral column, trachea, bronchi, epiglottis and the Eustachian tube.

Cartilage does not have its own blood supply vessels but depends on the oxygen and nutrients that diffuse across nearby tissues.

It is the harder part of an animal that forms the framework for protection and support of the body.

Types Of Skeletons

The main types of skeletons in animals are the:

- Endoskeleton
- Exoskeleton
- Hydrostatic Skeleton

1. Endoskeleton

The endoskeleton is an internal support structure found in all vertebrates. It is primarily composed of bones, except in some primitive vertebrates like cartilaginous fishes (e.g., sharks and rays), where the skeleton is made entirely of cartilage.

Bones are living, dynamic tissues that constantly undergo remodelling. Their hardness and strength come mainly from the presence of calcium salts, especially calcium phosphate. These minerals make bones rigid and capable of supporting body weight.

Where two bones meet, such as in the hip, knee, or elbow joints—their contacting surfaces are covered with a smooth, slightly flexible tissue called cartilage (also known as gristle). Cartilage is less rigid than bone and serves to:

a. Reduce friction between bones during movement

b. Act as a shock absorber to prevent damage from impact

c. In mammals, cartilage is also found in:

- The external ear
- The nose
- The respiratory tract
- The foetal skeleton (which is later largely replaced by bone during development)

Examples of vertebrates with endoskeletons include cows, rats, humans, rabbits, snakes, bats, fishes, lizards, and birds.

2. Exoskeleton

An exoskeleton is a hard, external covering that protects and supports the bodies of invertebrates, particularly arthropods. It is mainly composed of chitin, a tough, flexible polysaccharide that resembles cellulose. As exoskeletons are rigid and non-expandable, animals with this type of skeleton must periodically moult or shed their exoskeleton in a process called ecdysis in order to grow. Examples of animals with exoskeletons include:

Spiders, crabs, lobsters, millipedes, centipedes, houseflies, cockroaches, butterflies, and beetles.

3. Hydrostatic Skeleton

A hydrostatic skeleton is a structure found in soft-bodied invertebrates that relies on the pressure of internal fluid to maintain shape and enable movement. It consists of a fluid-filled cavity surrounded by muscles. When muscles contract around the cavity, the incompressible fluid inside provides rigidity and support, allowing the animal to move or maintain its form.

Examples of animals with hydrostatic skeletons include earthworms, maggots, jellyfish, and sea anemones.

Functions of the Mammalian Skeleton

1. Provides a structural framework: It gives the body its basic shape and structure.
2. Maintains body shape: It helps to define the physical form and posture.
3. Supports the body: It holds up the body and keeps it upright.
4. Protects vital organs: The skull protects the brain, the ribcage shields the heart and lungs, and the vertebrae protect the spinal cord.
5. Provides surfaces for muscle attachment: Bones have projections and ridges (called facets) where muscles attach to facilitate movement.
6. Acts as a system of levers for movement: Bones, in combination with muscles and joints, allow for complex movement.
7. Site of blood cell formation: The bone marrow, found in the central cavities of certain bones, produces red blood cells, white blood cells, and platelets (a process called haematopoiesis).
8. Stores minerals: Bones serve as reservoirs for important minerals, particularly calcium and phosphorus, which can be released into the bloodstream when needed.

Structure and Composition of Bone

Bone is a living connective tissue made up of both organic and inorganic components, giving it a unique combination of strength, rigidity, and lightness. It consists of Living bone cells known as osteocytes, protein fibres, primarily collagen, which provide flexibility and tensile strength and mineral salts, mainly calcium phosphate and calcium carbonate, which provide hardness and rigidity. Approximately two-thirds of the bone mass is made up of inorganic mineral salts (non-living), while one-third consists of organic materials (living cells and protein fibres). Unlike cartilage, bone has its own blood supply, which allows for active nourishment, growth, and repair. This vascularisation makes bone a dynamic tissue that can remodel and heal when damaged.

Ossification (Bone Formation)

The process of ossification refers to the development of bone tissue and the deposition of minerals, such as calcium phosphate and calcium carbonate, into a tissue matrix, replacing cartilage or fibrous tissue to form hardened bone. Ossification occurs during foetal development, growth in children and adolescents, fracture healing and throughout life as part of bone remodelling.

There are two types of ossification: Intramembranous ossification and Endochondral ossification

Intramembranous ossification: where bone develops directly from mesenchymal (embryonic connective) tissue, e.g., in flat bones of the skull.

Endochondral ossification: where bone forms by replacing cartilage (e.g., in long bones like the femur)

Structure of a Long Bone

A long bone (such as the femur or humerus) has both compact and spongy regions:

Compact Bone are found in the hard outer shaft (diaphysis). It is dense and strong, and contains Haversian systems (osteons), which are structural units made of concentric rings of bone matrix (lamellae) arranged around Haversian canals. Osteocytes (bone cells) are found in small spaces called lacunae. Canaliculi (tiny channels) connect lacunae, allowing nutrients and waste to pass between osteocytes and nearby capillaries.

Spongy Bone (Cancellous Bone) is found in the expanded ends of the bone (epiphyses). It as a honeycomb-like structure with numerous bony struts called trabeculae. It contains red bone marrow within its spaces, which produces blood cells. Despite its porous appearance, it is well-adapted to withstand compressive forces.

Bone Marrow: The medullary cavity in the shaft contains yellow marrow, composed mostly of fat. The spongy bone in the epiphyses contains red marrow, active in blood cell production (haematopoiesis).

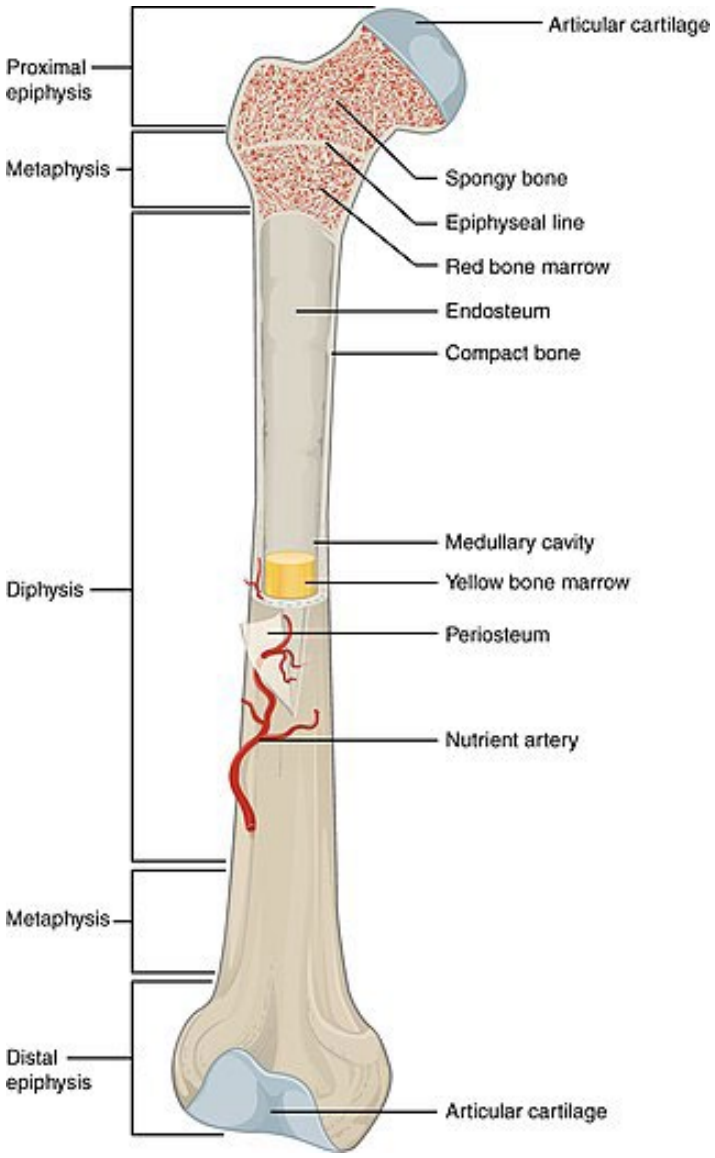


Figure 4.0: *Long bone*

Adaptation of Bone Structure: The design of bones makes them:

1. Strong yet lightweight, ideal for mobility and support
2. Capable of withstanding stress and pressure, especially through the strategic arrangement of trabeculae in spongy bone to resist compression forces
3. Efficient in nutrient and waste exchange via vascular and neural access through bone canals and pores

Parts of the mammalian skeleton

The mammalian skeleton consists of the following major parts.

1. The skull
2. The vertebral column.
3. The limbs and limb girdles.

The human skeleton

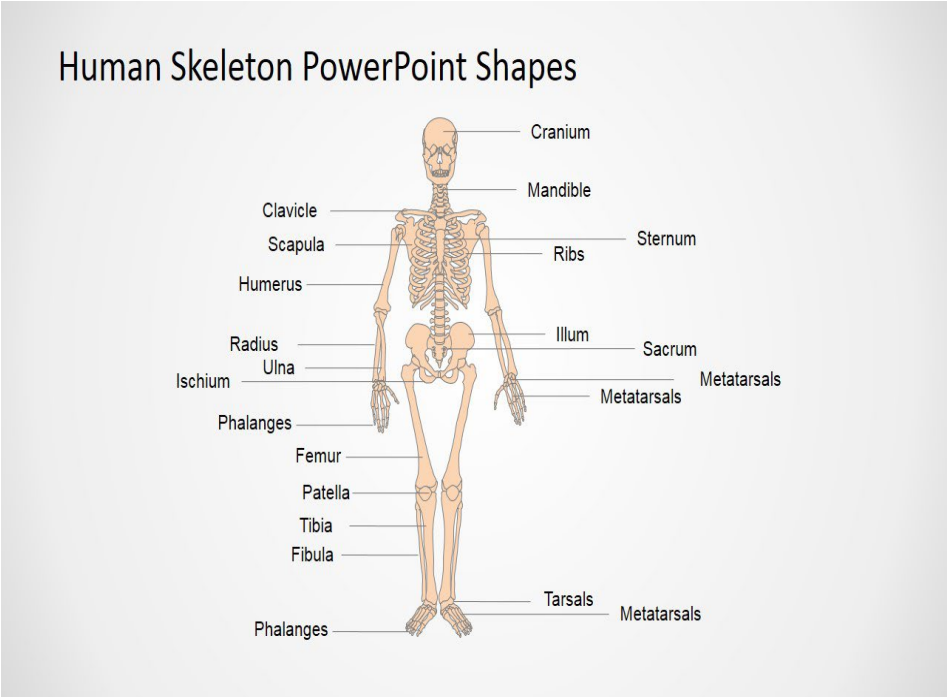


Figure 4.1: *A well labelled diagram of the human skeleton*

The mammalian skeleton is the internal framework that supports the body, facilitates movement, and protects vital organs. It can be divided into two main parts:

- Axial Skeleton
- Appendicular Skeleton

1. **Axial Skeleton**

The axial skeleton forms the central axis of the body and consists of the following parts:

a. **Skull**

The skull protects the brain and forms the structure of the face and head. The cranium (braincase) is made up of several flattened, thick bones that are fused together by immovable joints called sutures. The upper (maxilla) and lower (mandible) jaw bones are part of the skull. The lower jaw is movable and is responsible for chewing and biting food. The skull also includes facial bones and cavities called orbits that house and protect the eyes, as well as structures that protect the ears and nose.

b. **Vertebral Column (Backbone or Spine)**

The vertebral column runs along the dorsal (back) side of the mammal. It extends from the base of the skull to the pelvis (sacrum) in humans and to the caudal vertebrae in mammals with tails. It is composed of individual bones called vertebrae, which are joined end to end to form a flexible, protective tube for the spinal cord. Between each pair of vertebrae are intervertebral discs made of cartilage and fibrous tissue. These act as shock absorbers and allow flexibility and movement. The vertebral column provides support for the body, attachment for muscles, and protection for the spinal cord.

There are five main regions of vertebrae in most mammals, though the number of vertebrae in each region may vary among species. These bones are involved in locomotion, manipulation, grasping, and supporting the body during movement.

Main Groups of Vertebrae	No. of bones	Location
1) Cervical vertebrae	7	Neck region
2) Thoracic vertebrae	12	Chest/thoracic region
3) Lumbar	5	Abdominal region
4) Sacral vertebrae	5	Lower abdominal or hip region
5) Caudal Vertebrae	4	The tail region few in humans (form the **coccyx**) but more numerous in tailed mammals

c. **Ribs and Sternum (Breastbone)**

Ribs are curved bones attached at the back to the thoracic vertebrae and at the front (directly or indirectly) to the sternum.

The rib cage encloses and protects vital organs like the heart and lungs.

There are typically 12 pairs of ribs in humans:

1. True ribs (first 7 pairs) connect directly to the sternum via costal cartilage.
2. False ribs (next 3 pairs) connect indirectly to the sternum.
3. Floating ribs (last 2 pairs) are not attached to the sternum.

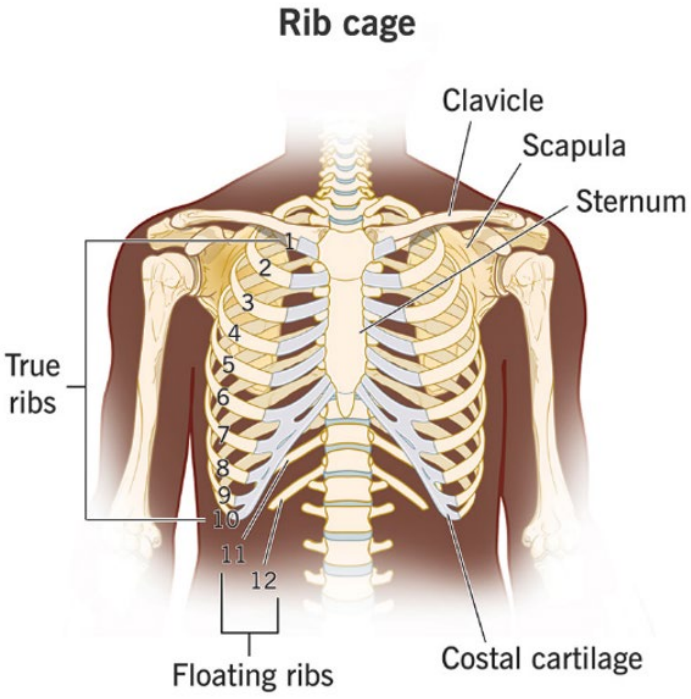


Figure.4.2: *Ribcage*

2. Appendicular Skeleton

The appendicular skeleton consists of the bones of the limbs and their associated girdles (shoulder and pelvic girdles), which attach the limbs to the axial skeleton.

a. **Limb Girdles**

Pectoral (Shoulder) Girdle: Composed of the scapula (shoulder blade) and clavicle (collarbone). Connects the forelimbs (arms) to the axial skeleton.

b. **Pelvic (Hip) Girdle**

Formed by the fusion of three bones: ilium, ischium, and pubis.

Connects the hindlimbs (legs) to the vertebral column.

c. **Limbs**

Each limb has three main sections

1. Upper segment (e.g., humerus in the arm, femur in the leg)
2. Lower segment, e.g., radius and ulna in the arm; tibia and fibula in the leg
3. Terminal segment, (e.g., hands and feet, including wrist/ankle bones, metacarpals/metatarsals, and phalanges or fingers/toes.

General Characteristics of the Vertebrae

All five groups of vertebrae have the following features in common

1. Centrum
2. Neural arch
3. Neural spine
4. Neural canal
5. Transverse processes
6. Anterior facets (prezygapophyses)
7. Posterior facets (postzygpophyses)

General Structure of a Vertebra

Each vertebra consists of several key parts that support and protect the spinal cord and allow movement and attachment of muscles:

1. **Centrum (Body)**
   The solid, cylindrical centrum forms the main body of the vertebra. It bears weight, provides structural support, and serves as the point of articulation with adjacent vertebrae via intervertebral discs. It also carries the neural arch and the neural spine.
2. **Neural Arch**
   This bony arch extends from the back of the centrum and, together with the centrum, encloses the neural (vertebral) canal. The neural arch forms the roof of the neural canal, which houses and protects the spinal cord from mechanical injury.

3. **Neural Spine (Spinous Process)**
   The neural spine projects upward (or backward in upright posture) from the neural arch. It provides a large surface area for the attachment of muscles and ligaments that support the spine and allow movement.
4. **Transverse Processes**
   These are paired lateral projections from the junction of the neural arch and centrum. They also serve as sites for muscle and ligament attachment**,** and in some vertebrae, articulate with ribs.
5. **Facets (Articular Processes)**
   Facets are smooth-surfaced projections that extend from the neural arch. They are arranged in anterior (superior) and posterior (inferior) pairs and articulate with adjacent vertebrae, forming synovial joints that permit controlled movement of the spine.
6. **Neural Canal (Vertebral Foramen)**
   This is the central hollow channel formed by the neural arch and centrum. It runs through all vertebrae and houses and protects the spinal cord.

Cervical Vertebrae (Neck Region)

Mammals, including humans, rabbits, and rats, have seven cervical vertebrae located in the neck region, regardless of the overall size of the animal.

Specialised Cervical Vertebrae

Atlas (C_1): The first cervical vertebra, located just beneath the skull. It lacks a centrum and has a ring-like structure with large articular facets that articulate with the occipital condyles of the skull. This joint allows nodding movements of the head (up and down motion, as in "yes").

Axis (C_2): The second cervical vertebra. It has a peg-like projection called the odontoid process (or dens), which projects upward into the ring of the atlas. This structure forms a pivot joint, allowing rotational movement of the head from side to side (as in "no").

The odontoid process fits into a groove on the ventral side of the atlas, stabilised by ligaments to allow safe rotation.

Distinguishing Features of Cervical Vertebrae

1. All cervical vertebrae have a vertebroarterial canal (also called transverse foramina) on each side of the transverse process.
   These allow passage of the vertebral arteries and veins, which supply blood to the brain.
2. The cervical vertebrae are generally smaller and lighter than thoracic or lumbar vertebrae.
3. They allow for a wide range of head and neck movements due to their flexibility and specialised structure.

Functions of Cervical Vertebrae

1. Support the head and allow its movement.
2. Protect the spinal cord, blood vessels, and nerves in the neck region.
3. Provide attachment surfaces for neck muscles that control head posture and movement.

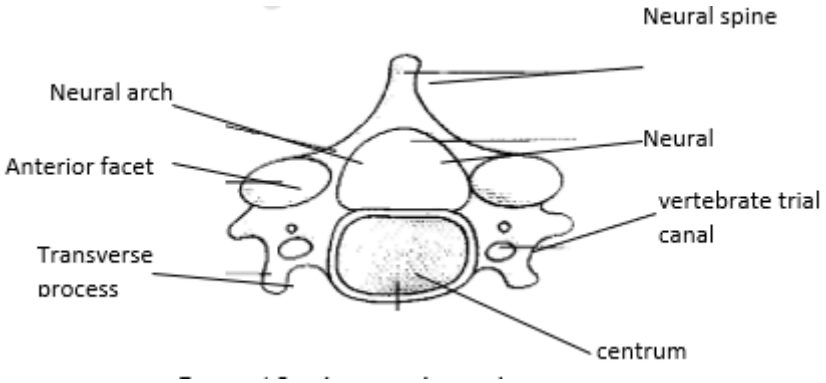


Figure.4.3a: *A general vertebra*

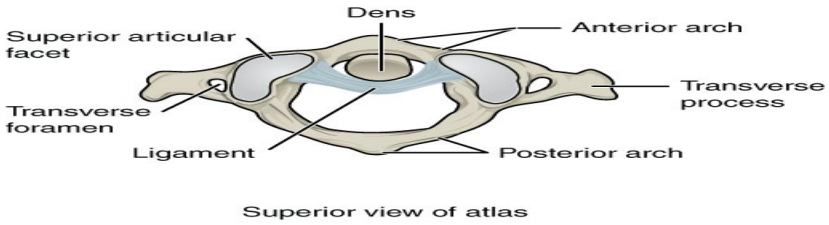


Figure. 4.3b: *A well labelled diagram of axis vertebra*

Atlas vertebra

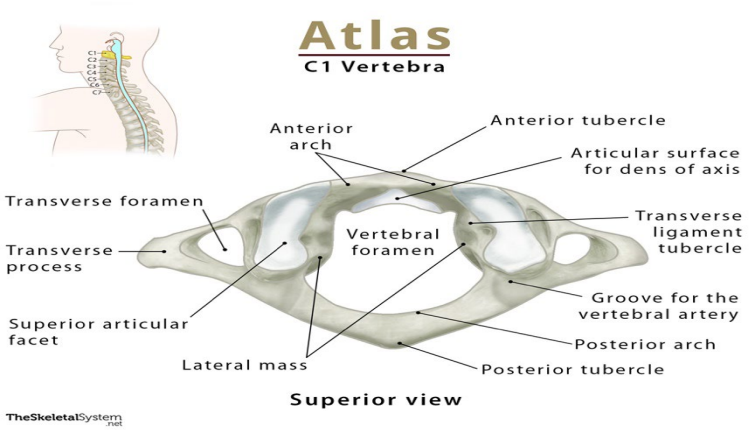


Figure.4.4: *A well labelled diagram of Atlas vertebra*

Thoracic Vertebrae

The thoracic vertebrae are located in the thoracic (chest) region of the vertebral column. They form the central part of the rib cage and play a crucial role in supporting the upper body and protecting internal organs such as the heart and lungs. In humans and rabbits, there are typically twelve (12) thoracic vertebrae. In rats, there are thirteen (13) thoracic vertebrae.

Each thoracic vertebra articulates with a pair of ribs, contributing to the formation of the thoracic cage or ribcage**.** These vertebrae are more robust than cervical vertebrae due to their role in bearing more weight and providing attachment for ribs and muscles.

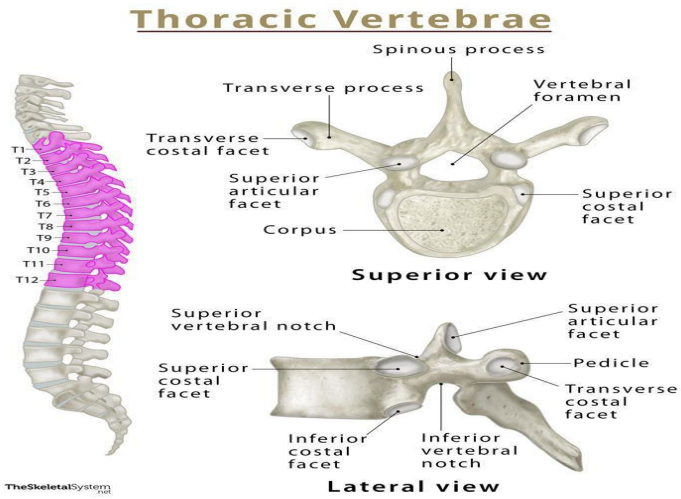


Figure.4.5: *Thoracic vertebrae*

Distinctive Features of Thoracic Vertebrae

1. **Long Neural Spine**
   The neural (spinous) process is long and points downward and backward, providing a large surface area for the attachment of thoracic muscles and ligaments.
2. **Facets for Articulation with Ribs**
   a. Each thoracic vertebra has two sets of facets
      i. Capitular (costal) facets on the centrum for articulation with the head (capitulum) of the rib.
      ii. Tubercular facets on the transverse processes for articulation with the tubercle of the rib.
   b. These articulations form synovial joints that allow limited movement of the ribs during breathing.
3. **Short Transverse Processes**
   The transverse processes are relatively short and stout, but they bear the tubercular facets for rib attachment.
4. **Heart-shaped Centrum**
   The centra (bodies) of thoracic vertebrae are larger and heart-shaped, increasing in size from T_1 to T_{12} to bear more weight from above.

Functions of Thoracic Vertebrae

1. **Support and Stability**
   The thoracic vertebrae provide strong support for the upper body, including the head, neck, shoulders, and arms.
2. **Protection**
   By forming the posterior part of the rib cage, the thoracic vertebrae help protect vital organs, such as the lungs and heart.
3. **Articulation with Ribs**
   Their structure allows the attachment of ribs, enabling the formation of the thoracic cage necessary for respiration.

SECTION 4: MOVEMENT OF VARIOUS PARTS OF THE HUMAN BODY

4. **Muscle Attachment**
   The long neural spines and transverse processes serve as anchoring points for back, shoulder, and thoracic muscles, facilitating posture and upper body movement.
5. **Facilitate Breathing**
   The slight mobility at the rib-vertebrae joints allows for expansion and contraction of the rib cage during inhalation and exhalation.

Lumbar Vertebrae

The lumbar vertebrae are located in the lower back or upper abdominal region, between the thoracic vertebrae and the sacrum. There are five (5) lumbar vertebrae in humans, seven (7) in rabbits, and six (6) in rats.

Features Lumbar Vertebrae

1. Large, thick centrum with broad facets for muscle attachment and support.
2. Long, flattened transverse processes, which serve as surfaces for attachment of strong back and abdominal muscles.
3. May have an extra accessory process, which also serves as a point for muscle attachment.

Functions

1. The large, thick centrum helps to support the upper half of the body, especially the trunk.
2. The broad facets and transverse processes provide ample surface area for muscle attachment, aiding in posture and movement.
3. Lumbar vertebrae absorb stress and shock from activities like walking, lifting, and twisting.

Sacral Vertebrae

There are five (5) sacral vertebrae in humans. These bones are fused together to form a single triangular bone known as the sacrum.

Functions

1. The sacrum articulates with the pelvic girdle at the sacroiliac joints, providing a strong, stable connection between the spine and the pelvis.
2. It helps to transmit the weight of the upper body to the lower limbs.
3. It forms the posterior wall of the pelvic cavity, protecting pelvic organs.

Caudal Vertebrae (Coccyx in Humans)

In humans, there are four (4) caudal vertebrae, which are fused to form the coccyx or tailbone.

Functions

1. The coccyx serves as an attachment point for ligaments and muscles of the pelvic floor.
2. In mammals with tails, the neural spine of the caudal vertebrae provides support for tail movement and muscle attachment.

Appendicular Skeleton

The appendicular skeleton includes the limbs and limb girdles. It is responsible for movement, support, and interaction with the environment. The main components are pectoral (shoulder) girdle, pelvic (hip) girdle and limbs (forelimbs and hindlimbs).

Each side consists of scapula (shoulder blade), clavicle (collar bone) and in some animals, a coracoid bone is present. The scapula provides a broad surface for muscle attachment and contains the glenoid cavity, a shallow socket that articulates with the head of the humerus to form the shoulder joint. The clavicle acts as a strut to stabilise the shoulder and allow free movement of the arm.

Pelvic Girdle (Hip Girdle)

The pelvic girdle is made up of two fused halves, joined at the front by the pubic symphysis. Each half consists of the Ilium, Ischium and Pubis. These bones encircle a large opening called the obturator foramen, through which nerves and blood vessels pass.

Function of the pelvic girdle

1. Supports the weight of the body.
2. Protects internal organs, especially the female reproductive system.
3. Articulates with the sacrum and the head of the femur at the acetabulum to form the hip joint.

Ribs

Humans have 12 pairs of ribs. The first 9 pairs are true ribs: their ventral ends are connected to the sternum by costal cartilage. The last 3 pairs are false ribs: The 10th pair may connect indirectly to the sternum. The 11th and 12th pairs are floating ribs, as they do not connect to the sternum at all.

Function

The ribs form the rib cage, which protects vital organs like the heart and lungs and aids in respiration.

Limbs

Mammals have two pairs of limbs: forelimbs (upper limbs in humans) and hindlimbs (lower limbs in humans).

Forelimb (Upper Limb in Humans)

Divided into five major parts:

1. Humerus: A long bone of the upper arm, articulating with the scapula at the shoulder joint and the radius/ulna at the elbow.
2. Radius and Ulna: Two bones of the forearm. The ulna is usually longer and forms the hinge joint at the elbow. The radius allows for rotation of the forearm (pronation and supination).
3. Carpals: Eight to nine small bones forming the wrist. They articulate with the radius/ulna above and metacarpals below.
4. Metacarpals: Five long bones forming the palm of the hand. They articulate with the carpals and the phalanges.

5. Phalanges (Digits): Bones of the fingers. The thumb (first digit) has two phalanges, while the other four digits each have three. Each phalanx may end in a nail or claw, depending on the species.

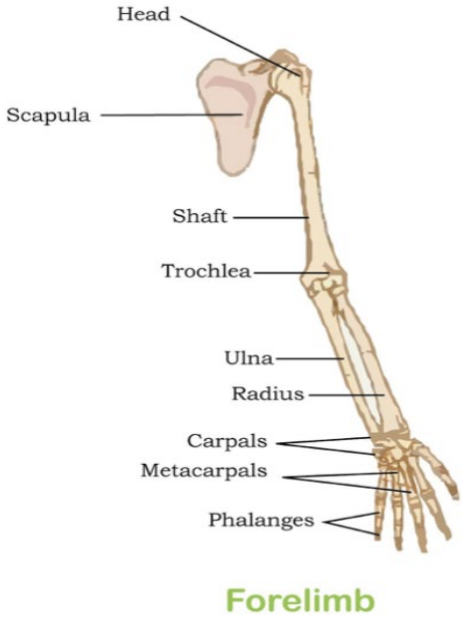


Figure. 4.6: *A well labelled diagram of fore limb*

Each hind limb is divided into five (5) regions namely:

1. Femur: long, single bone in the thigh of the hind limb. Articulates with the acetabulum of the pelvic girdle to form the ball and socket joint at the hip.
2. Tibia and fibula – these two bones make up the shank of the hind limb. The tibia is longer than the fibula. In most mammals the lower end of the Tibia and fibula are fused together while the upper end of the fibula is free.
3. Tarsals – There are nine small irregular shaped bones which make up the bones of the ankle. The longer tarsals fit into the tibia and fibula to form the ankle joint. The tarsals also articulate with the metatarsals of the foot.
4. Metatarsals – five comparatively longer bones than the tarsals. They make up the bones of the foot. They articulate with the tarsals and the phalanges.
5. Phalanges or digits – These bones make up the toes. There are all five in humans.

The pentadactyl limb

The fore and hind limbs are built on a basic pentadactyl plan – which consists of five digits (fingers and toes) i.e., pentadactyl limb.

Learning tasks

1. Identify the types of skeletons.
2. Construct model or anatomical diagram of human skeleton and label it.
3. Analyse how skeleton support movement, protection, and survival across different species and environments.

Pedagogical Exemplars

1. Collaborative learning

In mixed ability groups, provide learners with skeletal models, video and anatomical diagrams to observe. Guide learners in identifying major bones, joints, and muscles, emphasising their support, movement, and protection roles.

2. Demonstration/Simulation

- Use posters, diagrams, or multimedia presentations to guide learners to explain the different types of skeletons, including exoskeletons, endoskeletons, and hydrostatic skeletons in their groups.
- Provide learners with colourful visuals and animations on the parts of the mammalian skeleton. In mixed ability groups, assign specific tasks on the main parts of the mammalian skeleton to each group to discuss and present their findings for a whole class discussion.
- Use multimedia presentations, animations, and videos to guide learners to discuss the characteristics of the Vertebrae and illustrate complex concepts.

Key Assessment Level 3: Homework

1. Construct a comprehensive comparative analysis of the three main types of skeletons. Your response should:
   - At least two examples of organisms for each type.
   - Description of the skeletal material involved.
   - Advantages and limitations of each type in terms of movement and protection.
   - How each supports survival in different habitats. **(24 marks)**
2. Critical evaluation of how improper chair/desk height, poor lumbar support, and slouched sitting posture strain the spine. **(3 marks)**

PLC Session 8

45 minutes | **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to
   a. explain the week's concepts in a practical way that will make it easier for learners to understand
   b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject specific app to plan your lesson. Ask the app to
   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
   b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
   c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).

Note

- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Plan the week's key assessment with your app
   a. The key assessment for the week is ***homework***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the homework (NTS 3k-3q).

10 minutes **Content Exploration**

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
   a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
   b. all teachers in the group work through a similar problem individually for 3–4 minutes
   c. the group then works through the problem together step by step
   d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).

Note

- *This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?*
- *If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.*
- *Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.*

30 minutes **Enactment**

6. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).
   a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
   b. After the enactment, ask for structured feedback from the group
      i. was the concept explained in a way that a learner with no prior knowledge could follow?
      ii. were the examples grounded in contexts familiar to Ghanaian learners?
      iii. did any misconceptions surface and if so, how were they addressed?

5 minutes **Reflection**

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).

8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
    a. transfer your chats into your learning planner template.
    b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
    c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 9

Learning Indicator: *Demonstrate and explain the structure and function of the movement of muscle tissues*

Focal Area: Structure and function of the movement of muscle tissues

Muscles

There are three types of muscles in the human body. These are:

1. Smooth
2. Skeletal
3. Cardiac

Smooth (Visceral) Muscle

They consist of long, spindle-shaped cells and each cell has a nucleus. Smooth muscle is found in the walls of the alimentary canal (gut), uterus blood vessels, and the excretory system. Activity of the smooth muscles is controlled by the involuntary (autonomic) nervous system and not the consciously. They fatigue relatively slowly.

Cardiac Muscles

They are found in the walls of the heart. Cardiac muscle has the ability to contract and relax rhythmically throughout life without becoming fatigued. It is myogenic i.e., contractions are initiated by the muscle itself and not the nervous system, but the nervous system can control the rate of these contractions.

The fibres are striated, and the bundles of the fibres are joined together by cross-connections, forming an interconnecting network. The fibres are divided into each cell containing one nucleus (uninucleate).

Skeletal Muscles

They are attached to two or more bones. Skeletal muscles are striated but the bundles of fibres are not interconnected, each fibre contains many nuclei. One end of the muscle (the origin) is always attached to movable bone e.g., the scapula, and the end insertion is attached to movable bone e.g. radius.

Skeletal muscles are controlled by the nervous system; their action is controlled at will and therefore they are called voluntary muscles. They can contract and relax to bring about movement, but they fatigue rapidly. The ends of skeletal muscles are extended to form tendons which attach muscles to bones. Muscle fibres have a lot of nuclei.

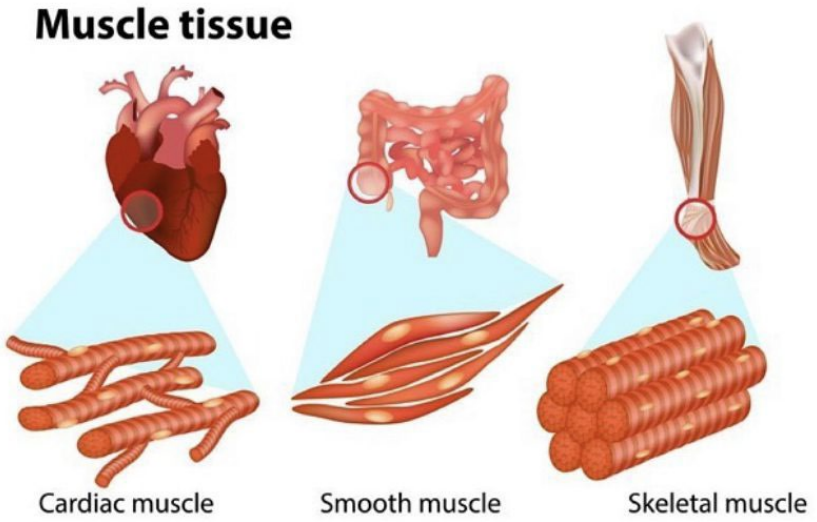


Figure. 4.7:*A diagram of muscle tissue*

Joints

Joints occur where two or more bones meet and may or may not allow movement. A joint may be movable or immovable.

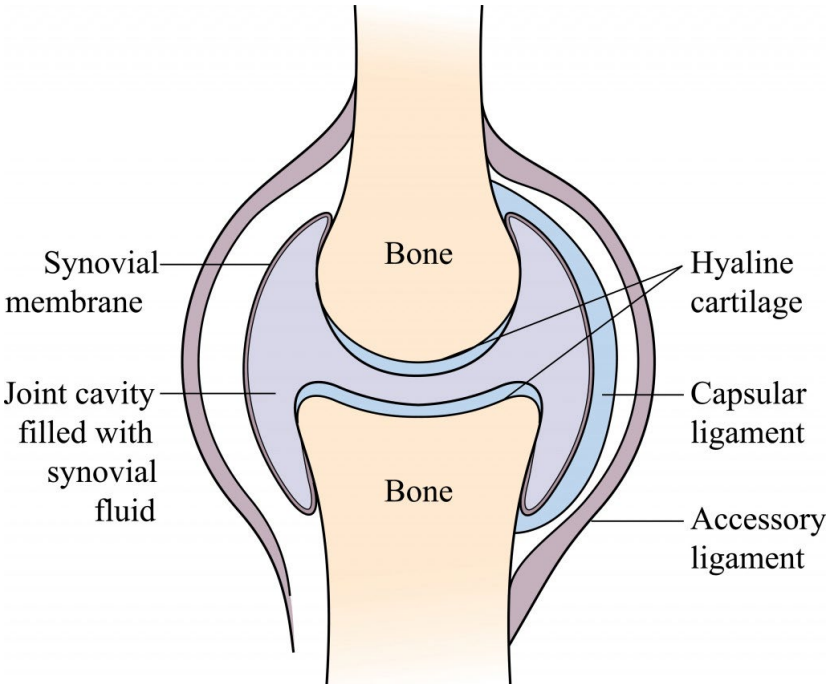


Figure. 4.8: *A well labelled diagram of Movable joints*

Movable joints allow movement of body parts. Movable joints are formed by bones which are not in direct contact with each other. The bones are held loosely together by ligaments and muscles. Movable joints are classified based on the degree of movement allowed. The various types of movable joints are ball and socket joint, hinge joint, gliding joint and pivot joint.

Ball and Socket Joint

They allow movement in more than one plane. Examples are the shoulder joint and the hip joint. They are called ball and socket joints because of the ball shaped end of the Humerus or Femur which fit into a socket end of the shoulder or pelvic girdle.

Hinge joint

The hinge joint allows movement in only one plane. Examples are the elbow joint and the knee joint. At the elbow, the forearm can be raised towards the shoulder in a hinge-like movement or a door on a hinge.

Gliding Joint

It allows bones to slide smoothly over each other. Examples are the bones in the wrist and ankle.

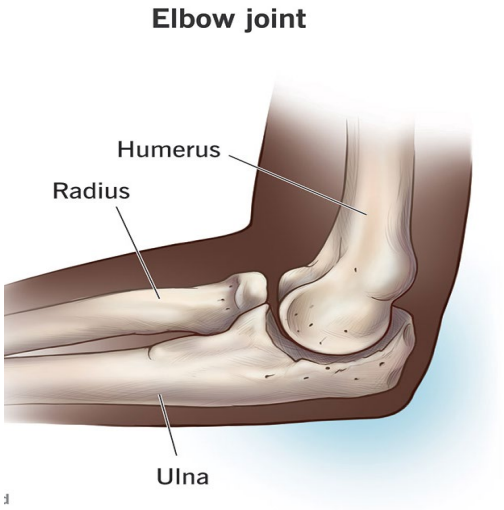


Figure. 4.9: *A well labelled diagram of elbow joint*

It allows bones to slide smoothly over each other. Examples are the bones in the wrist and ankle.

Pivot joint

It allows rotation of parts of the body (e.g., the head) on the other parts e.g. the joint between the atlas and axis vertebrae.

The bones at movable joint are held together by tough band of tissues called ligaments. The inner part of the ligament is lined by a lining called synovial membrane which produces a fluid called synovial fluid. The synovial fluid lubricates the bones, thereby enabling them to move over each other smoothly. Each joint bone has a cartilage at its ends which acts as a cushion to lessen the effect of shocks when the bones move against each other.

Immovable fixed joints

They are joints which do not allow any movements. The bones at the joints are in direct contact with each other are and firmly fused. For example, the joints in the skull (cranium) and the pelvic girdle.

Table 4.0: *Table of Immovable fixed joints*

Body part	Joint
Elbow	Hinge joint
Knee	Hinge joint
Hip	Ball and socket joint
Shoulder	Ball and socket joint
Ankle	Gliding joint
Wrist	Gliding joint
Cranium (skull)	Immovable joint

Movement of the Forelimb

The biceps muscle (also called the flexor) originates from the scapula (shoulder blade) and inserts on the radius, one of the two bones of the forearm. The triceps muscle (also known as the extensor) has its origins on the scapula and the posterior surface of the humerus, and its insertion is on the olecranon process of the ulna, the second bone of the forearm.

These two muscles work antagonistically meaning that when one contracts, the other relaxes. This coordinated action enables smooth and controlled movement of the forelimb.

When the biceps contract (under nervous stimulation), the triceps relax. This pulls the radius upward, bending the arm at the elbow (a movement called flexion).

When the triceps contract, the biceps relax. This pulls the ulna downward via the olecranon process, straightening the arm (a movement called extension). This antagonistic muscle action is essential for coordinated limb movement, allowing organisms to perform tasks such as lifting, pushing, pulling, and throwing. It also helps maintain **joint stability** and prevents sudden or jerky motions.

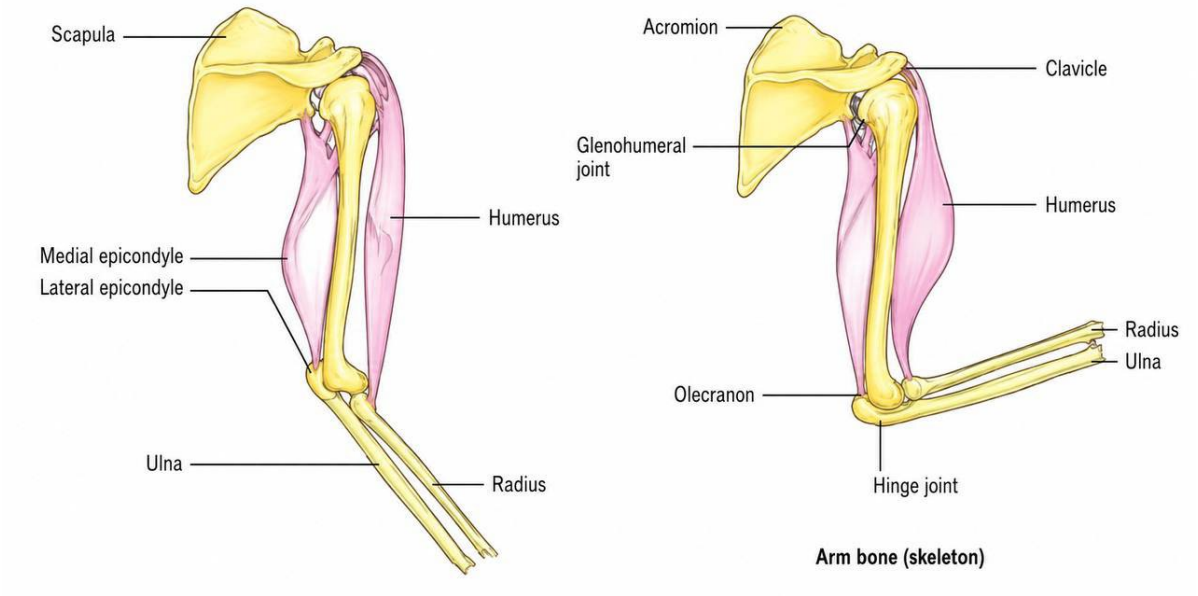


Figure 4.9.1: *Muscle movement*

Learning tasks

1. Explain how muscles and joints coordinate to produce limb movement
2. Analyse how joint structure is adapted to specific functions in the human body and evaluate how injury or disease can affect mobility.
3. Comparatively, analyse the different types of muscles (skeletal, smooth, and cardiac), including their structures and functions.

Pedagogical Exemplars

1. **Demonstration/Simulation**
   a. Provide learners with anatomical charts and models illustrating skeletal, smooth, and cardiac muscles, highlighting their distinct features and locations in the body.
   b. Guide learners through the identification and labelling of each muscle type, emphasising their structural differences and functional characteristics.
   c. Engage learners in kinaesthetic activities where they contract and relax their own muscles to experience the differences between skeletal, smooth, and cardiac muscle contractions.
   d. In mixed ability groups, provide learners with anatomical charts and models illustrating the structure and function of each type of joint.
   e. Allow learners to identify joint components, including bones, cartilage, ligaments, and synovial fluid, and discuss with learners how these structures facilitate movement.
2. **Project-based learning**
   Assign collaborative projects for learners in small groups to research on specific joints and the types of movement and present their findings to the class.

Key Assessment: Level 4: Group Project Work

Create a model using materials (e.g., rubber bands, cardboard, straws) to represent different joint types (hinge, ball-and-socket, pivot) and demonstrate how each allows for specific limb movements. **(13 marks)**

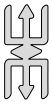
PLC Session 9

45 minutes | **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to
   a. explain the week's concepts in a practical way that will make it easier for learners to understand
   b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject specific app to plan your lesson. Ask the app to
   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.

b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)

c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Plan the week's key assessment with your app

   a. The key assessment for the week is ***group project***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the project (NTS 3k-3q).

10 minutes **Content Exploration**

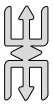
5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

   a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)

   b. all teachers in the group work through a similar problem individually for 3–4 minutes

   c. the group then works through the problem together step by step

   d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- *This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?*
- *If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.*
- *Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.*

30 minutes **Enactment**

6. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).

   a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.

   b. After the enactment, ask for structured feedback from the group

      i. was the concept explained in a way that a learner with no prior knowledge could follow?
      ii. were the examples grounded in contexts familiar to Ghanaian learners?
      iii. did any misconceptions surface and if so, how were they addressed?

5 minutes **Reflection**

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
   a. transfer your chats into your learning planner template.
   b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
   c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 4 Review

In Week 8, learners modelled and discussed the structure of the human skeleton and muscles. They identified major bones, joints, and muscle groups, and examined their roles in providing support, enabling movement, and protecting vital organs. Through interactive models and group discussions, learners developed a clearer understanding of how the skeletal and muscular systems work together.

In Week 9, the focus shifted to the structure and function of muscle tissue. Learners demonstrated and explained the differences between skeletal, smooth, and cardiac muscles, highlighting their characteristics, locations, and roles in body movement. Practical activities helped learners observe muscle contractions and better understand how different muscles function.

By the end of this section, learners had deepened their knowledge of the musculoskeletal system, gaining both conceptual understanding and practical insight into how muscles and bones coordinate to facilitate movement.

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 8

Question 1

Examples of organisms (6 marks)

Stating any 3 types of skeletons (1 mark each = 3 marks)

Correct and relevant examples for each skeleton type (1 mark for each = 3 marks)

E.g., Endoskeleton: Humans, fish

Description of skeletal materials (3 marks)

Describing the material composing each skeleton type (each 1 mark = 3 marks)

e.g., bone and cartilage for endoskeleton; chitin for exoskeleton; fluid-filled compartments for hydrostatic skeleton. Accurately describe the material for each type of skeleton.

Advantages of each skeleton type (6 marks)

Explains one advantage of each skeleton type regarding movement and protection. (2 marks each for the types)

E.g., Endoskeleton

Movement: Provides a strong internal framework that supports large muscle attachment for efficient movement (e.g., humans running or lifting).

Protection: Protects internal organs like the brain (inside the skull) and heart/lungs (inside the ribcage).

Each type with the advantage 2 marks = 3 x 2 = 6 marks

Limitations of each skeleton type (3 marks)

Explains one limitation for each skeleton type regarding movement and protection. (1 mark each, for the types)

E.g.

Endoskeleton

Movement: Bones are rigid, and joints can limit flexibility compared to soft-bodied organisms.

Protection: Some body parts (like skin, limbs) are exposed and vulnerable since the skeleton is inside.

Each type with the limitation 1 marks = 3x 1 = 3 marks

Survival support in habitats (6 marks)

Describes how each skeleton type supports organism survival in its natural habitat, with specific habitat examples. (2 marks each for the types)

E.g., Endoskeleton

Support for large body size and movement on land.

Example: Humans (terrestrial habitat) — internal skeleton allows upright posture and complex movement.

Example: Birds — lightweight endoskeleton supports flight in air environments.

Each type with the Survival support in habitats 2 marks = 3x 2 = 6 marks

(Total 24 marks)

Question 2

1. Improper chair or desk height causes students to bend awkwardly, straining the neck and back.
2. Lack of lumbar support fails to maintain the natural curve of the lower spine, leading to compression of spinal discs.
3. Slouched posture, especially during long sitting hours, can weaken back muscles and cause spinal misalignment, increasing the risk of chronic pain or spinal disorders over time.

Any three for 3 marks

(Total 3 marks)

WEEK 9

1. Accurate Representation of Joint Types (6 marks)

E.g., Pivot joint is able to show rotation, hinge joint moves to only one direction and a ball and socket joint able to move in all directions.

6 marks	4 marks	2 marks
All 3 joints (hinge, ball-and-socket, pivot) are clearly and accurately represented. (2 marks for each 3 joints= 6 marks)	Two joints (ball-and-socket, pivot) are clearly and accurately represented. (2 marks for each 2 joint)	Only one joint (hinge, ball-and-socket or pivot) are clearly and accurately represented.

2. Functionality and Demonstration of Movement (3 marks)

E.g., Hinge opens/closes, pivot rotates, and ball and socket move to all directions.

3 marks	2 marks	1 mark
All 3 joints show correct movement	Two joints show correct movement (e.g., hinge opens/closes, pivot rotates).	Only joint show correct movement (e.g., hinge opens/closes, pivot rotates).

3. Scientific Explanation of Joint Movements (4 marks)

Explanation of how two joint functions in the body using correct scientific terms. (2 marks for each joint, total of 4 marks)

E.g., Pivot Joints: A rounded end of one bone fits into a sleeve or ring formed by another bone and a ligament, allowing uniaxial rotation around a central axis. This allows rotational movement.

Ball-and-Socket Joints: The spherical head of one bone fits into a round socket of another, allowing multiaxial movement (all planes). This provides the greatest range of motion in the body, including flexion/extension, abduction/adduction, rotation, and circumduction.

(Total of 13 marks)

SECTION 5: LIGHT ENERGY IN LIFE

STRAND: VIGOUR BEHIND LIFE

Sub-Strand: Powering the future with energy forms

Learning Outcome: *Analyse light energy and its uses in nature*

Content Standard: *Demonstrate understanding of light energy, its sources and generation*

INTRODUCTION AND SECTION SUMMARY

Light energy is a form of energy that travels in waves and enables us to see the world around us. In this section, learners will explore the concept of light energy, its sources, and how it behaves when it interacts with different materials. They will investigate the practical uses of light, such as in vision, photography, solar energy, and communication. Learners will also explore the properties of lenses and mirrors, examining how they reflect and refract light to form images in tools like cameras, eyeglasses, telescopes, and microscopes.

By the end of this section, learners should be able to explain what light energy is, describe its uses in everyday life, and demonstrate how mirrors and lenses work to manipulate light for practical applications.
The weeks and the indicators covered by the section are:

Week 10

- Explain the concept of light energy and its uses.
- Explore lenses and mirrors in relation to light energy in life.

Week 11: Explore lenses and mirrors in relation to light energy in life.

SUMMARY OF Pedagogical Exemplars

This summary outlines learner-centred strategies for teaching light energy, focusing on real-world applications, scientific investigation, and collaborative learning.

Teachers facilitate understanding through case studies, guided inquiry, concept mapping, experiential learning, demonstrations, and simulations.

Learners analyse real-world lighting applications in domestic and industrial settings, examining factors that influence lighting choices. Through inquiry-based activities, they explore sources and properties of light energy, including its roles in photography, communication, and medicine. Learners present findings through reports or visual formats.

Concept maps support the discussion of key concepts like Snell's Law, total internal reflection, and the use of lenses and mirrors. In experiential tasks, learners investigate light behaviour using lenses and mirrors of varying shapes and materials.

Learners will explore light's properties and applications, understand related principles, and be able to experiment, analyse, and present scientific findings effectively.

ASSESSMENT SUMMARY

Learners will demonstrate their understanding of light energy and its applications through a range of assessments targeting higher-order thinking. To explain the concept of light energy and its uses (DOK Level 3: Strategic Reasoning), learners will complete homework designed to test conceptual understanding and the ability to apply knowledge to real-world contexts. For the indicator 'explore lenses and mirrors in relation to light energy in life', learners will engage in calculation and group project work to test their understanding.

These assessments, aligned with DOK Levels 3 and 4, will require learners to investigate scientific principles, analyse the role of optical devices in everyday life, and apply extended critical thinking to design solutions or explain phenomena using lenses and mirrors.

Indicators	DOK Level	Assessment Strategy and/or Mode
Explain the concept of light energy and its uses.	Key Assessment Level 3: Strategic Reasoning	Homework
Explore lenses and mirrors in relation to light energy in life	Key Assessment Levels: Level 3 Strategic reasoning Level 4 Extended critical thinking and reasoning	Computation Creativity
Explore lenses and mirrors in relation to light energy in life.	Key Assessment Levels: Level 3 Strategic reasoning Level 4 Extended critical thinking and reasoning	Computation Creativity

WEEK 10

Learning Indicators

1. *Explain the concept of light energy and its uses*
2. *Explore lenses and mirrors in relation to light energy in life*

Focal areas:

1. Concept of light and its properties

2. Lenses and mirrors in relation to light energy in life

Concept of light and its properties

Light is a form of energy that enables us to see the world around us. It travels in straight lines and does not need a medium to propagate. Light is part of the electromagnetic spectrum and is visible to the human eye.

Properties of Light

1. Light travels in a straight Line
2. Light can be reflected
3. Light can be refracted
4. Light can be absorbed
5. Some surfaces absorb light instead of reflecting it.
6. Dark surfaces absorb more light than light-coloured ones.
7. Light has a finite speed
8. The speed of light in a vacuum is approximately 300,000 km/s.
9. Light slows down in denser media like water or glass.
10. Light Is made of different colours

White light is a combination of seven colours (ROYGBIV – Red, Orange, Yellow, Green, Blue, Indigo, Violet).

Activity 5.1: Light travels in straight line

1. **Objective**: To show that light travels in straight lines.
2. **Materials**: Torch, cardboard with holes, white screen

Procedure

1. Place three cardboard pieces with holes in a straight line.
2. Shine a torch through the holes toward a screen.
3. Observe the light path.
4. Move one cardboard out of line and observe what happens.

Mirrors

In optics, a mirror is an optical device that reflects light, enabling us to see objects by redirecting the light rays that strike their surface. Mirrors typically have a smooth, highly reflective surface, usually made of glass coated with a thin layer of metal (such as silver or aluminium) on the back to enhance reflectivity.

The most common type is the plane (flat) mirror, which reflects light evenly and forms virtual, upright images of the same size as the object. However, there are also curved mirrors that have different shapes and optical properties. These include:

1. Concave mirrors (inward-curved, converging mirrors)
2. Convex mirrors (outward-curved, diverging mirrors)

Each type of mirror behaves differently with light and is used in various practical applications.

A mirror is defined as a reflecting surface and can be explained by the law of reflection.

The law of reflection states that when a ray of light is made to fall on the reflecting surface, the incident ray, the reflected ray and the normal to the surface of the mirror all lie in the same plane and the angle of incidence is equal to the angle of reflection.

Terms related to mirrors on reflection of light

1. Incident ray: It is defined as a ray of light that hits the surface.
2. Reflected ray: It is defined as the ray of light that is reflected back (bounces off) after hitting the surface.
3. Normal ray: It is defined as the ray that is 90° to the surface or the ray which is perpendicular to the reflecting surface.
4. Refracted ray: It is defined as the incident ray which passes through a second medium resulting in the change of direction.
5. Angle of incidence: It is defined as the angle between the incident ray and the normal at which the incidence occurs.
6. Angle of reflection: It is defined as the angle between the reflected ray with respect to the normal at which the reflection occurs.
7. Angle of refraction**:** It is defined as the angle between the refracted ray and the normal at which the refraction occurs.

Plane mirror

A plane mirror is a type of mirror that has a flat or plane reflecting surface. It reflects a replica of the object placed in front of it. It is polished at the back and reflects the surface from the front. It is commonly used in everyday life, such as in barbershops, cameras, microscopes or for decorative purposes.

Figure 5.1: *A picture of plane mirror*

Light Reflection in Plane Mirrors

When light rays strike a flat mirror, they are reflected. According to the laws of reflection, the angle of incidence is equal to the angle of reflection **(∠ i =∠ r)**.

Reflection of light is a process where a ray of light, emitted from a light source and incident upon a plane mirror, reflects into the same medium at the same angle is known as reflection of light. The image which is present in the mirror is obtained behind the plane. The image is virtual and erect, a reflection on a plane mirror.

There are two main Laws of Reflection:

- The angle of incidence (∠i) is equal to the angle of reflection(∠r). Mathematically,

  (∠i = ∠r).
- All three rays i.e., the incident ray reflected ray, and the normal at the point of incidence, all lie in the same plane.

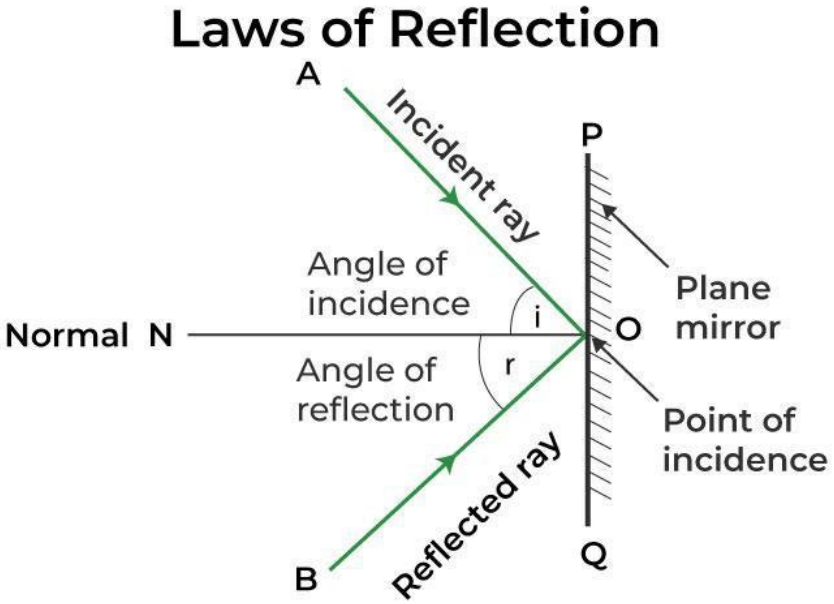


Figure 5.2: *A ray diagram a reflection of light on plane mirror*

Activity 5.2: Laws of reflection

Objective: To demonstrate the laws of reflection.

Materials: Plane mirror, drawing board, white paper. pins, protractor, ruler, pencil, small, wooden block to hold the mirror upright.

Procedure

1. Fix the white paper on the drawing board

   a. Draw a straight line (XY) across the paper and place the mirror strip vertically along this line, supported by the wooden block.

   b. Draw a normal (ON) at any point O on XY.

   c. Draw an incident ray (AO) at an angle to the normal (e.g., 30°). Fix two pins (P1 and P2) vertically on this line.

   d. Looking at the reflection of P1 and P2 in the mirror, fix two more pins (P3 and P4) such that P3, P4, and the images of P1 and P2 are in a straight line.

   e. Remove the mirror and the pins. Draw a line (OB) joining the pinpricks P3 and P4 and extend it to O. This is the reflected ray.

   f. Measure the angle of incidence (∠AON) and the angle of reflection (∠BON).

   g. Repeat for different angles of incidence (e.g., 45°, 60°).

Characteristics of the image formed by a plane mirror

1. **Virtual image:** It is an optical image formed when light rays diverge, appearing to originate from a point behind the mirror rather than actually converging there.

   The light rays reflected from a plane mirror do not actually converge at a point. Instead, our brain extends the reflected rays backward, and we perceive an image behind the mirror. This is why a plane mirror forms a virtual image. You cannot project this image onto a screen.

   a. **Upright (Erect):** The image is oriented in the same direction as the object. If you stand upright, your image is also upright.

   b. **Same size:** The image has the same dimensions as the object. A one-meter-tall person appears one-meter tall in a plane mirror.

   c. **Laterally inverted:** This is a phenomenon where a plane mirror reverses an object's left end right sides making them appear right and left respectively, while leaving the top and bottom unchanged.

      This is the most noticeable characteristic. Left and right are reversed. If you raise your right hand, your image appears to raise its left hand. This inversion is front-to-back, not top-to-bottom.

   d. **Image distance is equal to object distance:** The distance between the object and the mirror is equal to the distance between the image and the mirror. If you stand two meters in front of a plane mirror, your image appears to be two meters behind the mirror.

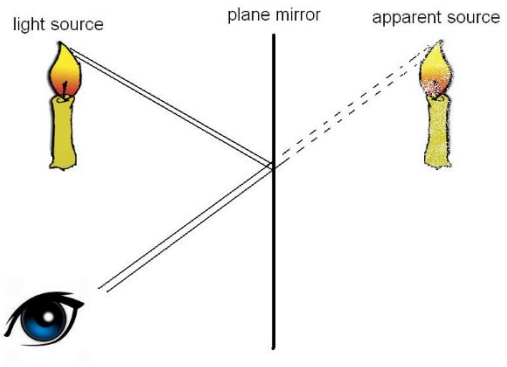


Figure 5.3: *A ray diagram of image form by plane mirror*

The incident rays from the light source reflect off the plane mirror and hit our eye. because our brain projects the reflected rays *behind* the mirror, meaning the light rays do not actually reach the image, we call it a *virtual image.*

Worked examples

1. A light ray strikes a plane mirror at an angle of incidence of **35°**. What is the angle of reflection?

   Solution

   According to the Law of Reflection:

   Angle of incidence=Angle of reflection

   So,

   Angle of reflection=35∘

2. A ray strikes a mirror at an angle of incidence of **40°**. What is the total angle between the incident ray and the reflected ray?

   Solution

   $\theta r = \theta i = 40^\circ$

   Total angle between the rays= $\theta i + \theta r = 40^\circ + 40^\circ = 80^\circ$

Uses of Plane Mirrors

Plane mirrors are used for variety of applications. The detailed applications of plane mirrors are mentioned below:

1. **Periscope:** Submarines use periscopes to see objects on the water's surface. It is impossible to bend light rays since they move in straight directions, although they can be reflected. The plane mirrors of a periscope adjust the direction of light rays so that the item can be seen by the submarine's viewer.
2. **Telescope:** A telescope is used to observe distant objects in the solar system, such as planets. Telescopes are classified into two types (Reflectors and Refractors). A set of lenses is used in a refracting telescope. Plane mirrors are used in conjunction with spherical mirrors in reflecting telescopes.

3. **Saloon:** We can create unlimited images by installing plan mirrors parallel to each other this trick allows the customer to view both the front and rear of a person.
4. **SLR cameras:** Single-lens reflex (SLR) cameras use plane mirrors.
5. **Microscopes:** Plane mirrors are used to reflect light onto the specimen to brighten it.
6. **Surveillance systems:** Mirrors that are placed in a certain way can help people keep an eye on places that they cannot see directly. This can be useful in surveillance systems where people want to observe things without being noticed.
7. **Education and science:** Plane mirrors are educational tools in science classrooms, to demonstrate the principles of optics and light reflection to learners.
8. **Navigation:** In navigation tools such as sextants, plane mirrors aid in celestial navigation by reflecting light from celestial bodies, assisting sailors and navigators in determining their position relative to the horizon and celestial objects.
9. **Decorative purposes:** Plane mirrors are used in interior design to create illusions of space by reflecting light and enhancing the appearance of rooms.

Concave Mirrors (Converging Mirrors)

A concave mirror, also known as a converging mirror, is a spherical mirror with a reflecting surface that curves inward, resembling the shape of a cave. This inward curvature gives the impression of looking into a hollow or cave-like surface. To analyse the behaviour of concave mirrors, we often use the mirror equation, which helps determine the position and size of the image formed. Unlike plane mirrors, the angle of incidence in a concave mirror is not always equal to the angle of reflection, as it depends on the specific point where the light ray strikes the curved surface.

Properties of Concave Mirrors

1. When light rays strike the surface of a concave mirror, they converge (come together) at a single point after reflection. This is why concave mirrors are called converging mirrors.
2. When the mirror is placed close to an object, it forms a magnified and virtual image.
3. As the distance between the object and the mirror increases, the image becomes smaller and real.
4. Concave mirrors can form images that are small or large, and either real or virtual, depending on the position of the object.

Applications of Concave Mirrors

1. **Shaving mirrors**: Concave mirrors are commonly used in shaving mirrors. When held close to the face, they produce a magnified and upright image, making it easier to see details.
2. **Ophthalmoscopes**: These mirrors are used in medical instruments such as ophthalmoscopes to help doctors examine the interior of the eye.
3. **Astronomical telescopes**: Large concave mirrors, sometimes with diameters of 5 meters or more, are used as objectives in astronomical telescopes to collect and focus light from distant celestial bodies.
4. **Vehicle headlights**: In car headlights, torches, and railway engines, concave mirrors act as **reflectors**. A small light source is placed at the focus of the mirror, causing the reflected light to travel in parallel rays, creating a strong and focused beam.

5. **Solar furnaces and ovens**: Large concave mirrors are used in solar devices to concentrate sunlight at a single focal point, generating intense heat. This heat is used for cooking, heating, or even melting metals.

Convex mirror

A convex mirror is a type of spherical mirror in which the reflecting surface is curved outward, like the back of a spoon. It is formed by painting the inner surface of a cut hollow sphere, making the outer bulged surface reflective.

In this mirror, the back is shaded so that reflection only occurs from the outward-curved surface.

A convex mirror is also called a diverging mirror because the light rays that strike its surface spread out (diverge) after reflection. Although the reflected rays diverge, they appear to originate from a common point behind the mirror. As a result, the image formed is:

1. Virtual (cannot be projected on a screen)
2. Erect (upright)
3. Diminished (smaller than the object)

Everyday Example:

The back of a stainless-steel spoon (the bulged-out part) acts like a convex mirror. It reflects a smaller, upright image of whatever is in front of it.

Applications of convex mirrors

Convex mirrors are widely used in daily life due to their ability to provide a wider field of view and form virtual, erect, and diminished images.

1. **Inside buildings (for Safety and Monitoring)**
    a. Convex mirrors are installed in **large offices, stores, hospitals**, and other public buildings:
        i. They allow people to see around corners in hallways and corridors.
        ii. Help prevent collisions by providing visibility in blind spots.

2. **In vehicles (as Rear-View Mirrors)**
    a. Convex mirrors are commonly used as rear-view or side mirrors in cars, motorcycles, and other vehicles:
        i. They give a wider field of view, helping drivers see more of the road and traffic behind them.
        ii. They produce virtual, upright, and reduced images, allowing more objects to be seen in a small mirror.

3. **In magnifying glass construction**
    a. Convex mirrors are sometimes used in the making of magnifying devices:
        i. In industrial applications, two convex mirrors can be placed back-to-back to enhance magnification effects.

4. **For security and surveillance**
    a. Convex mirrors are widely used for security purposes, especially:
        i. Near ATMs, allowing users to see if someone is behind them.
        ii. In shops or parking areas, to monitor suspicious activity or improve visibility.
5. **In street light reflectors**
    a. Convex mirrors are used in street lighting systems:
        i. Their diverging property helps to spread light over a wider area, improving coverage and illumination.

Important terms in concave and convex mirrors

Understanding the basic parts of a spherical mirror helps in studying how light behaves when it reflects.

Pole (P): The pole is the midpoint of the mirror's surface. It is represented by the letter P.

All distances (object distance, image distance, etc.) are measured from the pole.

Aperture: The aperture is the diameter of the reflecting surface of the mirror. It defines the size of the mirror and the area over which reflection of light occurs.

Principal axis: An imaginary straight line that passes through both the pole (P) and the centre of curvature (C). All incident rays and measurements are taken with respect to this axis.

Centre of curvature (C): It is the centre of the sphere from which the mirror surface is taken. Represented by C, it lies on the principal axis and is outside the mirror surface. For a concave mirror, it is in front of the mirror; for a convex mirror, it is behind.

Radius of curvature (R): The distance between the pole (P) and the centre of curvature (C). Denoted by R. It is equal to twice the focal length, i.e., $R = 2f$ (f being the focal length)

The focal length is the distance from the surface of the mirror to its principal focus

Principal focus (F): Also called the focal point. It is the point on the principal axis where: For concave mirror, parallel rays converge after reflection and for convex mirror,parallel rays appear to diverge from after reflection. Denoted by **F**.

Focus: A point on the principal axis where rays parallel to it either converge or appear to diverge after reflection. In spherical mirrors, the principal focus is typically referred to as the focus.

Characteristics of images formed by concave and convex mirrors

Images formed from a concave mirror:

1. The light rays coming from the object are parallel to the principal axis.
2. These parallel rays, after reflecting off the concave mirror, converge at the principal focus (F).
3. Therefore, the image is formed at the focus (F) of the mirror.

Characteristics of the image:

1. Position: At the principal focus (F)
2. Size: Highly diminished (almost point-sized)
3. Nature: Real and inverted

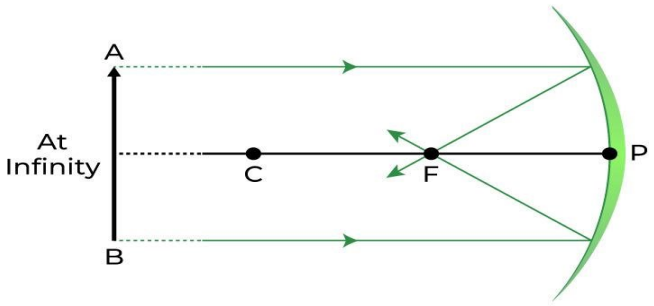


Figure.5.4: *A ray diagram of image formed by concave mirror when the object is placed at infinity*

When the object is placed between infinity and the centre of curvature (C) of a concave mirror (i.e., far away but not at infinity):

1. The rays coming from the object are nearly parallel, but not perfectly.
2. After reflection, these rays converge at a point between the centre of curvature (C) and the principal focus (F).
3. Therefore, the image is formed between C and F on the same side as the object.

Characteristics of the image

1. Position: Between the centre of curvature (C) and the focus (F)
2. Size: Diminished (smaller than the object)
3. Nature**:** Real and inverted

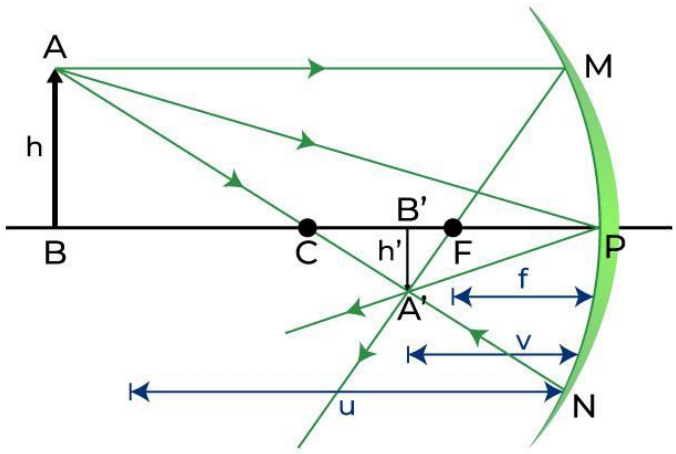


Figure 5.5: *A ray diagram of image formed by concave mirror when the object is placed between infinity and the centre of curvature (C*

When an object is placed exactly at the centre of curvature (C) of a concave mirror:

1. Light rays from the object reflect off the mirror and converge to form the image at the same point, i.e., at C.
2. The reflected rays meet at a point equal distance in front of the mirror, forming the image at C itself.

Characteristics of the image

1. Position: At the centre of curvature (C)
2. Size: Same size as the object
3. Nature: Real and inverted

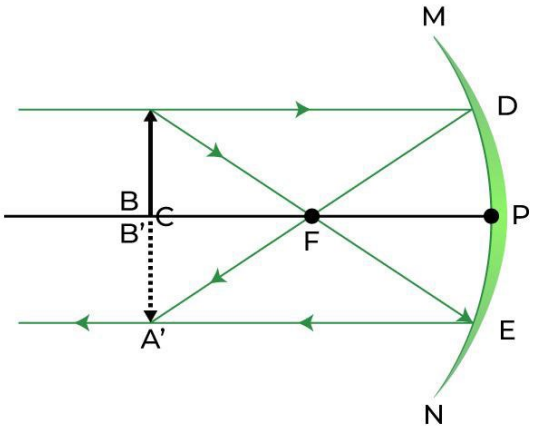


Figure 5.6: *A ray diagram of image formed by concave mirror when the Object is Placed at the Centre of Curvature (C)*

When an object is placed between the centre of curvature (C) and the principal focus (F) of a concave mirror:

1. The reflected rays from the mirror converge beyond the centre of curvature (C).
2. As a result, the image is formed beyond C, on the same side as the object.

Characteristics of the image

1. Position: Beyond the centre of curvature (C)
2. Size: Enlarged (bigger than the object)
3. Nature: Real and inverted

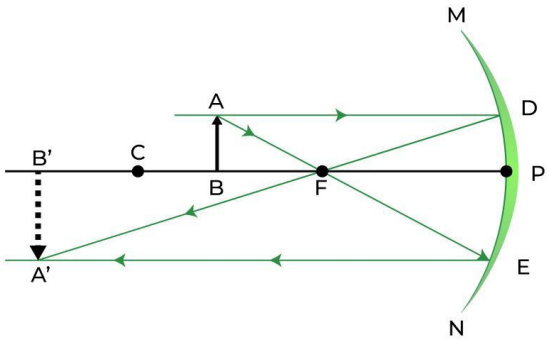


Figure 5.7: *A ray diagram of image formed by concave mirror when the object is placed between the centre of curvature (c) and the focus (f)*

When an object is placed exactly at the principal focus (F) of a concave mirror:

1. The reflected rays from the mirror become parallel to the principal axis after reflection.
2. Since parallel rays never meet, the image is formed at infinity.

Characteristics of the Image

1. Position: At infinity
2. Size: Highly enlarged (cannot be captured on a screen)
3. Nature: Real and inverted

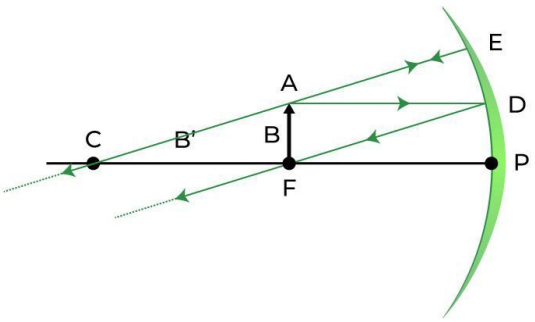


Figure 5.8: *A ray diagram of image formed by concave mirror when the object is placed at the principal focus (f)*

When an object is positioned between the focus (F) and the pole (P) of a concave mirror:

1. The reflected rays appear to diverge, but when extended backward, they seem to meet behind the mirror.
2. As a result, the mirror forms a virtual image that cannot be projected onto a screen.

Characteristics of the image

1. Position: Behind the mirror
2. Size: Enlarged (bigger than the object)
3. Nature: Virtual and erect

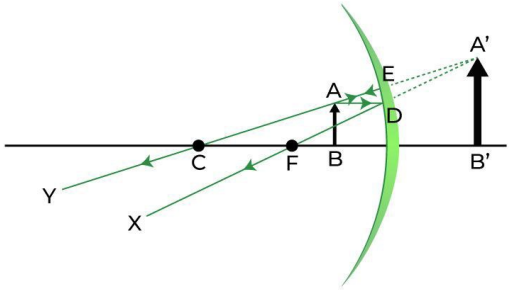


Figure 5.9: *A ray diagram of image formed by concave mirror when the Object is placed between the principal focus (F) and the pole (P)*

Table 5.1: *Characteristics of images formed concave mirror with respect to position of the object.*

Position of object	Position of image	Image Size	Nature of image
Within focus (Between P and F)	Behind the mirror	Enlarged	Virtual and erect
At focus	At infinity	Highly Enlarged	Real and Inverted
Between F and C	Beyond C	Enlarged	Real and Inverted
At C	At C	Equal to object	Real and Inverted
Beyond C	Between F and C	Diminished	Real and Inverted
At Infinity	At focus (F)	Highly Diminished	Real and Inverted

Image formed by convex mirror

Two possibilities of the position of the object are possible in the case of a convex mirror, which is when the object is at infinity and the object is between infinity and the pole of a convex mirror.

Object at infinity

Whenever the object is kept at infinity, we observe that a point-sized image is formed at the principal focus behind the convex mirror.

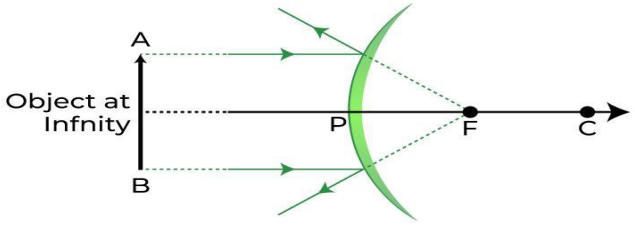


Figure .5.9.1: *A ray diagram of image formed by object at infinity.*

Properties of image: The image formed is highly diminished in size, virtual and erect.

Object is kept between infinity and the pole

Whenever the object is kept anywhere between the infinity and the pole of a convex mirror, then we get a diminished, virtual and erect image formed between the pole and focus behind the mirror.

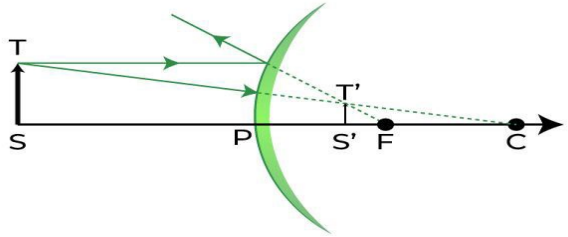


Figure 5.9.2: *A ray diagram of image formed by object between infinity and the pole*

Properties of image: The image formed is diminished in size as well as virtual and erect.

Table 5.2: *Characteristics of images formed convex mirror with respect to position of the object.*

Position of Object	Position of image	Image of Size	Nature of Image
Anywhere between pole P and Infinity	Behind the mirror between P and F	Diminished	Virtual and erect
At infinity	Behind the mirror at Focus (F)	Highly Diminished	Virtual and erect

Mirror Formula

To solve numerical problems involving spherical mirrors (concave or convex), we use the **mirror formula**. This formula helps calculate important quantities such as:

1. Focal length (f)
2. Object distance (u)
3. Image distance (v)
4. Magnification (m)
5. The mirror formula: 1/f=1/v+1/u

Where;

f = focal length of the mirror

v = image distance (from the pole)

u = object distance (from the pole

h_1= image height h_2= object height

Sign Convention (Based on the Cartesian System)

1. All distances are measured from the pole (P) of the mirror.
2. Distances measured to the right of the pole (along the direction of incident light) are positive.
3. Distances measured to the left of the pole (against the direction of incident light) are negative.
4. The focal length (f) is:
   - Negative for a concave mirror
   - Positive for a convex mirror
5. The object distance (u) is usually negative (as objects are generally placed in front of the mirror).
6. The image distance (v):
   - Positive if the image is formed behind the mirror (virtual)
   - Negative if the image is formed in front of the mirror (real)
7. Negative magnification means inverted image
   Positive magnification means upright image

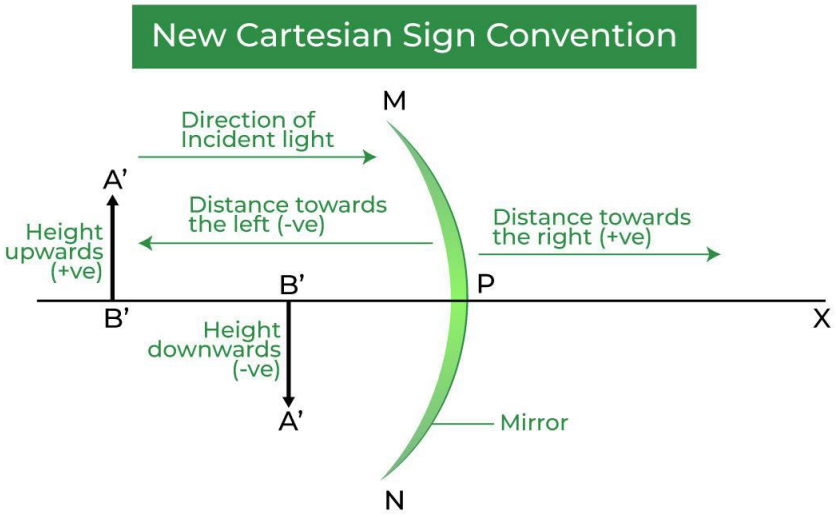


Figure 5.9.3: *New cartesian sign convention*

Worked examples

1. An object is placed 30 cm in front of a concave mirror. The focal length of the mirror is 15 cm. Find the position and nature of the image.

Solution

Object distance (in front of the mirror) = -30cm

Focal length (concave has negative f) = -15

Image distance =

Result

- The image is formed 30 cm in front of the mirror.
- It is real and inverted (because v is negative).
- Same size as the object (since).

2. An object is placed 20 cm in front of a convex mirror. The focal length is 10 cm. Find the position and nature of the image**.**

Solution

Object distance (in front of the mirror) = -30cm

Focal length (concave has negative f) = -15

Image distance = v

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

$$\frac{1}{-15} = \frac{1}{v} + \frac{1}{-30}$$

$$v = -30$$

Result

The image is formed 30 cm in front of the mirror.

It is real and inverted (because v is negative).

Same size as the object (since).

2. An object is placed 20 cm in front of a convex mirror. The focal length is 10 cm. Find the position and nature of the image.

Solution

Given

Object distance, $u = -20cm$

Focal length, $f = +10cm$ (convex mirror → positive)

Image distance, $v = ?$

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

$$\frac{1}{10} = \frac{1}{v} + \frac{1}{-20}$$

$$\frac{1}{v} = \frac{1}{10} + \frac{1}{20}$$

$$\frac{1}{v} = \frac{2+1}{20} = \frac{3}{20}$$

$$v = +6.67cm$$

Result

The image is formed 6.67 cm behind the mirror.

It is virtual and erect (because v is positive).

It is diminished in size.

Learning tasks

1. Explain the properties of light
2. Describe how images are formed in relation to light
3. Design an experiment to explain the properties of light.

Pedagogical Exemplars

1. **Guided Inquiry**
   a. Guide learners in mixed ability groups to explore the properties of light energy in fields like photography, communication technology, and medicine.
   b. Encourage learners to present their proposed solutions through written reports, presentations, or visual representations.
2. **Concept map**

   Engage learners to use concept maps in discussing the fundamental concepts of light energy such as Snell's Law, Total Internal Reflection, and refractive index and the role of lenses and mirrors in manipulating light.

3. **Experiential learning**
   a. Put learners into small groups and provide them with different types of lenses and mirrors. Encourage learners to experiment with optical devices, observing how light behaves when passing through or reflecting off each surface.
   b. Guide learners to conduct experiments where learners observe the effects of refraction and reflection using lenses and mirrors of different shapes and materials.
4. **Demonstrations and Simulations**
   a. Guide learners to conduct live demonstrations to illustrate Snell's Law and Total Internal Reflection using laser pointers and models.
   b. Let learners in their convenient groups showcase how light rays bend when passing through different media and demonstrate the concept of the critical angle for total internal reflection.
5. **Collaborative Learning**

   Assist learners in working in groups to explore the properties and applications of lenses and mirrors in the context of light energy and create criteria for learners to do presentations in groups to promote teamwork.
6. **Research Method**

   Encourage learners to conduct independent research on advanced topics related to lenses, mirrors, and their applications in optics. Assign projects that require learners to investigate current research advances in optical technologies and explore innovative uses of lenses and mirrors in various industries**.**

Key Assessment Level 3: Homework

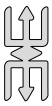
1. Describe how light energy enables vision and analyse the role of different light sources in various fields such as homes, schools, and hospitals. Use real-life examples to support your response. **(7 marks)**
2. Light travels at a speed of 3×10^8 m/s. If the distance between the Sun and Earth is 1.5×10^{11} meters, calculate how long it takes sunlight to reach Earth in minutes.
3. A magnifying glass has a convex lens with a focal length of 10 cm. An object is placed 25 cm from the lens.
   a. Calculate the image distance. **(3 marks)**
   b. Describe how convex lenses are useful in daily life, using this example. **(3 marks)**

PLC Session 10

45 minutes | **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to
   a. explain the week's concepts in a practical way that will make it easier for learners to understand
   b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).

3. Use your subject specific app to plan your lesson. Ask the app to
   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
   b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
   c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



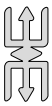
Note

- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Plan the week's key assessment with your app
   a. The key assessment for the week is ***homework***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the homework (NTS 3k-3q).

10 minutes **Content Exploration**

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
   a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
   b. all teachers in the group work through a similar problem individually for 3–4 minutes
   c. the group then works through the problem together step by step
   d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- *This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?*
- *If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.*
- *Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.*

30 minutes **Enactment**

6. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).
   a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
   b. After the enactment, ask for structured feedback from the group

i. was the concept explained in a way that a learner with no prior knowledge could follow?

ii. were the examples grounded in contexts familiar to Ghanaian learners?

iii. did any misconceptions surface and if so, how were they addressed?

5 minutes **Reflection**

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
   a. transfer your chats into your learning planner template.
   b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
   c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 11

Learning Indicator: *Explore lenses and mirrors in relation to light energy in life*

Focal Area: Concept of Snell's law and its application

Snell's Law describes how light bends (refracts) when it passes from one medium to another, like from air into water or glass.

Refraction of light

When a ray of light travels from one medium (like air) into another medium with a different optical density (like water or glass), its speed changes. This change in speed causes the light ray to bend at the boundary between the two media. This bending is called refraction.

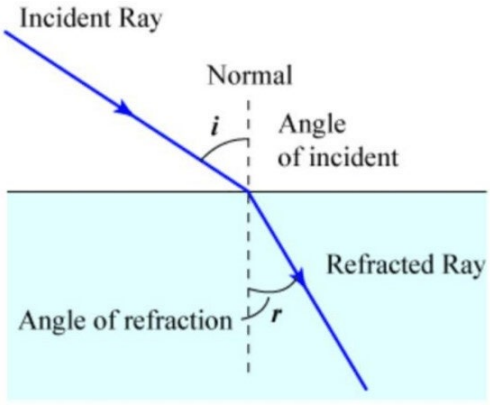


Figure 5.9.4: *A ray diagram of refraction of light*

1. **Incident ray:** The incoming ray of light
2. **Refracted ray:** The transmitted ray of light into another medium
3. **Medium of incidence:** The medium in which light travels before it strikes the boundary.
4. **Medium of refraction:** The medium through which refracted ray travels.
5. **Point of incidence:** The intersection of the incident ray and the boundary.
6. **Normal:** An imaginary line is drawn perpendicular to the boundary at the point of incidence.
7. **Angle of incidence (*i*):** The angle between the NORMAL and the incident ray.
8. **Angle of refraction (r):** The angle between the NORMAL and the refracted ray.

Activity 5.3: Refraction of Light

Objective: To observe refraction of light in different media.

Materials: glass of water, pencil/straw

Procedure

1. Fill the glass about two-thirds full with water.
2. Place the pencil or straw into the glass of water so that it is partially submerged.
3. Look at the pencil from the side, at the point where it enters the water.

Snell's Law

It states: "The ratio of the sine of the angle of incidence to the sine of the angle of refraction is equal to the ratio of the refractive indices of the two media."

Snell's Law Formula

What the symbols mean:

1. n_1 **(Refractive Index of the First Medium)**
   a. This tells us how much the medium slows down light compared to its speed in a vacuum.
   b. Air has a refractive index close to **1.00** (because light barely slows down).
   c. Water has a refractive index of about **1.33** (light slows down more).
   d. Glass can have an index ranging from **1.5 to 1.9**, depending on the type.
2. θ_1 **(Angle of Incidence)**
   a. This is the angle between the incoming light ray and the normal (an imaginary line perpendicular to the surface).
   b. The larger the angle, the more dramatic the potential bending.
3. n_2 **(Refractive Index of the second medium)**
   a. If light enters a denser medium (higher refractive index), it **slows down and bends toward the normal**.
   b. If light enters a less dense medium (lower refractive index), it **speeds up and bends away from the normal**.
4. θ_2 **(Angle of Refraction)**
   o This is the angle between the refracted light ray and the normal inside the second medium.
   o It depends on the ratio of the refractive indices and the incident angle.

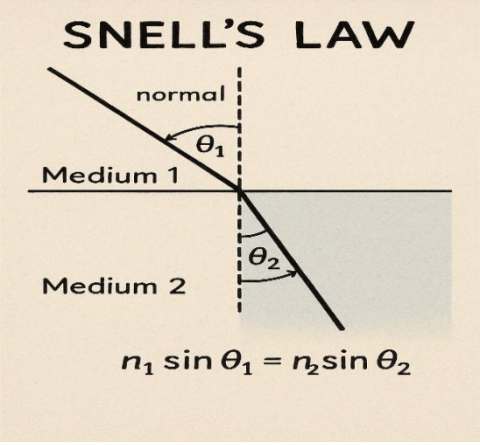


Figure 5.9.5: *A ray diagram of Snell's law*

How it works

- If light goes from a less dense medium to a denser medium (e.g., air to water), it bends toward the normal (line perpendicular to the surface).
- If light goes from a denser to a less dense medium (e.g., water to air), it bends away from the normal

- Snell's Law explains why a straw looks bent in a glass of water or why lenses focus light in cameras and eyeglasses.

Refractive index

The refractive index of a medium is a measure of how much the speed of light is reduced when it passes through that medium.

A higher refractive index means that light slows down more when traveling through the material compared to another medium. It's defined as the ratio of the speed of light in a vacuum (c) to the speed of light in the medium (v):

$$n = \frac{c}{v}$$

1. A vacuum has a refractive index of approximately 1.
2. Air has a refractive index very close to 1 (around 1.0003).
3. Water has a refractive index of about 1.33.
4. Glass typically has a refractive index around 1.5.
5. Diamond has a high refractive index of about 2.42.

Effects of Higher Refractive Index

1. **Greater Bending of Light:**
   - Materials with a higher refractive index cause light to bend more toward the normal when entering.
   - Example: **Diamond (n=2. 42)** bends light significantly, creating intense internal reflections that enhance its sparkle.

Worked examples

1. If the speed of light in a medium is 2.25×10^8m/s, what is the refractive index of the medium? (Speed of light in vacuum c=3.00×10^8m/s)

Solution

Refractive index=$\boldsymbol{n = \frac{c}{v}}$

Where;

n = refractive index

c = speed of light in vacuum (3.00×10^8m/s)

v = speed of light in the medium (2.25×10^8m/s)

Substituting the values:

$$\boldsymbol{n} = \frac{3.00 \times 10^8}{2.25 \times 10^8}$$

$$n = 1.33$$

2. If the refractive index of a medium is 2.0, what is the speed of light in the medium? (Speed of light in vacuum c=3.00×10^{8}m/s)

Solution

The speed of light in a medium is calculated using:

$$v = \frac{c}{n}$$

Where;

v = speed of light in the medium

c = speed of light in vacuum (3.00×108 m/s)

n = refractive index of the medium (2.0)

$$\frac{3.00 \times 10^8}{2.0}$$

$$v = 1.50 \times 10^8\, m/s$$

Light travels from air (refractive index = 1.00) into glass (refractive index = 1.50) at an angle of incidence of 30°. Find the angle of refraction.

Solution

Using Snell's Law

$$n_1 sin\theta_1 = n_2 sin\theta_2$$

n1=1.00, n2 = 1.50, $\theta_1 = 30°$

$$1.00 \times sin30° = 1.50 \times sin_2 0.5 = 1.50 \times sin\theta_2$$

$$sin\theta_2 = \frac{0.5}{1.50} = 0.333$$

$$\theta_2 = sin^{-1} \times 0.333$$

$$\theta_2 = 19.5°$$

4. A ray of light travels from water (refractive index = 1.33) into air (refractive index = 1.00). What is the critical angle for total internal reflection?

Solution

$$sin\theta_c = \frac{n_2}{n_1}$$

$$sin\theta_c = \frac{1.00}{1.33} = 0.752$$

$$\theta_c = sin^{-1} \times 0.752$$

$$\theta_c = 48.8^{\circ}$$

Hence, the critical angle is 48.8°.

5. Light passes from air (n1=1.00) into an unknown medium. The angle of incidence is θ1=60∘, and the angle of refraction is θ2=30∘.
   Find the refractive index n2of the medium.

Solution

$n_1 \times sin\theta_1 = n_2 \times sin\theta_2$

$1.00 \times sin60° = n_2 \times sin30°$

$0.8660 = n_2 \times 0.5$

$$n_2 = \frac{0.8660}{0.5}$$

$n_2 = 1.732$

Applications of Snell's Law

1. **Optical Lenses and vision correction**: Used in designing eyeglasses, contact lenses, and microscopes to correctly bend light into the eye or onto a focal point. Helps determine how light should refract through convex and concave lenses to correct vision problems like near-sightedness and far-sightedness.
2. **Fibre Optic communication**: Allows light signals to travel efficiently through optical fibres by ensuring total internal reflection. Used in high-speed internet and data transmission systems.
3. **Camera lenses and photography**: Helps engineers design camera lenses with precise refraction control. Used in autofocus and zoom mechanisms to adjust focus based on Snell's Law calculations.
4. **Medical imaging and microscopy**: Help enhance imaging techniques such as endoscopy, where light must bend correctly inside the human body. Used in microscopes to focus light for detailed analysis of microscopic structures.
5. **Mirage formation**: Explains how light bends due to temperature variations in the air, from hotter air (less dense) to cooler air (denser) creating illusions like a water mirage on hot roads.
6. **Underwater vision and diving**: Help divers understand why objects underwater appear closer and larger than they really are. Used in designing diving masks and underwater cameras to correct refraction distortions.

Real and apparent depth

When light passes from one medium to another, such as from water to air, it bends or refracts. This refraction causes objects submerged in water to appear shallower than they are. The difference between the actual depth (real depth) and the perceived depth (apparent depth) is an important concept in optics. Understanding real depth and apparent depth not only helps in physics but also has practical applications in fields such as underwater exploration, photography, and even fishing.

Real Depth

Real depth can be defined as the actual distance of an object from the surface of the medium. That is: depth at which an object is placed in a beaker or liquid such that the observer and object are in the same

medium. The propagation of light from the observer to the object or vice versa should be in the same medium.

Factors Affecting Real Depth

Real depth refers to the actual vertical distance between an object submerged in a medium and the surface of that medium. Although real depth remains constant regardless of how it is viewed, several factors can affect how it is measured or perceived:

1. **Medium density**: While density doesn't change the real depth itself, it can affect the ease and method of measurement. In denser liquids, specialised instruments may be required to account for buoyancy or resistance.
2. **Object's position**: The real depth is directly determined by the object's distance from the surface of the medium. This is a key factor in any depth measurement and forms the basis for calculating real depth.
3. **Measurement tools**: The accuracy and type of tool used (such as a ruler, depth gauge, or sonar) influence how precisely the real depth is recorded. Poor calibration or human error can lead to inaccurate depth readings.
4. **Water surface variations**: Changes in water level due to tides, waves, or environmental factors may temporarily alter the measured depth. These fluctuations must be considered in real-time depth assessments, especially in marine or hydrological studies.

Factors Affecting Apparent Depth

Apparent depth is how deep an object seems to be when viewed from above the medium. The apparent depth of an object submerged in a transparent medium (like water or glass) appears shallower than its actual depth due to the refraction of light. Several factors influence how much this apparent shift occurs:

1. **Refractive Index of the Medium**: The refractive index determines how much light bends when it passes from one medium to another. A higher refractive index results in a greater difference between the real and apparent depth. Example: Light bends more in glass (higher refractive index) than in water.

1. **Angle of observation**: The apparent depth depends on the angle at which the observer views the object. When viewed normally (perpendicularly from above), the effect of refraction is minimal. At oblique angles, the bending of light increases, making the object appear even shallower.
2. **Real depth of the object**: Greater real depth increases the difference between the actual and apparent position. Objects closer to the surface show less noticeable displacement.
3. **Optical properties of the medium**: Different materials (e.g., air, water, glass) have different optical densities and refractive indices. The change in depth perception depends on the contrast between the refractive indices of the two media (e.g., air and water).
4. **Surface curvature**: If the surface of the medium is curved (like in a lens or rippling water), the bending of light varies at different points. This causes non-uniform apparent depth, which is often observed in curved containers or lenses.
5. **Temperature of the medium**: Temperature can slightly affect the refractive index of a medium. For example, warmer water has a lower refractive index than cold water, slightly altering the apparent depth.

Calculation formula

$$\textbf{Apparent depth} = \frac{\textbf{Real depth}}{\textbf{Refractive index}}$$

Worked examples

1. A coin is placed at the bottom of a beaker filled with water. The real depth of the coin is measured to be 12 cm. If the refractive index of water is 1.33, calculate the apparent depth of the coin as observed from directly above the beaker.

Solution

$$\textbf{Apparent depth} = \frac{\textbf{Real depth}}{\textbf{Refractive index}}$$

Given

Real depth $Real\ depth = 12cm$

$Refractive\ index\ of\ water = 1.33$

Calculation

$$\textbf{Apparent depth} = \frac{\textbf{12cm}}{\textbf{1.33}} = \textbf{9.02cm}$$

An object appears to be at a depth of 10 cm when viewed from directly above a tank filled with water. If the refractive index of water is 1.33, calculate the real depth of the object.

Solution

Given

$\textbf{Apparent depth} = \textbf{10cm}$

$\textbf{Refractive index} = \textbf{1.33}$

Calculation

$Real\ depth = Apparent\ depth \times Refractive\ index$

$Real\ depth = 10 \times 1.33$

$Real\ depth = 13.3cm$

Total Internal Reflection (TIR)

Total Internal Reflection (TIR) is an optical phenomenon that occurs when light traveling from a medium with a higher refractive index (optically denser) to a medium with a lower refractive index (optically less dense) strikes the interface between the two media at an angle of incidence greater than a specific angle called the critical angle.

This can simply be explained as the phenomenon where a light ray completely reflects back into a medium from its boundary with another medium, without any refraction occurring. This happens when light travels from a denser medium to a rarer medium, like from water to air.

Under these conditions, instead of refracting (passing through and bending) into the less dense medium, all the light is reflected back into the denser medium.

The critical angle is the minimum angle of incidence at which light is totally reflected, not refracted.

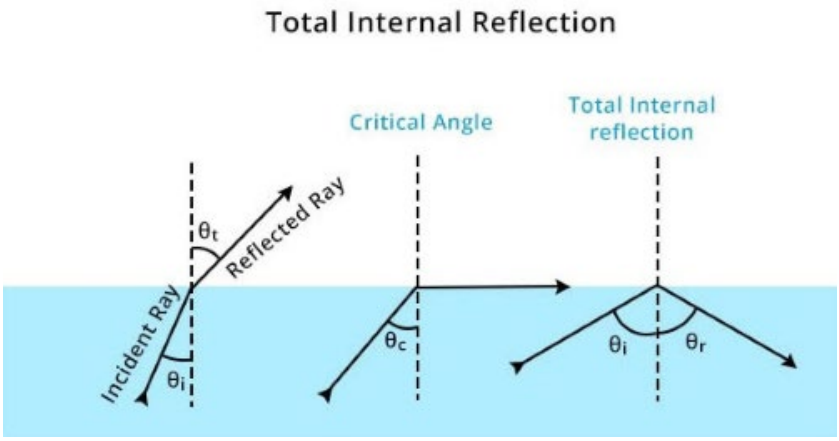


Figure 5.9.6: *A ray diagram of total internal reflection*

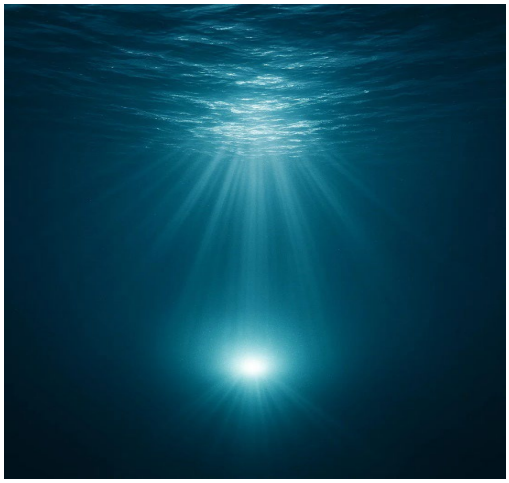


Figure 5.9.7: *Diagram of Total Internal Reflection in water*

Conditions for Total Internal Reflection

1. Light must travel from a denser medium to a less dense medium (e.g., from water to air, or glass to air)
2. The angle of incidence must be greater than the critical angle

How it works

1. When light hits the boundary between two materials (like glass and air), some of it is refracted (bent), and some is reflected.
2. If the angle of incidence is too large, all the light reflects inside the first medium.
3. No light escapes into the second medium — this is total internal reflection.

Example

1. Light inside a swimming pool (water) hits the surface at a steep angle.
2. If the angle is greater than the critical angle (~48.6° for water to air), the light reflects back underwater.
3. That's why you sometimes see a mirror-like surface when you look up underwater.

Why Does TIR Occur?

As light moves from a denser to a less dense medium, it speeds up and bends away from the normal. As the angle of incidence increases, the angle of refraction gets closer to 90 degrees. At the critical angle, the refracted ray is right along the surface. If the angle of incidence is increased further, there's no angle of refraction greater than 90 degrees possible according to Snell's Law. Instead, the energy of the light wave is entirely reflected back into the original medium.

Applications of Total Internal Reflection

TIR is a crucial phenomenon with numerous important applications:

1. Optical Fibres: This is perhaps the most significant application. Optical fibres are thin strands of glass or plastic that transmit data as pulses of light. The light signals are guided along the fibre by repeated total internal reflection at the interface between the high refractive index core and the lower refractive index cladding. This allows for high-speed, long-distance communication with minimal signal loss.
2. Prisms in Optical Instruments: Prisms are used in binoculars, telescopes, and single-lens reflex (SLR) cameras to reflect light and change its path. Using TIR within a prism provides a highly efficient reflection with minimal light loss, often superior to using mirrors.
3. Medical Endoscopes: Endoscopes use bundles of optical fibres to transmit images from inside the human body to a viewing screen. Light is shone into the body through some fibres, and the reflected light carrying the image is transmitted back through other fibres, all relying on TIR.
4. Sensors: TIR-based sensors can be used to measure various physical quantities or detect the presence of specific substances by detecting changes in the conditions required for TIR at an interface.
5. Gemstones: The brilliance and sparkle of gemstones like diamonds are partly due to their high refractive index and the occurrence of total internal reflection within the cut facets, trapping and reflecting light back to the observer.
6. Mirages: While an optical illusion, mirages are a natural example of TIR occurring in the atmosphere. When light passes through layers of air with significantly different temperatures (and thus different refractive indices), it can undergo total internal reflection, creating the appearance of water on a hot road or inverted images of distant objects.

Lasers and Fibre optics

Fibre optics refers to the technology that uses thin, flexible strands of glass or plastic fibres to transmit light signals over long distances. These light signals can carry data, voice, and images at very high speeds.

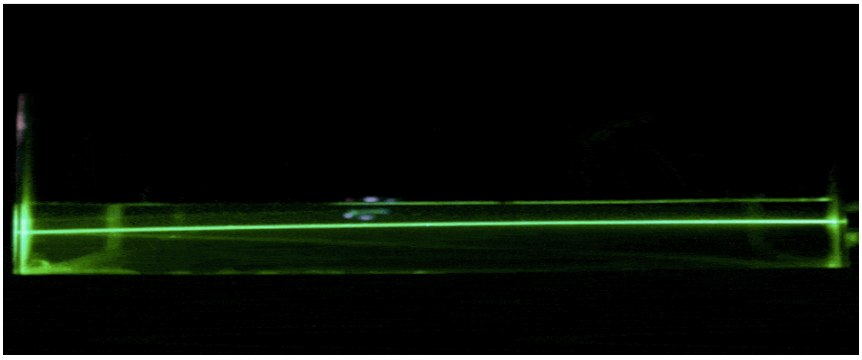


Figure 5.9.8: *A laser light*

How Fibre Optics Work

The working of fibre optics is based on the principle of **Total Internal Reflection (TIR)**. When light enters the core of the fibre at a certain angle, it bounces off the cladding and stays trapped inside the core. This reflection continues along the fibre, allowing the light to travel long distances without escaping.

Properties of Fibre Optics

Table. 5.3: *Properties of Fibre Optics*

Property	Description
High Speed	Can carry huge amounts of data at the speed of light.
Long Distance Transmission	Signal loss is very low, making it ideal for long-distance communication.
Lightweight and Flexible	Easy to install and handle.
Immune to Electromagnetic Interference	Not affected by electrical noise or magnetic fields.
Secure	Difficult to tap into, making it ideal for secure communication.

Activity 5.4: Fibre Optics Demonstration

Objective: To demonstrate how light travels through a fibre using total internal reflection.

Materials: A large transparent plastic bottle, water

1. Laser pointer or flashlight, tape or cork with a small hole

Procedure

1. Fill the bottle with water and make a small hole on its side near the bottom.
2. Shine the laser through the top while water flows out of the hole.
3. Observe how the light bends and follows the stream of water – mimicking total internal reflection inside a fibre.

Differences between laser and fibre optics

Table. 5.4: *Differences between laser and fibre optics*

Feature	Laser	Fibre Optics
Definition	A device that emits light through a process of optical amplification based on stimulated emission of electromagnetic radiation.	A technology that transmits light signals through thin flexible fibres of glass or plastic.
Type of Light	Produces **coherent**, monochromatic, and directional light.	Transmits any light (often laser or LED) through a fibre; the light can be coherent or incoherent.
Purpose	Used to **generate** a focused light beam.	Used to **transmit** light signals from one point to another.
Function	Acts as a **light source**.	Acts as a **light carrier or medium**.
Beam Nature	Very **narrow, intense, and focused beam**.	The light spreads inside the fibre but stays guided within it by total internal reflection.
Direction of Light	Highly directional.	Light bounces along the fibre, maintaining internal direction.
Common Uses	Laser cutting, laser surgery, barcode scanning, CD/DVD reading, laser pointers.	Internet and telecommunication (data transmission), endoscopy, sensors.
Speed of Transmission	Emits light at high intensity but is not used for direct transmission over distance.	Transmits data at **high speeds** over **long distances**.
Core Material	Uses mirrors, gases, crystals, or semiconductors to amplify light.	Uses **glass or plastic fibres** with core and cladding.
Power Requirement	Requires electrical energy to excite atoms.	Requires a light source (like a laser or LED) to transmit data.

Activity 5.5: Building a prototype of periscope

Aim

To understand how light reflects using mirrors and construct a basic periscope that can see over or around obstacles.

Materials: Two small plane mirrors (about 5 cm x 5 cm), a rectangular cardboard box or sturdy cardboard sheets (approximately 30 cm long), ruler, pencil, cutter or scissors, glue or tape, protractor (for measuring 45° angles), black paper (optional, to reduce light inside the periscope)

Procedure

1. **Prepare the Body**
   a. Use a long cardboard box (like a cereal box), or create a rectangular tube using cardboard sheets.
   b. Make sure the box is closed on all sides except for openings at both ends.

2. **Mark Mirror Openings**
   a. At the top and bottom ends of the box, mark two square holes on the front and back faces.
   b. These holes will allow light to enter and exit the periscope.
3. **Cut the Holes**

   Carefully cut out the marked squares using scissors or a cutter.
4. **Mark Mirror Placement**
   a. Inside the box, draw lines at 45° angles near both the top and bottom ends.
   b. Use a protractor to ensure accuracy.
5. **Attach Mirrors**
   a. Place one mirror at the top angled at 45° facing the top opening.
   b. Place the second mirror at the bottom angled at 45° facing the bottom opening.
   c. Secure mirrors with glue or tape.
6. **Close and Finish**
   a. Ensure the box is sealed except for the view holes.
   b. Optionally line the inside with black paper to minimise internal reflections.

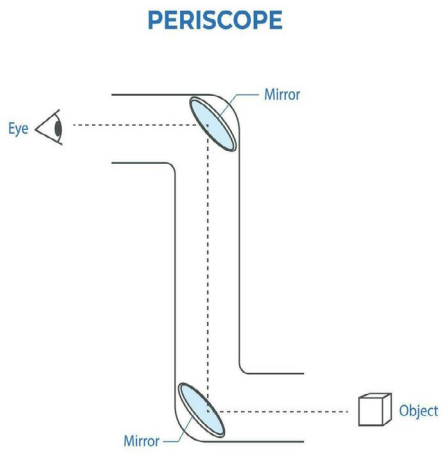


Figure 5.9.9: *A diagram of a periscope*

Learning tasks

1. Explain Snell's law
2. Describe how fibre optics works
3. Calculate the refractive index of media in relations to Snell's law

Pedagogical Exemplars

1. **Guided Inquiry**
   a. Guide learners in mixed ability groups to explore the properties of light energy in fields like photography, communication technology, and medicine.
   b. Encourage learners to present their proposed solutions through written reports, presentations, or visual representations**.**
2. **Concept map**

   Engage learners to use concept maps in discussing the fundamental concepts of light energy such as Snell's Law, Total Internal Reflection, and refractive index and the role of lenses and mirrors in manipulating light.
3. **Experiential learning**
   a. Put learners into small groups and provide them with different types of lenses and mirrors. Encourage learners to experiment with optical devices, observing how light behaves when passing through or reflecting off each surface.
   b. Guide learners to conduct experiments where learners observe the effects of refraction and reflection using lenses and mirrors of different shapes and materials.
4. **Demonstrations and Simulations**
   a. Guide learners to conduct live demonstrations to illustrate Snell's Law and Total Internal Reflection using laser pointers and models.
   b. Let learners in their mixed groups showcase how light rays bend when passing through different media and demonstrate the concept of the critical angle for total internal reflection.
5. **Collaborative Learning**
   a. Assist learners in working in groups to apply the mirror equation to solve calculation questions. Assign questions with respect mirror equation to learners. Allow learners to present their findings to the class.
6. **Research Method**
   a. Encourage learners to conduct independent research on advanced topics related to lenses, mirrors, and their applications in optics. Assign projects that require learners to investigate current research advances in optical technologies and explore innovative uses of lenses and mirrors in various industries**.**

Key Assessment Level 4: Project work

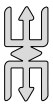
In your group, design and construct a functional optical device, such as a periscope, magnifier, projector, or simple microscope, pin, using locally available materials.

Demonstrate how your model works and explain the scientific principles of reflection or refraction used. Justify how this device could solve a problem in your community or daily life. **(20 marks)**

PLC Session 11

45 minutes | **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to
   a. explain the week's concepts in a practical way that will make it easier for learners to understand
   b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject specific app to plan your lesson. Ask the app to
   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
   b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
   c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



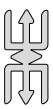
Note

- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Plan the week's key assessment with your app
   a. The key assessment for the week is ***project work***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the project (NTS 3k-3q).

10 minutes | **Content Exploration**

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
   a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
   b. all teachers in the group work through a similar problem individually for 3–4 minutes
   c. the group then works through the problem together step by step
   d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- *This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?*
- *If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.*

- *Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.*

30 minutes **Enactment**

6. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).
   a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
   b. After the enactment, ask for structured feedback from the group
      i. was the concept explained in a way that a learner with no prior knowledge could follow?
      ii. were the examples grounded in contexts familiar to Ghanaian learners?
      iii. did any misconceptions surface and if so, how were they addressed?

5 minutes **Reflection**

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
   a. transfer your chats into your learning planner template.
   b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
   c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 5 Review

In **Week 10**, learners were introduced to the concept of light energy and its uses in daily life and various fields such as communication, medicine, and photography. They identified different sources of light; both natural and artificial; and discussed how light energy is essential for visibility and supports a range of human activities.

Also in Week 10, learners began to explore lenses and mirrors, examining how they manipulate light through reflection and refraction. Using demonstrations and experiments, learners investigated how concave and convex lenses and mirrors function in practical situations.

In **Week 11**, this exploration continued with a deeper focus on the application of lenses and mirrors in everyday life. Learners engaged in hands-on activities and collaborative investigations to observe light behaviour and understand how optical devices are used in spectacles, cameras, telescopes, and other technologies.

By the end of this section, learners had gained a clear understanding of light energy and its interaction with lenses and mirrors.

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 10

Question 1

1. Light energy enables vision by reflecting off objects and entering the human eye. *(1 mark)*
2. When light enters the eye, it is focused by the lens onto the retina, which sends signals to the brain to form an image. *(1 mark)*
3. In homes, artificial light sources like bulbs help people perform tasks such as cooking, reading, and cleaning after sunset. *(1 mark)*
4. In schools, light (usually from fluorescent bulbs or daylight) helps students read the board and write in their books clearly. *(1 mark)*
5. Hospitals require very bright, focused light during operations to see details clearly, often using surgical lamps or high-intensity LEDs. *(1 mark)*
6. Various types of light are used for different situations. For example, a soft bedside lamp creates a relaxing atmosphere, while a bright overhead light helps with reading or working. (2 marks)

(Total 7 marks)

Question 2

Formula:

$$\text{Time} = \frac{\text{Distance}}{\text{Speed}}$$ (1 mark)

Given: Speed of light $= 3 \times 10^8\ m/s$

Distance between Sun and Earth $= 1.5 \times 10^{11} m$

$$Time = \frac{1.5 \times 10^{11} m}{3 \times 10^8\ m/s}$$

$$= 5 \times 10^2 s = 500\ seconds$$ (1 mark)

Change seconds to minutes

$$\frac{500\ seconds}{60} = 8.33\ minutes.$$ (1 mark)

Total marks = 3

Correct Formula (1 mark)

Correct substitution and simplification (1 mark)

Correct final answer with conversion unit (1 mark)

Correct final answer without conversion unit. (½ mark)

Question 3

a. Scoring rubrics and marking scheme

Use the lens formulaCorrect formula and substitution of values: (1 mark)

Correct simplification: (1 mark)

Correct final answer with unit measurement: (1 mark)

Correct answer without or wrong unit measurement. (½ mark)

(Total 3 marks)

b. Usefulness of Convex Lenses in Daily Life. (3 marks)

1. Magnifying Glasses – As seen in this example, convex lenses magnify small objects, helping with reading fine print or examining tiny details.
2. Cameras – They help focus light onto the film or sensor, creating clear images.
3. Eyeglasses & Contact Lenses – Convex lenses correct vision for people with farsightedness by adjusting light focus onto the retina.
4. Projectors – These lenses enlarge images and project them onto a screen.
5. Microscopes & Telescopes – Used to observe tiny or distant objects, crucial for scientific research.

Any 1 well explained 2 marks

Real life example 1 mark

(Total marks 3 marks)

WEEK 11

Scoring rubrics

Design and Construction (5 marks)

1. Using fragile or unsuitable materials, resulting in a device that breaks easily or does not function as expected. (2 marks)

2. Functionality and effectiveness of the device (3 marks)

Demonstration (4 marks)

1. Demonstration of how the optical device works (4 marks)

Scientific Explanation During presentation (5 marks)

1. Explanation of all reflection or refraction principles (3 marks)

2. Use of scientific concepts (2 marks)

Application and Justification (3 marks)

1. Explanation of practical application of the device in daily life (2 marks)

2. Justification for its usefulness in the community (1 mark)

Presentation and Organisation (3 marks)

1. Confidence in presenting the project (1 mark

2. Organised presentation of the project. (1 mark)

3. Group collaboration (1 mark)

(Total 20 marks)

SECTION 6: FORCES AND MOTION

STRAND: VIGOUR BEHIND LIFE

Sub-strand: Forces acting on substances and mechanisms

Learning Outcome: *Explain the concept of momentum and its application*

Content Standard: *Recognise the various forms of forces and their effects on motion.*

INTRODUCTION AND SECTION SUMMARY

In our everyday environment, we are surrounded by forces that affect the motion and behaviour of objects. Whether it's the force of gravity pulling us towards the Earth, friction slowing down a sliding object, or a magnetic force attracting metal, these interactions are part of our daily experiences. Learning about the different types of forces and how they operate helps us understand the physical world better. Additionally, when objects collide, they do so in different ways some bounce apart, while others stick together. These events are described as elastic and inelastic collisions, and they reveal important principles about energy and motion.

In this lesson, we explored the various types of forces, including gravitational, frictional, magnetic, and applied forces, along with their practical applications in everyday life. We also examined the differences between elastic and inelastic collisions. Elastic collisions conserve kinetic energy and involve objects rebounding off each other, while inelastic collisions result in a loss of kinetic energy and may cause objects to stick together or deform. Understanding these concepts helps us analyse how objects move and interact, both in natural settings and in human-made systems like transportation and sports.

The weeks and the indicators covered by the section are:

Week 12

- Identify different types of forces and their daily applications.
- Examine the differences between elastic and inelastic collisions of moving objects.

SUMMARY OF Pedagogical Exemplars

This instructional framework integrates inquiry-based, collaborative, experiential, and application-based learning strategies to enhance students' understanding of forces, friction, and collisions. Through hands-on experiments and investigations at learning stations, learners explore types and applications of forces and friction, ask questions, make predictions, and draw conclusions based on their observations. Collaborative learning is promoted through group discussions, peer teaching, and think-pair-share activities, allowing learners to analyse fluid friction, share findings, and suggest methods of reducing friction. Mixed-ability group work and simulations make abstract concepts more tangible and encourage deeper peer interactions. Experiential learning activities enable learners to observe elastic and inelastic collisions and relate them to theoretical concepts, while application-based learning through real-world case studies, such as car and sports collisions, allows students to apply knowledge and propose collision-avoidance strategies. These ideas are communicated through poster presentations and gallery walks, promoting critical thinking, creativity, and real-world connections.

ASSESSMENT SUMMARY

This assessment combines tasks that develop both critical thinking and conceptual understanding in learners. At Level 4, learners are presented with real-life scenarios requiring them to identify various types of forces such as gravitational, frictional, magnetic, applied, and tension; and explain how these forces operate and interact in everyday situations like opening a door, pushing a swing, or the motion of a falling object. This challenges learners to apply their scientific knowledge across multiple contexts, reason through cause-and-effect relationships, and justify their responses. At Level 2, learners are given multiple-choice questions to examine the differences between elastic and inelastic collisions, using familiar examples such as bouncing balls or vehicle impacts. They must demonstrate understanding of concepts such as energy conservation and momentum transfer, supported by basic calculations or diagrams. By completing these tasks, learners should know the types and effects of forces, understand how energy behaves during collisions, and be able to apply this knowledge in both theoretical and practical contexts using appropriate scientific reasoning and vocabulary.

Indicators	DOK Level	Assessment Strategy and/or Mode
Identify different types of forces and their daily applications.	Level 4 Extended critical thinking and reasoning	Case study
Examine the differences between elastic and inelastic collisions of moving objects.	Level 2: Skills of conceptual understanding	Multiple choice question

WEEK 12

Learning Indicators

1. *Identify different types of forces and their daily applications*
2. *Examine the differences between elastic and inelastic collisions of moving objects*

Focal Area: Understanding Forces and Their Everyday Roles

Introduction to Forces

In simple terms, a force is a push or a pull acting on an object. This interaction can cause an object to change its state of motion (i.e., to start moving, stop moving, speed up, slow down, or change direction) or to change its shape. Force is a vector quantity, meaning it has both magnitude (how much force) and direction.

Units of Force

The standard unit of force in the International System of Units (SI) is the Newton (N). One Newton is defined as the force required to accelerate a one-kilogram mass at a rate of one meter per second squared ($1\ N = 1\ kg{\cdot}m/s^2$).

Types of Forces

Forces can be broadly categorised into contact forces and non-contact forces (or forces at a distance).

1. **Contact Forces**: Contact forces are types of forces that result when the two interacting objects are perceived to be physically contacting each other. Examples of contact force:
   a. **Muscular force (Applied Force):** This is the force exerted by the action of muscles in living beings (humans or animals). It's the force we use for everyday activities like lifting, pushing, pulling, walking, and even internal bodily functions like breathing and digestion. Examples of force pushing a door, pulling a cart, lifting a bag, chewing food, an animal ploughing a field.
   b. **Normal Force:** When an object rests on a surface, the surface exerts a push on the object that is perpendicular to the surface. This supporting force is called the normal force. Examples of normal force: A book resting on a table is supported by the normal force from the table and A person standing on the ground are supported by the normal force from the ground.
   c. **Tension Force:** This is the force transmitted through a string, rope, cable, or wire when it is pulled tight by forces acting from opposite ends. The tension force is directed along the length of the wire and pulls equally on the objects on the opposite ends of the wire. Examples are pulling a bucket of water from a well using a rope, a tug-of-war and the force in a guitar string.
   d. **Spring Force:** This is the force exerted by a compressed or stretched spring upon any object that is attached to it. The force acts to restore the spring to its original (equilibrium) shape. Example of force:
      i. Pens with click mechanisms use springs to extend and retract the pen tip.
      ii. Door closers have springs that automatically pull doors to shut after opening.
      iii. Spring mattresses and cushions contain coils that compress and return to shape for comfort and support.
      iv. Trampolines use springs to provide the bouncing action when someone jumps.

v. Mechanical clocks and watches rely on wound springs to store and release energy gradually.
vi. Suspension systems in vehicles include springs to absorb shocks and maintain stability.
vii. Wind-up toys use internal springs to store energy and create motion when released.
viii. Clothespins and paper clips include springs to maintain a firm grip on objects.
ix. Spring-based weighing scales measure weight based on how much the spring stretches.
x. Safety pins use springs to enable secure opening and closing mechanisms.

e. **Upthrust: Upthrust**, also known as buoyant force, is the upward force that a fluid (like water or air) exerts on an object placed in it.

Example of Upthrust:

i. When you swim, you feel lighter in water. That is because upthrust pushes your body upward, helping you float.
ii. Boats and ships float on water because the upthrust balances their weight. Their shape helps them displace enough water to stay afloat.
iii. Plastic or wooden fishing floats stay on the surface of water due to upthrust. When a fish pulls on the line, the float may dip — showing a change in balance.
iv. Submarines control upthrust by filling or emptying tanks with water or air. This helps them sink or float as needed.
v. In air (a gas), upthrust also acts. A hot air balloon rises because heated air inside is lighter, creating greater upthrust than the balloon's weight.

2. **Non-Contact Forces (Forces at a Distance)**

These forces act between two objects even when they are not in physical contact with each other.

a. **Gravitational Force:** This is the force of attraction between any two objects with mass. The more massive the objects and the closer they are, the stronger the gravitational force. Earth's gravity pulls everything towards its centre. Example of gravitational force:

i. Keeps us and objects on the ground.
ii. Responsible for the orbits of planets around the Sun and the Moon around the Earth.
iii. One of the best examples of gravitational force is a falling object. When you drop a book, it falls to the ground due to the gravitational force pulling it downward.
iv. The gravitational pull of the Moon and the Sun on Earth's oceans causes the rise and fall of tides.

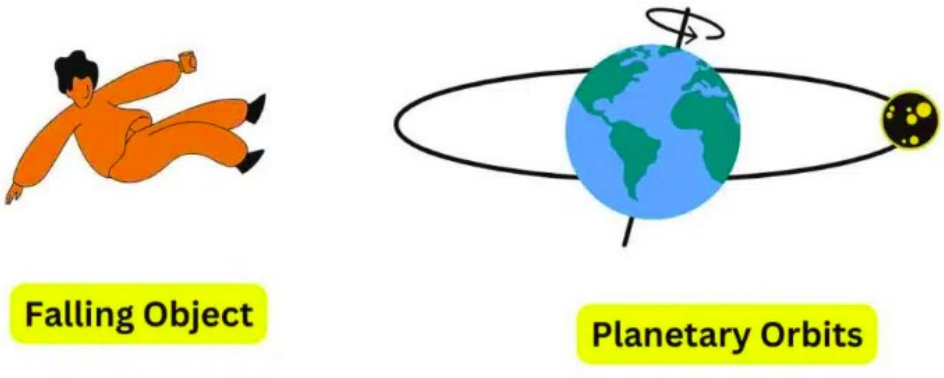


Figure. 6.0: *Gravitational force*

b. **Magnetic Force:** This force is exerted by magnets on magnetic materials (like iron, nickel, cobalt) or other magnets. It can be attractive (pulling together) or repulsive (pushing apart). Magnets have two poles (North and South); like poles repel, and opposite poles attract. Example of magnetic force:

   i. Magnets help keep refrigerator and freezer doors tightly closed. A magnetic strip inside the rubber seal ensures the door stays shut, preserving cool air and saving energy.

   ii. Magnets are used in the speakers, microphones, and vibration motors of smartphones and laptops. Some laptop lids also use magnets to trigger sleep mode when closed.

   iii. Electromagnets are used in traditional mechanical doorbells. When pressed, the circuit activates an electromagnet that pulls a metal striker to hit a bell.

   iv. Magnets are used in MRI (Magnetic Resonance Imaging) machines, which produce detailed internal body images without using X-rays.

   v. Motors in electric fans and washing machines use electromagnets to convert electricity into motion.

c. **Electrostatic Force:** This force exists between electrically charged objects or particles. Like charges repel each other, while opposite charges attract. This force arises from the accumulation of electric charge on the surface of an object, often due to friction. Example of electrostatic force:

   i. Clothes cling together due to static electricity after drying.

   ii. Spray painting uses electrostatic forces for even coating.

   iii. Lightning occurs due to charge buildup in clouds.

   iv. Hair stands up when rubbed with certain materials due to static buildup.

   v. Plastic wrap sticks to surfaces using electrostatic adhesion.

   vi. Charged balloons attract small paper pieces.

   vii. Electrostatic charges help in inkjet printing.

d. **Frictional Force:** Friction is a contact force that opposes the relative motion or the tendency of such motion between two surfaces in contact. It acts parallel to the surfaces.

Types of Friction

a. **Static friction:** The friction that acts on objects when they are stationary and prevents them from starting to move. For example, the force that keeps a heavy box from moving when you first start to push it. Static friction is generally greater than kinetic friction.

b. **Kinetic friction (Dynamic Friction):** The friction that acts on objects when they are moving.

   i. Sliding Friction: Occurs when one solid surface slides over another (e.g., pushing a book across a table).

   ii. Rolling Friction: Occurs when an object rolls over a surface (e.g., a ball rolling, wheels of a car). Rolling friction is generally much less than sliding friction, which is why wheels are so useful.

How Friction Helps Motion (Advantages)

1. Walking/Running: Friction between our shoes and the ground allows us to push off and move forward without slipping.
2. Gripping: Friction allows us to hold objects.
3. Writing: Friction between a pen/pencil and paper allows the ink/graphite to transfer.
4. Braking: Brakes in vehicles use friction to slow down or stop.
5. Lighting a matchstick: Friction generates heat to ignite the match.
6. Holding nails and screws: Friction keeps them in place in wood or walls.

How Friction Reduces Motion (Disadvantages)

1. Wear and tear: Friction causes rubbing surfaces to wear out over time (e.g., soles of shoes, machine parts, tires).
2. Energy loss: Friction converts useful kinetic energy into heat, reducing the efficiency of machines. For example, parts of a machine get hot due to friction.
3. Makes movement difficult: We need to apply more force to overcome friction when moving objects.

Factors Affecting Friction

Two main factors influence the amount of friction between solid surfaces:

1. Nature of the surfaces in contact**:** Rougher surfaces generally have more friction than smoother surfaces. This is due to the interlocking of irregularities on the surfaces.
2. Normal Force (How hard surfaces are pressed together): The greater the force pressing the two surfaces together (the normal force), the greater the friction. This is why it's harder to push a heavy box than a light one across the same surface.

Fluid Friction (Drag)

Fluid friction, also known as drag, is the force that opposes the motion of an object through a fluid (a liquid or a gas).

Factors Influencing Fluid Friction

1. Viscosity of the fluid: Viscosity is a measure of a fluid's resistance to flow. Thicker, more viscous fluids (like honey) cause more friction than thinner fluids (like water or air).
2. Shape of the object: Objects with a streamlined shape (pointed at the ends and broader in the middle, like a fish or an airplane wing) experience less fluid friction.
3. Speed of the object: Fluid friction increases with the speed of the object moving through the fluid. The faster an object moves, the greater the drag.
4. Surface area of the object: A larger surface area exposed to the fluid generally leads to greater fluid friction.
5. Nature of the fluid: Denser fluids generally exert more drag.
6. Temperature of the fluid: For gases, fluid friction generally increases with temperature. For liquids, viscosity (and thus fluid friction) often decreases with increasing temperature.

Ways of Reducing Friction

In many situations, reducing friction is desirable to improve efficiency and reduce wear.

1. Lubrication: Applying lubricants like oil, grease, or graphite between moving parts creates a thin film that separates the surfaces, reducing direct contact and friction. This is common in engine parts and bicycle chains.
2. Streamlining: Designing objects with smooth, tapered shapes (streamlined shapes) allows fluids (air or water) to flow past them more easily, reducing drag. Examples include the bodies of airplanes, racing cars, ships, and even birds and fish.
3. Using rollers/Ball bearings: Replacing sliding friction with rolling friction significantly reduces frictional forces. Ball bearings are used in wheels, motors, and many machines.
4. Polishing Surfaces: Making surfaces smoother reduces the irregularities that interlock, thereby decreasing friction.
5. Using appropriate materials: Some materials have naturally lower coefficients of friction (e.g., PTFE, also known as Teflon).
6. Reducing contact area (in some specific cases of fluid friction): While for solid friction, area of contact has little direct effect (it is more about normal force and surface nature), for fluid friction, minimising the frontal area can reduce drag.

Increasing Friction (When necessary)

Sometimes, friction is essential and needs to be increased for safety or functionality.

1. Treads on tires and shoes: The grooves (treads) on tires and shoe soles increase friction, providing better grip on the road or ground, especially in wet conditions.
2. Brake pads: Brake pads in vehicles are made of materials that create high friction when pressed against the brake discs or drums, allowing the vehicle to slow down or stop effectively.
3. Using rougher surfaces: For example, gymnasts apply coarse powder to their hands for a better grip. Kabaddi players might rub their hands with soil.
4. Increasing the normal Force: Pressing surfaces together more firmly increases friction.
5. Stopping relative motion: Static friction is generally higher than kinetic friction.

Daily applications of Forces (The 3E Learning Model: Engage, Explore, Explain)

The 3E Learning Model provides a framework to understand these real-life applications.

1. **Engage:** This stage piques curiosity.

   Think about it: Why does a ball thrown upwards always come down? How can you pick up small pieces of paper with a comb after running it through your hair? Why is it easier to skate on ice than on a rough road? How do boats float?
2. **Explore:** This stage involves hands-on investigation and observation. Try this:

   a. Push a toy car on a smooth floor and then on a carpet. What do you observe about its motion?
   b. Drop a feather and a small stone simultaneously. Which one reaches the ground first? Why?
   c. Bring two magnets close to each other in different orientations. What happens?
   d. Rub a balloon on your sweater and try to stick it to a wall or bring it near small pieces of paper.

3. **Explain:** This stage connects observations to scientific concepts. Understanding the 'Why':
   a. **Pushing/Pulling:** When you push a door (muscular force), you are applying a force to move it. When you pull a drawer open (muscular force), you are applying a force to change its position.

b. **Resisting motion (Friction):** The toy car stops sooner on the carpet because the frictional force between the carpet and the wheels is greater than between the smooth floor and the wheels. Friction always opposes motion.

c. **Lifting (Upthrust/Buoyancy):** When an object is immersed in a fluid (like water or air), it experiences an upward force called upthrust or buoyant force. If the upthrust is equal to or greater than the object's weight, the object floats. This is why ships made of heavy steel can float – their shape displaces a large volume of water, creating a large upthrust. Animals like fish use upthrust to control their depth in water.

d. **Magnetism in daily life:** Refrigerator magnets stick due to magnetic force. A compass needle aligns with Earth's magnetic field to show direction.

Activity 6.1: Understanding application of forces through 3E (Engage–Explore–Explain)

Frictional force

1. **Engage (Get learners interested)**

Instructions

a. Let learners in a mixed group watch a short video clip or perform simple demos such as pushing a toy car, stretching a rubber band, dropping a ball and pulling a chair.

b. Ask them to discuss: "What do you notice happening?", "What made the car move or the rubber band stretch?" and "Have you ever used force today without thinking about it?" "What Just Happened?"

2. **Explore (Hands-on and minds-on learning)**

Activity 6.2: Instructions

Set up **5 stations** around the class. Learners rotate in small groups to explore different types of force and their applications.

Station	Activity	Type of Force	Sample Materials
a	Push a toy car		Toy cars, ramps
b	Pull a box using string		Boxes, ropes
c	Stretch a rubber band		Rubber bands
d	Drop a ball		Balls of different sizes
e	Use a magnet to attract nails		Magnets, nails

Worksheet
Complete the table for each station activity

Question	Response
Action	

What happened?	
What type of force was applied?	
Real-life example of this force	

Purpose
Allow students to observe, manipulate, and record how different forces act in real-world contexts.

3. Explain (Connect experiences to concepts)

Instructions

a. Put learners in mixed-ability and guide them to discuss their observations at each station.

b. Let learners discuss types of forces: push and Pull (basic mechanical forces), friction (e.g., slowing down a sliding object), tension (in ropes or strings), spring, Force (in stretched or compressed materials), gravitational force (falling objects) and magnetic force (attraction or repulsion of magnetic materials)

Key questions for discussion

1. What do all these forces have in common?
2. What happens when no force is applied?
3. Where do you experience each type of force at home or in school?

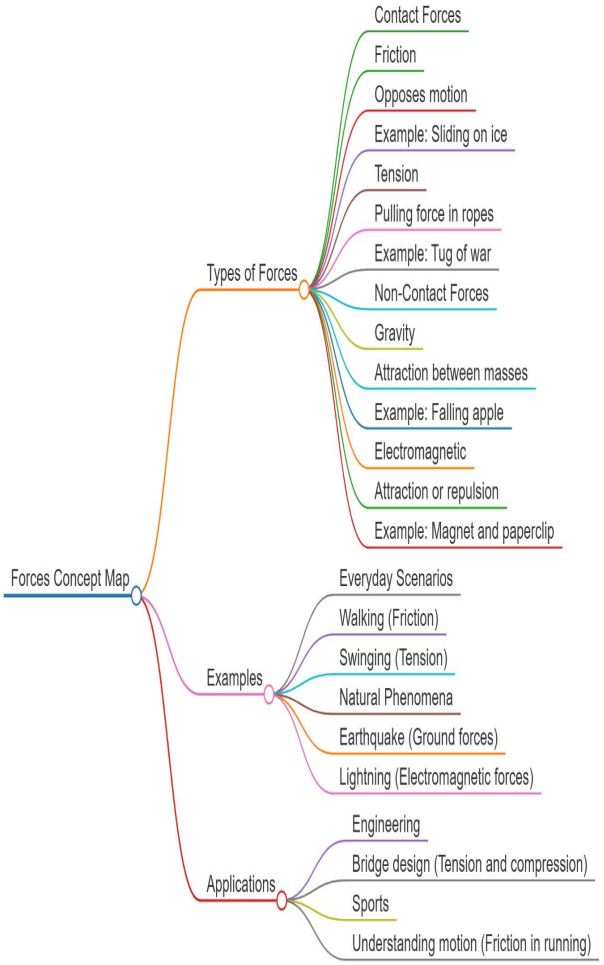


Figure 6.1: *Concept map on forces*

Activity 6.3: Upthrust: "Why do some objects float?"

Objective

To observe and explain how upthrust affects whether an object floats or sinks in water.

Materials Needed (per group): Clear container or bucket with water, small plastic bottle with cap, stone or metal spoon, wooden block, rubber ball, small spring balance, string

Procedures

Step 1: Predict

Ask learners to look at each object and predict whether it will float or sink. Ask them to write their predictions down.

Step 2: Test

1. Drop each object into the container of water one at a time.
2. Observe which objects sink, which float, and which stay in between.
3. Discuss the results as a group.

Step 3: Feel the Difference

Let learners hold an object in air, then slowly lower it into the water while holding it with their hand.

Key questions

1. Does the object feel lighter in water?
2. What could be pushing it up?

Viscosity

It is the measure of a liquid's resistance to flow.

Activity 6.4: Viscosity

Aim: To show viscosity in liquids

Engagement

Materials (per group): A small ramp (e.g., a smooth board or tray tilted with books), stopwatch or phone timer, measuring cup, marker, liquids to test (e.g., water, cooking oil, shampoo, liquid soap, honey) and spoons or small cups for pouring.

Procedure

1. Mark a start and finish line on the ramp.
2. Pour a spoonful of each liquid at the top of the ramp and start the timer.
3. Time how long it takes each liquid to reach the bottom.
4. Record the time for each liquid.
5. Compare results and rank the liquids from fastest to slowest.

Explanation

- Liquids that flow slowly have high viscosity (e.g., honey).
- Liquids that flow quickly have low viscosity (e.g., water).
- The thicker the liquid, the greater the resistance to flow.

Activity 6.5: Explore Methods of Reducing Friction

Activity: The Great Slide-Off

Setup: Create a ramp. Have various small, identical objects (e.g., wooden blocks).

Aim: Measure how far an object slides off the ramp onto a standard surface (e.g., a table).

Procedure

1. Place a sheet of sandpaper on the sliding surface (increases friction).
2. Place a smooth, polished surface (e.g., wax paper or a polished tile).
3. Sprinkle a fine powder (like talcum powder) on the surface.
4. Place a few straws or round pencils under the object to act as rollers.
5. (If safe and appropriate) Apply a tiny amount of oil to a surface (demonstrating lubrication, with caution and proper clean-up).

Measure and compare: Learners measure how far the object slides with each modification.

Discussion: Which methods were most effective in reducing friction? How do these methods relate to real-world applications (e.g., oil in engines, ball bearings in wheels, polishing floors)?

Collisions

In the realm of physics, a collision is a dynamic event where two or more objects exert forces on each other over a relatively short period. These interactions are fundamental to understanding the motion of objects and are governed by the foundational principles of conservation of momentum and energy. Collisions can be broadly classified into two main categories: elastic and inelastic collisions. The key distinction between them lies in the conservation of kinetic energy.

Elastic Collisions

An elastic collision is defined as a collision in which the total kinetic energy of the system remains constant. This means that the sum of the kinetic energies of the colliding objects before the collision is equal to the sum of their kinetic energies after the collision. In an ideal elastic collision, there is no loss of kinetic energy to other forms such as heat, sound, or deformation of the objects.

Characteristics of Elastic Collisions

1. **Conservation of momentum:** The total momentum of the system is conserved. This is a universal principle for all collisions in an isolated system.
2. **Conservation of kinetic energy:** The total kinetic energy of the system is conserved.
3. **Reversible process:** The objects bounce off each other, and the collision process is theoretically reversible.

Real-World Examples

While perfectly elastic collisions are an idealisation and do not truly occur in our everyday experience, some scenarios come very close. Examples include:

1. **Steel ball bearing:** The collision between two steel ball bearing is a classic example that approximates an elastic collision.
2. **Atomic and Subatomic Particles:** Collisions between atoms and subatomic particles, such as those in a gas, are considered to be almost perfectly elastic.
3. **Newton's Cradle:** The interaction between the swinging balls in a Newton's cradle demonstrates the principles of an elastic collision.

Activity 6.6: Newton's Cradle (Homemade Version)

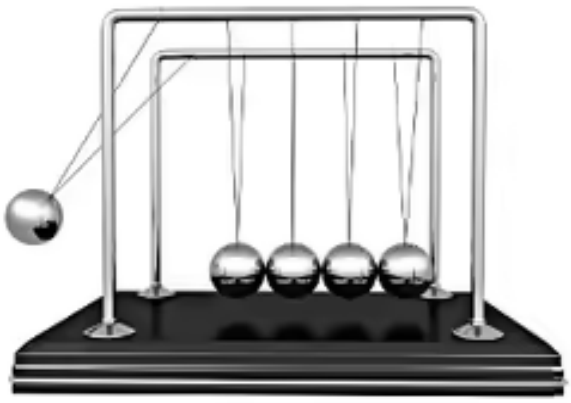
Title: To explore Newton's Cradle

Materials Needed: Five small metal balls (e.g., marbles, ball bearings, or even round beads), strong string or thread, A stiff cardboard box, wooden frame, or hanger (as a support), Glue or tape, ruler and scissors

Procedures

1. Make 5 holes in the top of the frame or hanger, evenly spaced.
2. Tie strings around each ball, making sure each hang at the same height and barely touches the next.
3. Suspend each ball from the frame so they are in a straight line and just touching each other.
4. Roll one marble toward the stationary ones and observe what happens.
5. Repeat by rolling two marbles at once.

Observation: The number of marbles that move on the opposite end should equal the number that hit from one side; demonstrating momentum transfer.



Mathematical Representation

For a one-dimensional elastic collision between two objects with masses m_1 and m_2, and initial velocities u_1 and u_2, their final velocities v_1 and v_2 can be determined using the conservation of momentum and kinetic energy equations.

1. **Conservation of momentum**
   a. $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

2. **Conservation of Kinetic Energy**
   $\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$

Worked examples

1. A 5 kg object is moving at a velocity of 3 m/s. What is its momentum?

   Solution

   Mass= 5kg, v= 3 m/s

   $p = m \times v$

   $= 5\ kg \times 3\ m/s = 15\ kgm/s$

Inelastic Collisions

In contrast to elastic collisions, an inelastic collision is one where the total kinetic energy of the system is not conserved. While momentum is still conserved in an inelastic collision, some of the initial kinetic energy is transformed into other forms of energy, such as thermal energy (heat), sound energy, and the energy required for permanent deformation of the colliding objects.

Characteristics of inelastic collisions

1. **Conservation of Momentum:** The total momentum of the system is conserved.
2. **Non-conservation of Kinetic Energy:** The total kinetic energy of the system decreases during the collision.
3. **Irreversible Process:** The collision process is not reversible due to the energy lost to other forms.

Types of inelastic collisions

1. **Inelastic Collision:** The objects may or may not stick together after the collision.
2. **Perfectly Inelastic Collision:** This is a specific type of inelastic collision where the objects stick together after impact and move with a common final velocity. This results in the maximum possible loss of kinetic energy.

Real-World Examples

Most collisions in the world are inelastic. Examples include:

1. **Car accidents:** A significant amount of kinetic energy is converted into the crumpling of the car bodies, sound, and heat.

2. **A bullet embedding in a target:** When a bullet is fired into a block of wood and becomes embedded, it's a perfectly inelastic collision.
3. **A ball of clay dropped on the floor:** The clay deforms and does not bounce, indicating a loss of kinetic energy.

Mathematical representation

For a perfectly inelastic collision where two objects stick together, the conservation of momentum is used to find their common final velocity (v_f).

Conservation of Momentum

$$\mathbf{P_{-initial} = P_{-final}}$$

$$m_1u_1 + m_2u_2 = (m_1 + m_2)v_f$$

Classroom Application

1. **Experiments and Simulations:** Teachers can facilitate experiments using air tracks, carts, and motion sensors to allow students to observe and collect data on different types of collisions. Simulations can also be used to explore scenarios that are difficult to replicate in a classroom setting.
2. **Guiding Questions:** Instead of providing direct answers, teachers can pose guiding questions to prompt students to analyse their observations and formulate their own conclusions about the conservation of momentum and energy in different collision scenarios.
3. **Real-World Analysis:** Students can be tasked with analysing real-world examples of collisions, such as sports footage or videos of car crashes, to identify the type of collision and explain the energy transformations involved.

Learning Tasks

1. Create comprehensive concept maps to explain different types of forces and their applications
2. Explore, and Explain friction forces using the 3E learning model
3. Compare elastic and inelastic collisions through hands-on exploration

Pedagogical Exemplars

1. **Inquiry-based learning**
   a. Encourage learners to explore types of forces, application of forces and friction through hands-on experiments and investigations at learning stations.
   b. Allow learners to ask questions, make predictions, and draw conclusions based on their observations through presentations.
2. **Collaborative learning**
   a. Facilitate group discussions and collaborative projects where learners can work together to analyse factors influencing fluid friction and effects of frictional force
   b. Engage learners to share their findings and collectively discuss ways of reducing friction.

3. **Experiential learning**
   a. Let learners utilise hands-on experiments and demonstrations to allow them to observe the concepts of collisions
   b. Encourage learners to draw connections between the experimental observations and the theoretical principles of elastic and inelastic collisions.
4. **Collaborative learning**
   a. Organise learners in mixed-ability groups for discussions on real-world examples and simulations to make abstract concepts more tangible and relatable.
   b. Encourage peer teaching and learning, think-pair-share, where learners can explain concepts to each other.
5. **Application-based learning / Case Study**
   a. Provide opportunities for students to apply their knowledge of elastic and inelastic collisions in practical scenarios such as car collisions, sports collisions etc.
   b. Encourage learners to devise ways of avoiding collision of moving objects and present their work for poster presentation and gallery walk.

Key Assessment: Practice Paper 1

Choose the correct answer

1. Two identical carts on a frictionless track collide and bounce off. If total kinetic energy before and after is the same, what type of collision occurred?
   A. Explosive
   B. Elastic
   C. Inelastic
   D. Static
2. A 4 kg object moving at 3 m/s collides with a 2 kg object at rest. If they stick together, what is the final velocity?
   A. 2 m/s
   B. 1.5 m/s
   C. 3 m/s
   D. 6 m/s

Use the diagram below to answer question 3.

3. Which force is used in pushing the box?

   A. Normal force
   B. Gravitational force
   C. Frictional force
   D. Applied force

Study the table below and use it to answer question 4

Object	Initial Momentum (kg·m/s)	Final Momentum (kg·m/s)
A	10	4
B	0	6
Total	10	10

5. Which type of collision is likely represented?
   A. Inelastic
   B. Elastic
   C. Explosive
   D. Both collision

6. Two objects stick together after colliding. Object A (3 kg) moves at 2 m/s; B (2 kg) is stationary. What is their common velocity after the collision?

   A. 1.2 m/s
   B. 1.5 m/s
   C. 1.8 m/s
   D. 2.0 m/s

HINT

*Conduct **Practice Paper 1**. It should cover contents taught from Year 1 to 3. Refer to the **Table of Specification and Structure of the Paper** at the end of this section. Learners' papers should be marked immediately and scores entered into the SAP.*

TEST SPECIFICATION TABLE- PAPER ONE

Strand	Sub-strand	Indicator	DOK level				Total
			1	2	3	4	
1. Exploring materials	Science and materials in nature	Explain the characteristics of science in nature.		1	1		
		design projects using the characteristics of science			1		
		apply the characteristics of science where appropriate.	1				
		classify different solids and their uses			1		
		apply the properties of solids to everyday use		1			
		discuss the relationship between binary compounds, the composition of binary compounds and the names of compounds			1		

		differentiate among acids, bases and water.			1		
		apply the knowledge of acids and bases in analysing the formation of salts and their uses	1	1			
		describe how to measure the concentration of solutions and how to use the pH scale to identify the concentration of acids and bases/	1	1			
		identify air as a mixture and explain the uses of the components of air.	1				
		prepare carbon (IV) oxide and discuss its uses.	1		1		
		prepare oxygen and discuss its uses		1			
		total for stand 1	**5**	**5**	**6**	**0**	**16**
2	Essentials for survival	Design, model and explain the process of osmosis and indicate its application to everyday life	1	1			
		explain the concept of diffusion and its application in life			1		
		explain reproduction in plants and humans.			1		
		explain the female menstrual cycle and show how that can be used to address reproduction-related issues.		1			
		apply knowledge of reproduction-related issues (teenage pregnancy, STI, reproductive health) to address challenges of adolescent reproductive health.		1			
		analyse the structure and function of the excretory organs in the human body.			1		
		describe the processes for the removal of waste from the human body		1			
		evaluate disorders of the human excretory organ system			1		

		explain, with diagrams, the concept of the movement of air in humans and its importance.	1				
		describe the structure of the lungs and investigate the products of aerobic respiration		1			
		discuss disorders associated with the respiratory system			1		
		analyse the central nervous system			1		
		explain the peripheral nervous system		1			
		describe the structure and functions of the neurons	1				
		model and discuss the structure of the skeleton and muscles	1				
		demonstrate and explain the structure and function of the movement of muscle tissues			1		
		total for strand 2	**4**	**6**	**7**	**0**	**17**
3. Vigour behind life	Powering the future with energy forms Explore consumer electronic careers	Describe the generation of electricity from solar cells/panels			1		
		design and build Solar panels using locally available materials			1		
		explain the concept of electrical energy and power	1				
		explain the principle of the transformer and its function		1			
		explain the concept of light energy and its uses	1				
		explore lenses and mirrors in relation to light energy in life	1				
		identify and explain concepts associated with forces		1			
		discuss the relationship between upthrust and the law of floatation.			1		
		identify different types of forces and their daily applications.	1				

		explain the uses of electronic components in household electronic devices and amplifiers			1		
		explain the principle of 'doping' behaviour in relation to semiconductors		1			
		perform experiments using circuits containing LEDs and diodes to build phone chargers.	1				
		discuss consumer electronic devices and their components			1		
		explore Consumer Electronic careers		1	1		
		total for strand 3	**5**	**4**	**6**	**0**	**15**
4. Relationships with the environment	The human body and health	Describe the process of local soap production.	1		1		
		explain the processes of producing different types of soap.	1		1		
		investigate the production of an indigenous food to identify the science processes in the stages of production.		1	1		
		explain the science in the production of indigenous beverage		1			
		design an experiment to produce a local beverage	1		1		
		analyse the scientific processes involved in gari production	1	1	1		
		total for strand 4	**4**	**3**	**5**	**0**	**12**
Overall total			**16**	**17**	**15**	12	**60**

TEST SPECIFICATION TABLE FOR PAPER 2 SECTION A

Strand	Sub- strand	Learning Indicator	Levels of Assessment				Total
			L1	L2	L3	L4	
1	Science and Materials in Nature	Design projects using the characteristics of science Apply the knowledge of acids and bases in analysing the formation of salts and their uses		1	1		2
2	Essentials for Survival	Design, model and explain the process of osmosis and indicate its application to everyday life Explain the female menstrual cycle and show how that can be used to address reproduction-related issues. Describe the processes for the removal of waste from the human body		1	1	1	3
3	Powering the Future with Energy Forms. Forces acting on substance and mechanisms. Consumer Electronics	Explain the concept of electrical energy and power			1		1
		Explain the concept of light energy and its uses			1		1
		Discuss consumer electronic devices and their components			1		1
4	The Human Body And Health Technology in our local industries.	Investigate the production of an indigenous food to identify the science processes in the stages of production.			1		1
		Analyse the scientific processes involved in gari production			1		1
Total				**2**	**7**	**1**	**10**
				20%	**70%**	**10%**	**100%**

SECTION B

Strand	Sub- strand	Learning Indicator	Levels of Assessment				Total
			L1	L2	L3	L4	
1	Science and Materials in Nature	Differentiate among acids, bases and water. Apply the characteristics of science where appropriate. Classify different solids and their uses Apply the knowledge of acids and bases in analysing the formation of salts and their uses Describe how to measure the concentration of solutions and how to use the pH scale to identify the concentration of acids and bases/ alkalis. Discuss the relationship between binary compounds, the composition of binary compounds and the names of compounds		1 1 1 1	 1 1		6
2	Essentials for Survival	Design, model and explain the process of osmosis and indicate its application to everyday life Explain the concept of diffusion and its application in life Explain reproduction in plants and humans. Apply knowledge of reproduction-related issues (teenage pregnancy, STI, reproductive health) to address challenges of adolescent reproductive health. Analyse the structure and function of the excretory organs in the human body. Evaluate disorders of the human excretory organ system Demonstrate and explain the structure and function of the movement of muscle tissues Model and discuss the structure of the skeleton and muscles		1 1 1 1 1	1 1 1 1		8

3	Powering the Future with Energy Forms. Forces acting on substance and mechanisms. Consumer Electronics	Identify and explain concepts associated with forces Describe the generation of electricity from solar cells/panels Explain the uses of electronic components in household electronic devices and amplifiers		1 1	1		3
		Explain the uses of electronic components in household electronic devices and amplifiers Perform experiments using circuits containing LEDs and diodes to build phone chargers.			1 1		3
		Explore Consumer Electronic careers		1			
4	The Human Body and Health Technology in 23our local industries.	Explain the processes of producing different types of soap. Explain the science in the production of indigenous beer/gin. Design an experiment to produce a local beverage Analyse the scientific processes involved in gari production		1	1 1 1		4
Total						**0**	**24**

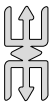
TEST SPECIFICATION TABLE FOR PAPER 3 (TEST OF PRACTICAL)

STRAND	SUB-STRAND	NO. OF QUESTIONS
Exploring Materials	Science and Materials in Nature	1
PROCESSES FOR LIVING	ESSENTIALS FOR SURVIVAL	1
VIGOUR BEHIND LIFE	POWERING THE FUTURE WITH ENERGY FORMS	1
RELATIONSHIPS WITH THE ENVIRONMENT	THE HUMAN BODY AND HEALTH	1
TOTAL		**4**

PLC Session 12

45 minutes | **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous session, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to
   a. explain the week's concepts in a practical way that will make it easier for learners to understand.
   b. identify three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners (NTS 3a, 3g and 3m).
3. Use your subject specific app to plan your lesson. Ask the app to
   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
   b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q).
   c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



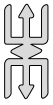
Note

- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Use your app to plan and administer the mode of assessment for the Student Assessment Portal (SAP)
   a. The key assessment for the week is ***practice paper 1***. Chat with your app to plan this assessment by reviewing or developing the assessment items/tasks and marking schemes/rubrics for the practice paper (NTS 3k-3q).

10 minutes | **Content Exploration**

5. As a subject group, select one problem or topic/idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
   a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
   b. all teachers in the group work through the problem individually for 3–4 minutes
   c. the group then works through it together the problem, step by step
   d. highlight the most common errors made at each step (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- *This part is not 'How do I teach this?' but how do I teach it for learners to understand?*
- *If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.*

- *Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.*

30 minutes **Enactment**

6. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).
   a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
   b. After the enactment, ask for structured feedback from the group
      i. was the concept explained in a way that a learner with no prior knowledge could follow?
      ii. were the examples grounded in contexts familiar to Ghanaian learners?
      iii. did any misconceptions surface and if so, how were they addressed?

5 minutes **Reflection**

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
   a. transfer your chats into your learning planner template.
   b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
   c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 6 Review

In this section, we learned that forces are pushes or pulls that can cause objects to move, stop, change direction, or change shape. The main types of forces include gravitational force, which pulls objects toward the Earth; frictional force, which opposes motion between surfaces; magnetic force, which attracts or repels magnetic materials; and applied force, which is exerted by a person or object. These forces are part of our daily experiences for example, gravity keeps us grounded, friction helps us walk without slipping, and applied force is used when we push a door open.

We also examined the differences between elastic and inelastic collisions. In elastic collisions, objects bounce off each other with no loss of total kinetic energy, as seen in games like table tennis or billiards. In inelastic collisions, part of the kinetic energy is converted into other forms such as heat or sound, and the objects may stick together or become deformed, like in car crashes. Understanding these types of collisions helps us analyse how energy and momentum are transferred during motion, which is important in areas like transportation, sports, and engineering.

By the end of this section, learners should be able to identify different types of forces, describe their effects and everyday uses, and explain how elastic and inelastic collisions differ in terms of energy and motion.

MARKING SCHEME FOR THE KEY ASSESSMENT

WEEK 12

1. B
2. A
3. D
4. A
5. B

(Total of 5 marks)

SECTION 7: ELECTRONICS II

STRAND: VIGOUR BEHIND LIFE

Sub-Strand: Consumer electronics

Learning Outcome: *Knowledge of electronic circuits to identify careers in electronics*

Content Standard: *Demonstrate knowledge and recognition of selected electronic components and their uses in household electronic devices*

INTRODUCTION AND SECTION SUMMARY

In this section, learners explore the importance and functions of consumer electronic devices commonly used in homes, schools, and workplaces, such as mobile phones, televisions, radios, computers, and kitchen appliances. They learn that these devices are designed to perform specific tasks by converting electrical energy into useful forms such as sound, light, or motion. Learners are expected to identify and describe the key components of these devices, including circuit boards, resistors, capacitors, transistors, microchips, batteries, and display screens. They should understand the function of each part and explain how these components work together to enable the device to operate effectively. Additionally, learners examine various career opportunities within the consumer electronics industry, such as electronics technician, product designer, circuit board assembler, repair specialist, and electrical engineer. By the end of this section, learners should be able to describe these roles, understand the skills and training they require, and recognise how these careers contribute to technological innovation and maintenance in both local and global contexts.

The week and the indicators covered by the section are:

Week 13

- Discuss consumer electronic devices and their components
- Explore Consumer Electronic careers.

SUMMARY OF Pedagogical Exemplars

This part should provide explanation of how teachers need to teach, what learners need to know, understand and be able to do.

ASSESSMENT SUMMARY

Learners will be assessed through two classwork tasks under the topic of consumer electronics. In the first task, which targets Depth of Knowledge (DOK) Level 2, learners will demonstrate conceptual understanding by identifying and describing common consumer electronic devices and their components. They will choose two or three devices; such as a television, microwave, or radio; and describe their purpose, list at least three major components, and explain how each component contributes to the device's overall function. This will assess their ability to connect parts to purpose logically and clearly. In the second task, aligned with DOK Level 3, learners will explore careers in the consumer electronics

industry. They will research and compare at least two careers, such as an electronics technician and a product designer, describing their roles, required skills, qualifications, and work environments. Learners will also evaluate which career would best suit a person with a specific interest (e.g., hands-on work or design) and provide justified reasoning. Both tasks are designed to build understanding and strategic thinking about how electronic systems work and the professional paths available within the field. Provide a summary of the assessment used against the indicator. For instance,

Indicators	DOK Level	Assessment Strategy and/or Mode
Discuss consumer electronic devices and their components	Level 2: Skills of conceptual understanding	Classwork
Explore Consumer Electronic careers.	Level 3: Strategic reasoning	Classwork

WEEK 13

Learning Indicators

1. *Discuss consumer electronic devices and their components*
2. *Explore Consumer Electronic careers*

Focal Area: Consumer electronics and its career opportunity

Consumer Electronic Devices

Consumer Electronic Devices are electrical or electronic gadgets intended for everyday use, primarily in private homes. These devices are an integral part of modern life, assisting with communication, entertainment, and household chores. They range from simple, single-function items to complex, multi-functional smart devices.

Examples of Consumer Electronic Devices

1. **Mobile Phones:** These are portable devices that allow for communication over a cellular network. Modern smartphones combine the functions of a phone with those of a computer, offering internet access, cameras, and a vast array of applications.
2. **Laptops:** A portable personal computer that can be easily carried and used in various locations. Laptops are essential for work, education, and entertainment.
3. **Televisions:** Devices that receive and display broadcast signals, now commonly used for streaming content from the internet and connecting to other media devices.
4. **Radios:** Devices that receive electromagnetic waves and convert them into audible sound.
5. **Microwaves:** A kitchen appliance that uses microwave radiation to heat and cook food quickly.

Figure 7.0: *Consumer electronic devices*

Components of Electronic Devices

Every electronic device, regardless of its function, is made up of several key components working together. These components can be broadly categorised as active (requiring a power source to function) or passive (not requiring an external power source). Let's explore the fundamental parts you'll find in most consumer electronics.

1. **Power Supply Unit (Battery or Adapter):** This is the heart of any electronic device, providing the necessary electrical energy for it to operate.
   a. **Batteries:** Store chemical energy and convert it into electrical energy. They are essential for portable devices like mobile phones and laptops.

b. **Adapters (Power Bricks):** Convert the high-voltage alternating current (AC) from a wall outlet into the low-voltage direct current (DC) that most electronic components require.

2. **Display unit (Screen, LEDs):** This component provides visual output to the user.
   a. **Screens (LCD, OLED):** Found in devices like phones, laptops, and TVs, these display complex images and text.
   b. **LEDs (Light Emitting Diodes):** Simple lights used as indicators, for example, to show that a device is on or a battery is charging.

3. **Microcontroller/Processor: The "Brain"**

   Often called the Central Processing Unit (CPU) or microprocessor, this component is the control centre of the device. It executes instructions from the device's software and performs calculations, managing the overall operation of the gadget.

4. **Sensors: The Input Devices**

   Sensors detect changes in the environment (motion, light, temperature) and convert them into electrical signals that the microcontroller can understand.

   Examples

   a. **Touchscreens:** Detect the position of a finger or stylus on the screen.
   b. **Accelerometers:** Detect motion and orientation, used in smartphones for rotating the screen. (switching screen views between portrait and landscape modes)
   c. **Microphones:** Convert sound waves into electrical signals for recording or communication.

5. **Memory/Storage: Storing Information**
   a. **RAM (Random Access Memory):** This is the device's short-term memory, used to store data that the processor is actively using. It is volatile, meaning its contents are lost when the device is turned off.

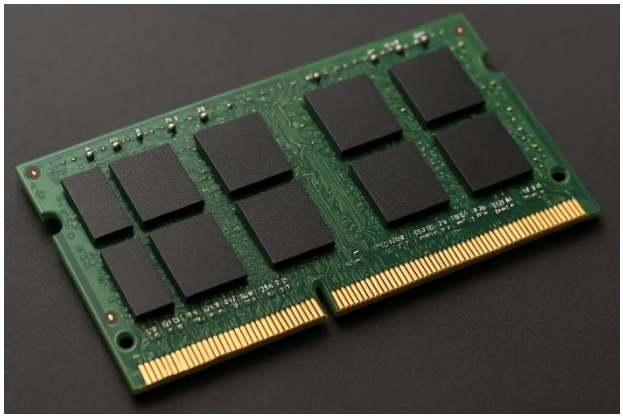


Figure 7.1: *Read Access Memory (RAM)*

   b. **Hard Drives (HDD) and Solid-State Drives (SSD):** This is the long-term storage for the operating system, applications, and user files. It is non-volatile, retaining data even without power.

Figure 7.2: *Hard drive*

c. **Flash Memory:** A type of non-volatile storage used in USB drives, memory cards, and smartphones.

6. **Speakers and microphones: Audio Input and Output**

   a. **Speakers:** Convert electrical signals back into sound waves, allowing you to hear audio from your device.

   b. **Microphones:** Capture sound and convert it into electrical signals.

7. **Buttons, Switches, and Ports: User Interface and Connectivity**

   a. These components allow the user to interact with the device and connect it to other peripherals.

   b. **Buttons and Switches:** Provide physical controls for functions like power, volume, and navigation.

   c. **Ports (USB, HDMI, etc.):** Allow for data transfer, charging, and connecting to external displays.

8. **Printed Circuit Boards (PCBs): The Foundation**

   A PCB is a rigid board with a network of copper "traces" that physically support and electrically connect all the other components. It acts as the skeleton of the device, holding everything in place and allowing for communication between parts.

Career Opportunities in Consumer Electronics

The electronics industry is not just about designing the next smartphone. It is a vast ecosystem of roles that involve design, manufacturing, repair, sales, and support. Below are some of the key career paths you can explore.

1. **Electronics Technician:** These are the problem-solvers who repair and maintain the electronic devices we use daily. When a television, radio, or computer malfunctions, a technician uses diagnostic tools to identify the issue and performs the necessary repairs, which might involve replacing components or fixing faulty wiring.

2. **Hardware Engineer:** A hardware engineer is an innovator who designs and develops the physical components of electronic devices. They work in teams to create circuit boards, processors, and other hardware, often using computer-aided design (CAD) software to build and test prototypes before they go into mass production.

3. **Mobile Device Repair Specialist:** With the widespread use of smartphones and tablets, this has become a highly specialised and in-demand field. These technicians focus specifically on fixing mobile devices, handling common issues like cracked screens, battery replacements, and water damage.
4. **Electronics Sales Specialist:** This role is the bridge between the manufacturers' product and the customer needs. A sales specialist works in retail environments, educating customers on the features and benefits of different devices. They need excellent communication skills and a deep understanding of the products to help customers make informed choices.
5. **Appliance Technician:** Modern household appliances like refrigerators, microwaves, and washing machines are complex electronic systems. An appliance technician specialises in installing, troubleshooting, and repairing these essential home devices.
6. **Robotics or Automation Technician:** In an increasingly automated world, these technicians are crucial. They work with smart appliances and automated systems (like those in smart homes or factories), programming their functions, performing regular maintenance, and troubleshooting any issues to keep them running smoothly.
7. **Product Tester / Quality Control (QC) Officer:** Before any gadget reaches the market, it must be thoroughly tested. A QC officer ensures that products meet all safety, quality, and functionality standards. They follow strict testing protocols to identify defects, ensuring the final product is safe and reliable for consumers.
8. **Consumer electronics marketer:** This professional is responsible for creating excitement and demand for electronic products. They develop marketing campaigns, manage social media promotions, and create advertising materials to reach potential customers and communicate the value of the devices.
9. **IoT (Internet of Things) Technician:** The "Internet of Things" refers to the network of interconnected smart devices. An IoT technician installs, manages, and secures these systems, such as smart home setups that connect lighting, security cameras, and speakers, ensuring they work together seamlessly.
10. **Entrepreneur in Electronics Repair/Assembly:** For those with a business mindset, starting their own electronics company is a viable path. This could be a local repair shop, a service for custom-building computers, or a small-scale assembly business. This requires both technical skills and business knowledge in areas like customer service, marketing, and finance.

Addressing Misconceptions

It is common to have preconceived notions about certain career fields. A key part of learning is to identify and correct these misconceptions with factual information.

Common Misconception

Common Misconception	Correct understanding
"Electronics jobs are only for men."	This is incorrect. Careers in electronics are for everyone, regardless of gender. Success in this field depends on interest, skill, and dedication. Many successful female engineers, technicians, and entrepreneurs are leading figures in the industry.
"All electronics work is dangerous."	While working with electricity has potential risks, the industry is highly regulated. With proper training, safety protocols, and the use of protective equipment, the work is very safe.

"You need a university degree for any good job in electronics."	This is untrue. While some roles like Hardware Engineer require a university degree, many high-demand and well-paying roles, such as Electronics Technician or Mobile Repair Specialist, require technical or vocational training from a specialised college. There are multiple paths to a successful career.
"All electronic components are basically the same."	As learned in the previous chapter, every component has a unique and specific function. A processor acts as the brain, a capacitor stores energy, and a resistor-controls current. A device can only work when all these distinct parts function together correctly.
"You cannot repair modern devices, so you should just throw them away."	Many devices are designed to be repairable, and a skilled technician can often fix them for a fraction of the cost of a new one. Repairing devices is also environmentally responsible as it reduces electronic waste (e-waste).

Learning Tasks

1. Investigate how electronic components work together in household devices
2. Research and analyse career opportunities in consumer electronics field
3. Create concept maps showing consumer electronics importance while addressing misconceptions

Pedagogical Exemplars

1. **Use of 3E model (Explain, Explore, Engage)**
   a. Facilitate group discussions where learners reflect and explain the meaning of consumer electronic devices in the context of connectivity, convenience, and innovation.
   b. Guide learners to explain the role of consumer electronics devices in society and their technological advancements.

      Engage learners to discuss the impact of consumer electronic devices on daily life through their personal experiences and observations related to their use of electronic devices.

      Explore: Differentiate instruction by posing open-ended questions that prompt learners to investigate the evolution of consumer electronics, societal implications, and future trends.
2. **Experiential Learning**

   Using inclusive and differentiated learning, engage learners to observe pictures, videos and drawings of consumer electronics devices and discuss their components for poster presentations and gallery walk.
3. **Inquiry-based Teaching**
   a. Let learners explore and explain career opportunities available in the field of consumer electronics.
   b. Assist learners in working in mixed-ability groups to use concept maps to illustrate the importance of consumer electronics and present their findings in class
   c. Address common misconceptions about electronic components and household appliances.

4. **Research Approach**

   Task learners to explore consumer electronic devices found at home and school such as smartphones, smartwatches, laptops, and televisions.

   Let learners investigate and present their findings on how these components enable them to perform their daily activities.

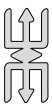
Key Assessment Levels 2 and 3: Classwork

1. Explain the function of at least four major components found in a mobile phone. Use examples to support your explanation. **(10 marks)**
2. Describe how the components of a television work together to produce sound and images. Include at least three components in your answer. **(8 marks)**
3. Imagine you are leading a team to develop a new smart home device. Identify three roles from the consumer electronics industry that would be essential for your team. Explain the function of each role and how they must collaborate to ensure a successful product. **(8 marks)**

PLC Session 13

45 minutes | **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to
   a. explain the week's concepts in a practical way that will make it easier for learners to understand
   b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject specific app to plan your lesson. Ask the app to
   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
   b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
   c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



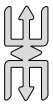
Note

- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Plan the week's key assessment with your app
   a. The key assessment for the week is ***classwork***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the classwork (NTS 3k-3q).

10 minutes Content Exploration

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
   a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
   b. all teachers in the group work through a similar problem individually for 3–4 minutes
   c. the group then works through the problem together step by step
   d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- *This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?*
- *If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.*
- *Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.*

30 minutes Enactment

6. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).
   a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
   b. After the enactment, ask for structured feedback from the group
      i. was the concept explained in a way that a learner with no prior knowledge could follow?
      ii. were the examples grounded in contexts familiar to Ghanaian learners?
      iii. did any misconceptions surface and if so, how were they addressed?

5 minutes Reflection

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
   a. transfer your chats into your learning planner template.
   b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
   c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 7 Review

This section covers week 13, where learners focused on two key indicators: discussing consumer electronic devices and their components and exploring careers in the consumer electronics industry. They examined common devices such as televisions, radios, and microwaves, identifying key components like circuit boards, power supplies, and speakers, and explaining how these parts work together to produce sound, images, or perform functions. This built their conceptual understanding of how electronic systems operate. In addition, learners explored various career paths within the field, including roles such as electronics technicians, product designers, and embedded systems developers. They compared the qualifications, skills, and responsibilities required for each role and evaluated which career options best matched different interests or strengths. The activities included research, group discussions, and presentations, helping students connect theoretical knowledge with real-world applications while developing both understanding and strategic reasoning skills.

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 13

Question 1

Explanation of component with examples (2 marks)

E.g.

The battery is the power source of a mobile phone. It stores electrical energy and supplies it to all other components. Without it, the phone cannot function. For example, when the battery runs out, the phone switches off.

For each component:

Identification of component. (½ mark) E.g. Battery, processor, touchscreen, speaker

Explanation with examples (1½ marks), or

Explanation without examples (1 mark)

Any 4 components for a maximum 8 marks

Organisation and clarity (2 marks)

The response is well-organised with clear structure, proper grammar, and logical flow. The answer includes complete sentences and connects ideas smoothly.

(Total 10 marks)

Question 2

Identifying the components (1 mark for each= 3 marks)

E.g., Tuner, Video processor/display system, etc

Explanation of the Function of the component. (1 mark for each= 3 marks)

E.g., The tuner receives broadcast signals through an antenna, satellite, or cable. It selects the desired channel and separates the audio and video signals.

Description of how the components work together (2 marks)

E.g.,

These components work together by synchronising the video and audio signals so that the picture on the screen matches the sound coming from the speakers, creating a realistic viewing experience.

(Total 8 marks)

Question 3

Identifies three relevant roles in the consumer electronics industry. (1 mark for each = 3 marks)

E.g.,

Hardware engineer, software developer, UX designer, etc.

Describes the specific function of each role. (1 mark for each =3 marks)

E.g.,

Hardware engineer – Designs the physical components and circuitry of the device, such as sensors, chips, and power systems.

Software developer – Writes the code that controls the device's functions, user interface, and connectivity features (e.g., through Wi-Fi or Bluetooth).

User Experience (UX) Designer – Ensures the product is easy and enjoyable to use by designing intuitive interfaces and improving interaction between user and device.

Explains how the roles collaborate/integrate to achieve the goal. (2 marks)

E.g.,

The hardware engineer designs the internal components like the microphone, speaker, and processor. Once the hardware specifications are finalised, the software developer creates the voice assistant system and ensures it runs smoothly on the chosen hardware. After that, the UX designer works on the user interface, such as button layout and mobile app control, based on both the physical design and software functions. Finally, the entire team tests the prototype together to identify issues and make adjustments before launching.

(Total 8 marks)

SECTION 8: HEREDITY

STRAND: RELATIONSHIPS WITH THE ENVIRONMENT

Sub-Strand: The human body and health

Learning Outcome: *Describe the various features of heredity.*

Content Standard: *Apply knowledge of human reproduction to understand heredity*

INTRODUCTION AND SECTION SUMMARY

In this section, learners explore heredity; the process by which traits are passed from parents to their offspring through genes; by observing and discussing common traits in humans such as eye colour, hair type, height, and facial features. They learn how these traits are inherited and how genes influence physical characteristics. Learners also examine hereditary diseases, such as sickle cell disease, haemophilia, and certain types of diabetes, to understand how some health conditions are passed down through families. By the end of the section, learners are expected to identify and describe inherited traits, explain how they are transmitted through genes, distinguish hereditary diseases from other types of illnesses, and recognise the role family history plays in personal health. This knowledge helps them understand the importance of genetics in both human diversity and health management.

The weeks and the indicators covered by the section are:

- **Week 14:** Discuss heredity using traits observed in humans.
- **Week 15:** Discuss hereditary diseases in humans.

SUMMARY OF Pedagogical Exemplars

To promote deeper understanding of reproduction and heredity, teachers should apply collaborative, visual, and research-based strategies. Collaborative learning should be used to support peer interaction and discussion. Teachers should put learners into mixed-ability groups to review key concepts such as reproduction in humans and assign each group specific hereditary terminologies (e.g., gene, allele, dominant trait, recessive trait) to research and explain. These group activities allow for peer teaching, where learners present their findings and critique each other's work to address misconceptions and build shared understanding.

To enhance conceptual organisation, teachers should introduce concept mapping, guiding learners to create visual connections among terms. Starting with broad ideas like "genes" and "traits," learners can branch out into more specific vocabulary, showing how concepts are related. This approach helps them visually organise knowledge and recall relationships more effectively.

Teachers should also assign collaborative research projects focused on inheritable traits or hereditary diseases. Learners investigate and present findings using case studies or real-life patient stories that illustrate symptoms and family impact. Teachers guide students to identify patterns of inheritance

using Punnett squares and pedigrees, helping them determine genotypic and phenotypic ratios of simple Mendelian traits. This combines theoretical learning with practical application.

To make learning inclusive and engaging, teachers should integrate multimedia presentations, videos, and visual aids, especially when explaining complex genetic conditions. These resources support different learning styles and help learners better understand the impact of genetic inheritance on individuals and populations.

ASSESSMENT SUMMARY

Learners will be assessed through two case study activities designed to deepen their understanding of heredity and its real-life implications. In the first task, aligned with Depth of Knowledge (DOK) Level 2, learners will use conceptual understanding to discuss heredity by identifying and analysing observable traits in humans, such as eye colour, dimples, blood type, or attached earlobes. They will examine how these traits are passed from parents to offspring and use case examples to describe dominant and recessive inheritance patterns. In the second task, at DOK Level 3, learners will apply strategic reasoning to investigate hereditary diseases in humans, such as sickle cell anaemia or cystic fibrosis. Through case studies, they will examine symptoms, family inheritance patterns, and the social and health impacts of these conditions. Learners will analyse and explain how such diseases are inherited, compare them with non-hereditary conditions, and draw conclusions based on the evidence presented. These activities will help learners connect scientific concepts with real-world applications, strengthening both their understanding and reasoning skills

Indicators	DOK Level	Assessment Strategy and/or Mode
Discuss heredity using traits observed in humans.	Level 2: Skills of conceptual understanding	Homework
Discuss hereditary diseases in humans.	Level 3: Strategic reasoning	Case study

WEEK 14

Learning Indicator: *Discuss heredity using traits observed in humans*

Focal Area: Concept of heredity

Overview

Heredity or hereditary is the process of passing the traits and characteristics from parents to offspring through genes. The offspring, get their features and characteristics that is genetic information from their mother and father. Heredity and genetics are the reason you look so much like your parents. Genetics is a branch of science that studies the DNA, genes, genetic variation, and heredity in living organisms

Hereditary: Passed on from parent to offspring or from one generation to another. E.g., Disease.

Heritable: Capable of being inherited. It is the genetic or nongenetic factors that influence the phenotypic value. However, no offspring is exactly like their parents and no two children of the same parents are exactly alike. The differences in characters that exist between parents and offspring is known as variation.

Variation: The morphological and physiological differences which occur within a species which could be hereditary or acquired from the environment.

Characters that are can be transmitted are those controlled by genes and the sum of the

genes that an offspring inherits from its parents is known as its genotype or genetic makeup. It usually sets the limits within which characters can vary.

Variations shown by inherited characters may be due to:

1. The effect of the environment or
2. The use or misuse of body parts.

For example, a person may inherit genes for the development of light – coloured skin, but the

exact colour of any part of the skin is determined by extent to which it is exposed to sunlight.

The actual physical expression of characters is the organism's phenotype, which is due to the

interaction between an organism genotype and its environment.

Some common terms used in genetics

These terms provide a foundational understanding of genetics and are essential for studying the inheritance of traits and genetic variation.

1. Chromosomes – These are thread-like structures made up of nucleic acids (DNA) and proteins. They are mostly found in the nucleus of the cells. They carry the hereditary or genetic information in the form of genes.

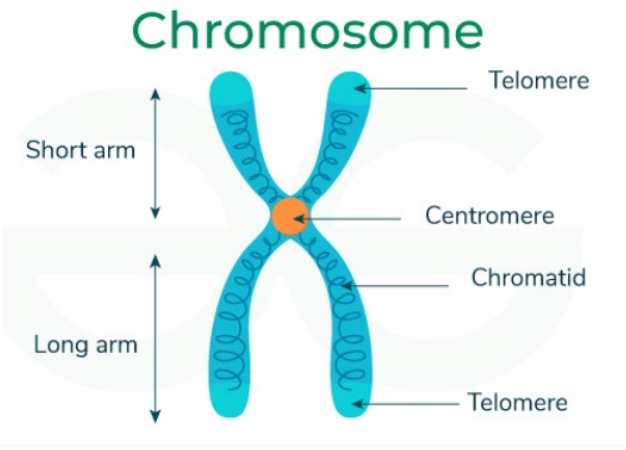


Figure 8.1.a: *Shows the part of a chromosome*

2. Gene: A segment of DNA that contains the instructions for building a specific protein or performing a specific function in an organism, or basic units of inheritance responsible for the transmission of characters from parents to offspring.

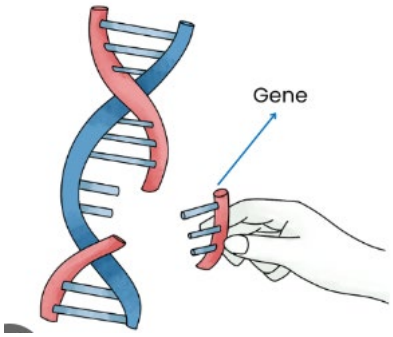


Figure 8.1 b: *Shows the part of a Gene*

3. Allele: Different forms or variants of a gene. Alleles can be dominant or recessive.
4. Genotype: The genetic makeup of an organism, often represented by the combination of alleles for a particular gene.
5. Phenotype: The observable physical or biochemical characteristics of an organism, which result from the interaction of its genotype with the environment.
6. Homozygous: When an individual has two identical alleles for a particular gene – one from each biological parent (e.g., AA or aa).

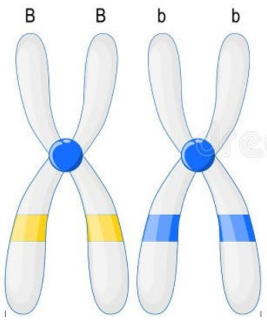


Figure 8.2.a: *Shows the part of a Gene*

7. Heterozygous: When an individual has two different alleles for a particular gene – one version from the mother and a different version from the father (e.g., Aa).

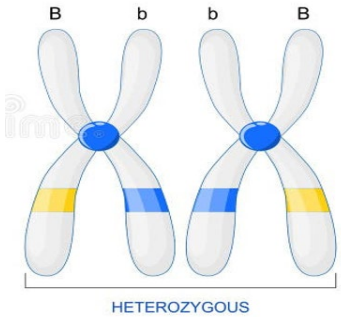


Figure 8.2.b: *Shows the part of a Gene*

8. Dominant: An allele that, when present, will determine the phenotype, even if a recessive allele is also present. Dominant alleles are typically represented with capital letters (e.g., A).
9. Recessive: An allele that is only expressed when two copies of the recessive allele – one from each parent are present (aa or bb) (homozygous). Recessive alleles are typically represented with lowercase letters (e.g., a). It is masked or overridden by a dominant allele in a heterozygous pairing.
10. Chromosomes: Thread-like structures in the cell nucleus that carry genetic information in the form of genes. Humans have 46 chromosomes (23 pairs).
11. DNA (Deoxyribonucleic Acid): The molecule that carries genetic information (for development, growth, function and reproduction) in all living organisms.
12. Mutation: A permanent change in the DNA sequence of an organism. Mutations can be beneficial, harmful, or have no effect on an organism.
13. Genetic Trait: A specific inheritable characteristic or feature that is determined by one or more genes. It can be influenced by both genotype and environmental factors.
14. Codominance: When two different alleles for a gene are both fully and equally expressed in the phenotype.
15. Incomplete Dominance: When the phenotype of a heterozygous individual is intermediate between the two homozygous forms. For example, in incomplete dominance, a red flower crossed with a white flower might produce pink flowers.
16. Pedigree: A chart or family tree that tracks the inheritance of a particular trait through generations.
17. Genetic Disorder: A condition caused by abnormal or mutated genes, leading to health problems or abnormal traits. Examples include cystic fibrosis, Down syndrome, and sickle cell anaemia.
18. Filial generation: The offspring of parents make up the filial generation. The first, second and third generations of offspring are known as the first, second and third filial generations respectively and denoted by the symbols F_1, F_2 and F_3 respectively, too.

Transmittable Characters or Traits in Human Beings

In both humans and plants, only traits that are part of the genetic makeup of the parents can be transmitted and expressed in the offspring. In humans, these inheritable traits include physical features such as skin colour, eye colour, hair colour and texture, body size and stature, shape of the head, ears, mouth, lips, and nose, as well as the length of the neck, arms, and legs. Other transmissible traits include blood group, baldness, tongue rolling ability, voice tone, intelligence, temperament, attitude, and certain genetic disorders like sickle cell anaemia and haemophilia. Some of these traits are controlled by single genes, while others are polygenic or influenced by environmental factors. These traits are passed on through genetic inheritance and can be selectively bred for desirable characteristics.

Activity 8: 1

Exploring Human Inheritance: An Earlobe Observation and Analysis Activity

This activity provides a tangible and relatable way for students to explore the fundamental principles of heredity by observing a common human trait: earlobe attachment. Through systematic data collection and analysis, students will learn to identify patterns of inheritance and formulate a basic scientific rule.

Materials: Observation sheet/data table prepared**,** pen/pencil.

Procedure:

1. Define and identify earlobe types (ensuring consistency)
2. Before beginning, it is crucial to establish a clear and consistent definition for "free" and "attached" earlobes to ensure accurate data collection.
    a. Free Earlobe: The earlobe hangs freely below the point of attachment to the head, often appearing somewhat rounded or distinct from the cheek. There is a clear indentation where the earlobe attaches.
    b. Attached Earlobe**:** The earlobe is directly connected to the side of the head, appearing to be fused with the cheek or jawline, with little to no visible indentation.
3. Show clear diagrams or photographs. Have students practice identifying each type on their own ear and on a peer's ear (with permission) to ensure everyone understands the distinction.
4. Classroom Earlobe Survey (Phenotype Data Collection)
5. Instruct students to discreetly observe the earlobes of all their classmates (with respect and permission). Emphasise that this is a scientific observation, not a judgment.
6. On their prepared data sheet, create a list of all students in the class.
7. For each student, record whether they have "Free" or "Attached" earlobes.
8. Calculate Percentages**:** Once all classmates have been observed, calculate the percentage of students in the class who have free earlobes and the percentage who have attached earlobes. This provides a snapshot of the trait's distribution within the current generation. Formula: (Number of students with X earlobe type / Total number of students) * 100%
9. Family Earlobe Survey (Parental Phenotype Data Collection)
10. This step requires students to gather information from their parents.
11. Instructions for Students**:** Ask students to observe their mother's and father's earlobes carefully. If parents are not physically present, they can describe it or even send a photo to the student for confirmation.
12. Data Recording: On the same or a separate data sheet, for each student, record their own earlobe type, their mother's earlobe type, and their father's earlobe type. Emphasise confidentiality of family data.

Example Data Table

Student Name	Student Earlobe Type	Mother's Earlobe Type	Father's Earlobe Type
Ama	Free	Free	Attached
Kofi	Attached	Attached	Attached
Adjoa	Free	Free	Free
Kwame	Attached	Free	Free

Correlate Earlobe Types (Pattern Recognition and Analysis)

1. Now, analyse the collected family data to identify patterns between parents and offspring. Look for specific combinations:
   a. Case 1: both parents have free earlobes: what earlobe types do their children have? Are they always free, or do some children have attached earlobes? (This is a key indicator for recessive traits).
   b. Case 2: both parents have attached earlobes: what earlobe types do their children have? Are they always attached?
   c. Case 3: One parent has free; one has attached earlobes: what earlobe types do their children have? Is there a consistent pattern?

2. Formulate a possible rule for inheritance (Hypothesis Generation)

   Based on the evidence collected, students should propose a rule that explains how earlobe types might be passed down through families. This rule should try to account for all observed patterns.

   a. **Guiding Questions for Rule Formulation:**
      i. Which earlobe type seems to appear more often or can show up even if only one parent has it? (Suggests a "stronger" or **dominant** trait).
      ii. Which earlobe type seems to "hide" sometimes, only showing up if a child gets it from both parents? (Suggests a "weaker" or **recessive** trait).
      iii. Are there any instances where two parents with the "stronger" trait have a child with the "weaker" trait? (If so, this strongly suggests the "stronger" trait is dominant and those parents must carry the "weaker" trait without showing it).
   b. **Example of a Possible Rule (Hypothesis):** "Based on our observations, it appears that **free earlobes** are a 'stronger' trait, meaning if you get the 'free' instruction from even one parent, you will have free earlobes. **Attached earlobes** seem to be a 'weaker' trait, and you only have attached earlobes if you get the 'attached' instruction from both your mother and your father."

Discussion

1. Variations: Acknowledge that human traits can sometimes have more complex inheritance patterns (e.g., influenced by multiple genes or environmental factors).
2. Connecting to Genetics**:** The teacher can then introduce the scientific terms (dominant, recessive, allele, gene, genotype, phenotype) and explain how the students' proposed rule aligns with the established principles of Mendelian inheritance for this trait. This activity serves as an excellent foundation for understanding heredity in a meaningful way.

Characters or Traits Are Transmitted from Generation to Generation

Inherited characters are determined by genes, which are segments of DNA located on chromosomes. In diploid organisms—organisms with two sets of chromosomes—each gene exists in two copies, located at identical positions (called loci) on homologous chromosome pairs. These organisms produce reproductive cells, or gametes, through a process called meiosis, which occurs in their reproductive organs. During meiosis, the number of chromosomes is halved, resulting in haploid gametes: sperm cells in males and egg cells in females. Each gamete contains only one set of chromosomes, and thus only one copy of each gene. During sexual reproduction, a male and a female gamete fuse in a process called fertilisation to form a zygote, which is diploid, receiving one set of chromosomes from each parent. This is how genes, and the traits they control, are transmitted from parents to offspring. The individuals that produce gametes make up the parental (P) generation, while their offspring are referred to as the first filial (F_1) generation. The process of mating or sexual union is called a cross (represented as "×"). A gene controlling a particular trait may exist in alternative forms called alleles, which may result in different expressions of the trait.

The science of heredity and genetic inheritance was founded by Gregor Mendel (1822–1884), who is regarded as the father of genetics. Mendel conducted experiments using pea plants and developed the principles of inheritance using two main methods: monohybrid inheritance, which involves a single pair of contrasting traits, and dihybrid inheritance, which involves two pairs of contrasting traits. Through his work, Mendel established the foundational laws of inheritance that explain how traits are passed from generation to generation.

Inheritance of one Gene (Monohybrid Inheritance)

Gregor Mendel, often hailed as the "father of genetics," laid the foundational principles of heredity through his meticulous experiments with garden pea plants (Pisum sativum). His studies on monohybrid inheritance involved crossing plants that differed in only one specific, contrasting character at a time, such as tall versus short plant height. These experiments provided crucial insights into how traits are passed from one generation to the next.

The Parental (P) Generation Cross

Mendel began his experiments with **true-breeding** (or purebred) pea plants. A true-breeding plant consistently produces offspring identical to itself when self-pollinated over many generations, ensuring that it carries only one type of allele for the trait in question. For his monohybrid cross focusing on plant height, Mendel selected:

1. True-breeding tall pea plants: These plants always produced tall offspring when self-pollinated. Their genetic makeup for height can be represented as TT (homozygous dominant).
2. True-breeding dwarf pea plants: These plants always produced dwarf offspring when self-pollinated. Their genetic makeup can be represented as **tt** (homozygous recessive).

Mendel then performed an **artificial cross-pollination** (or hybridisation) between these two contrasting true-breeding parental types. He carefully transferred pollen from the flowers of a tall plant to the stigma of a dwarf plant (and vice-versa, performing reciprocal crosses to ensure the results were consistent regardless of which parent contributed the pollen).

The First Filial (F_1) Generation: A Glimpse of Dominance

The seeds resulting from this initial cross were collected and planted to grow the F_1 generation (First Filial generation). Mendel observed a striking and consistent result: all the plants in the F_1 generation grew to be tall.

This observation was ground-breaking because the dwarf trait seemed to have disappeared entirely. Mendel deduced that one trait must be "masking" or "dominating" the other. He termed the trait that was expressed in the F_1 generation (tallness) the dominant trait, and the trait that disappeared (dwarfness) the recessive trait. Using his symbolic representation, if 'T' represents the allele for tallness and 't' represents the allele for dwarfness:

1. The true-breeding tall parent contributed only 'T' alleles to its gametes.
2. The true-breeding dwarf parent contributed only 't' alleles to its gametes.
3. Therefore, all F_1 offspring inherited one 'T' allele from the tall parent and one 't' allele from the dwarf parent, resulting in a heterozygous genotype of Tt.
4. Despite having the 't' allele, all F_1 plants were phenotypically tall, identical to the homozygous dominant (TT) parent, confirming the dominance of the 'T' allele.

The Second Filial (F_2) Generation: The Principle of Segregation Unveiled

To further investigate why the dwarf trait reappeared, Mendel allowed the plants of the F_1 generation to self-pollinate. The seeds produced from these self-pollinating F_1 plants were then collected and planted, giving rise to the F_2 generation (Second Filial generation). The results from the F_2 generation were even more revealing:

1. In the F_2 generation, Mendel observed both tall plants and dwarf plants.
2. Crucially, he found that these traits appeared in a remarkably consistent ratio: approximately three-quarters (3/4) of the plants were tall, and one-quarter (1/4) of the plants were dwarf. This is famously known as the 3:1 phenotypic ratio for a monohybrid cross.

This re-emergence of the recessive dwarf trait in the F_2 generation, after its complete absence in the F_1, led Mendel to propose the Law of Segregation. This law states that during gamete formation, the two alleles for a heritable character (e.g., T and t) separate (segregate) from each other so that each gamete carries only one allele. When the F_1 plants (Tt) self-pollinate, their gametes (T and t) randomly combine, leading to the observed 1:2:1 genotypic ratio (TT: Tt :tt) and the 3:1 phenotypic ratio in the F_2 generation.

Mendel's monohybrid crosses, with their simple design and clear mathematical ratios, provided the foundational evidence for the existence of discrete heritable factors (what we now call genes and alleles) and established the basic rules by which these factors are transmitted from one generation to the next. The genotype for F_1 is Tt.

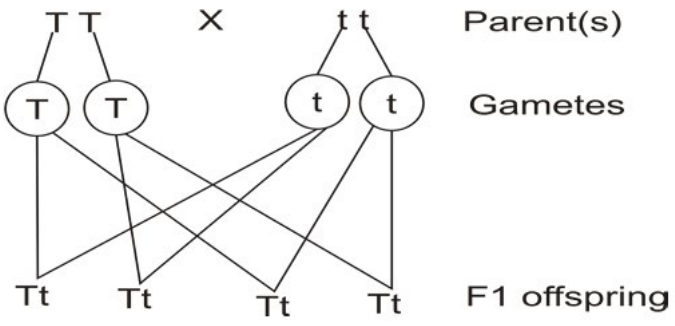


Figure 8.3.a: *Shows F_1 generation*

The phenotype: all tall, but they are heterozygous (not – pure breed).

From this he concluded that T is the dominant allele which expresses itself irrespective of the second allele present.

In F_2 generation, tall plants with genotype TT and Tt appeared while dwarf plants with tt gene appeared. He concluded that 't' is the recessive allele, and it can only express itself in the presence of the same recessive allele. Mathematically he calculated that in F_2 generation ¼ tall plants were with genotype TT while ½were Tt and ¼ were tt. But Tt and TT were tall, so phenotypically ¾ of the plants were tall while the only ¼ of them were phenotypically and genotypically dwarf. The phenotypic ratio was calculated to be ¾ of tall: ¼ of dwarf i.e., 3 : 4. The genotypic ratio was calculated to be ¼ : ½: ¼ (TT : Tt : tt), i.e. 1 : 2 : 1. Mendel concluded all this with the help of Punnett square. The cross explained is a monohybrid cross as inheritance of only one trait is considered at one time only It is monohybrid and an example of complete dominance

If there is self-pollination to obtain second generation, we will observe the following outcome below;

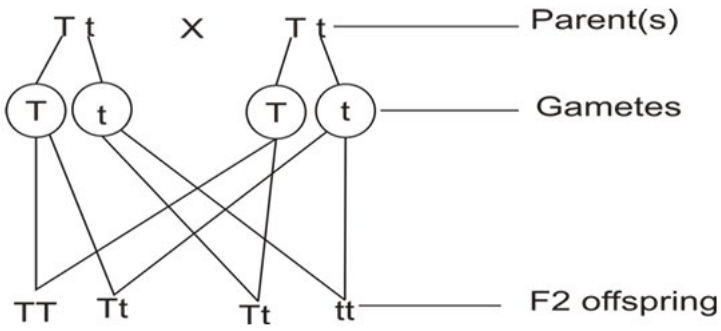


Figure 8.3.b: *showing F_1 generation*

Genotypic ratio: 1 : 2 : 1

Phenotype: 3 : 1

Mendel's Findings

Gregor Mendel's meticulous experiments with pea plants led to profound discoveries about heredity, which he explained through a series of observations and fundamental principles. His work, though initially overlooked, laid the foundation for modern genetics.

Mendel's Observations and Ratios

Through his monohybrid crosses (as seen with tall and dwarf pea plants), Mendel made several crucial observations:

1. The F_1 Generation's Uniformity: When he crossed two true-breeding parents differing in a single contrasting trait (e.g., pure tall TT with pure dwarf tt), the entire First Filial (F_1) generation uniformly resembled only one of the two parental traits. For instance, all F_1 pea plants were tall, even though one parent was dwarf. This indicated that one trait was expressed while the other seemed to disappear.
2. The F_2 Generation's Re-emergence and Ratios: When the F_1 generation plants (which were all phenotypically dominant) were allowed to self-pollinate, the Second Filial (F_2) generation exhibited a predictable pattern:
    - Phenotypic Ratio: Both the dominant and recessive forms of the trait reappeared. Roughly three-quarters (¾) of the F_2 plants displayed the dominant phenotype (e.g., tall), while one-

quarter (¼) displayed the recessive phenotype (e.g., dwarf). This established a consistent 3:1 phenotypic ratio (dominant : recessive).

- Genotypic Ratio: Further analysis (later confirmed by test crosses) revealed that the F_2 generation possessed a specific genotypic ratio of 1:2:1. This ratio represented 1 part homozygous dominant (e.g., TT), 2 parts heterozygous (e.g., Tt), and 1part homozygous recessive (e.g., tt). This showed that while the outward appearance (phenotype) was 3:1, the underlying genetic makeup (genotype) was more varied.

Interpretation of Mendel's Results

Mendel's genius lay not just in his careful experiments but also in his ability to interpret these numerical patterns. He proposed that hereditary characteristics are controlled by discrete "factors" (what we now call genes), which are transmitted from parents to offspring. Each factor, or gene, contains specific information about a particular form of a trait. He understood that these factors exist in pairs within an individual and that they somehow separate and combine predictably.

Mendel's Fundamental Laws of Inheritance

From these observations and interpretations, Mendel formulated two seminal laws:

1. **The Principle (or Law) of Dominance:** This law states that in a cross between two true-breeding parents that differ in a single trait, only one form of the trait (the dominant one) will appear in the F_1 generation. The other form of the trait (the recessive one) is masked or suppressed in the F_1 but can reappear in subsequent generations. When an individual inherits two different alleles for a trait (i.e., is heterozygous, like Tt), the allele that determines the observable phenotype is the dominant allele. The allele whose expression is hidden in the presence of the dominant allele is the recessive allele. This principle explains why all F_1 pea plants were tall, despite receiving a dwarf allele from one parent.

2. **The Law of Segregation:** This law states that during the formation of gametes (sperm and egg cells), the two alleles for a heritable character separate (segregate) from each other so that each gamete carries only one allele. This principle explains the re-appearance of the recessive trait in the F_2 generation. For example, an F_1 heterozygous pea plant (Tt) produces two types of gametes in equal proportions: one carrying the 'T' allele and one carrying the 't' allele. These alleles do not blend or contaminate each other while in the F_1 individual; they remain distinct and simply separate during meiosis. When gametes from two such F_1 individuals fuse randomly during fertilisation, the recessive 't' allele can combine with another 't' allele (tt), leading to the expression of the recessive dwarf trait in the F_2 generation. This segregation ensures that genetic variation is maintained in gametes and passed on across Generations.

Inheritance of two Gene (Dihybrid Inheritance)

Following his ground-breaking work on monohybrid inheritance, Gregor Mendel further expanded his understanding of heredity by studying the simultaneous inheritance of two different traits at a time. This type of genetic investigation is known as a dihybrid cross, and it proved pivotal in formulating his second major law of inheritance.

The Parental (P) Generation Cross: Setting the Stage

Mendel began his dihybrid cross by selecting true-breeding pea plants that differed in two distinct pairs of contrasting characters. He chose:

- Plants with Round and Yellow seeds: These were true breeding for both traits, meaning they always produced round, yellow seeds when self-pollinated. Their genotype was represented as RRYY (homozygous dominant for both traits).
- Plants with Wrinkled and Green seeds: These were true breeding for their respective traits, always producing wrinkled, green seeds. Their genotype was represented as rryy (homozygous recessive for both traits).

Mendel then performed an artificial cross-pollination between these two contrasting parental types (RRYY x rryy).

The First Filial (F_1) Generation: All Dominant Phenotypes

The seeds resulting from this cross were planted, yielding the F_1 generation. All the plants in this F_1 generation exhibited the dominant phenotype for both traits: they all produced round and yellow seeds.

This result was consistent with Mendel's Law of Dominance, which he had established from his monohybrid crosses. Each F_1 individual inherited one allele for seed shape (R) and one for seed colour (Y) from the RRYY parent, and one allele for seed shape (r) and one for seed colour (y) from the rryy parent. This made all F_1 individuals heterozygous for both traits, with a genotype of RrYy.

Gamete Formation in the F_1 Generation: The Law of Independent Assortment

The most crucial stage for understanding the dihybrid cross lies in the formation of gametes by these F_1 (RrYy) individuals. Here, Mendel's observations led to his second major principle: The Law of Independent Assortment.

Principle: This law states that alleles for different traits (e.g., the alleles for seed shape, R/r, and the alleles for seed colour, Y/y) segregate independently of each other during gamete formation (meiosis). This means that the inheritance of one trait does not influence the inheritance of the other trait.

Mechanism: When an F_1 individual (RrYy) produces gametes, the 'R' allele segregates from the 'r' allele, and the 'Y' allele segregates from the 'y' allele. Crucially, these two segregation events happen independently. Therefore, a gamete can receive any combination of one allele from each gene pair.

For example, a gamete could receive 'R' along with 'Y' (RY).

Or, it could receive 'R' along with 'y' (Ry).

Similarly, it could receive 'r' along with 'Y' (rY).

Or, it could receive 'r' along with 'y' (ry).

Gamete Ratios: Because of independent assortment, these four types of gametes (RY, Ry, rY, ry) are produced in approximately equal proportions, each representing 25% or 1/4th of the total gametes produced by an F_1 (RrYy) individual.

The Second Filial (F_2) Generation: The Characteristic 9:3:3:1 Ratio

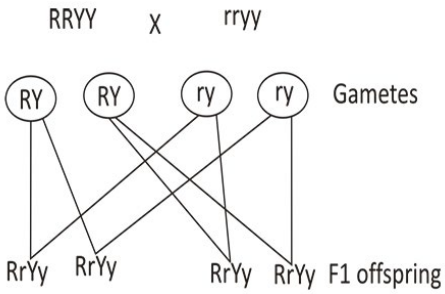
Mendel allowed the F_1 (RrYy) plants to self-pollinate. The seeds produced from this self-pollination yielded the F_2 generation, which displayed a variety of phenotypes, not just the two parental types. By counting the number of individuals in each phenotypic category, Mendel consistently observed a characteristic 9:3:3:1 phenotypic ratio:

- 9 parts: Round and Yellow seeds (dominant for both traits)

- 3 parts: Round and Green seeds (dominant for shape, recessive for colour)
- 3 parts: Wrinkled and Yellow seeds (recessive for shape, dominant for colour)
- 1 part: Wrinkled and Green seeds (recessive for both traits)

This complex ratio, derived from the random combination of the four types of gametes (RY, Ry, rY, ry) in a 16-square Punnett square (an extension of the 2x2 monohybrid square), provided strong evidence for the independent assortment of different genetic traits. It demonstrated that alleles for different genes are sorted into gametes independently of one another, leading to a wider range of phenotypic combinations in the offspring than would be possible if traits were inherited together. Mendel's dihybrid cross was a monumental achievement, revealing the elegant predictability of trait transmission.

E.g., a round yellow and wrinkled green seeds,



F_2 cross pollinated each other.

	RY	Ry	rY	ry
RY	RRYY	RRYy	RrYY	RrYy
Ry	RRYy	RRyy	RrYy	Rryy
rY	RrYY	RrYy	rrYY	rrYy
ry	RrYy	Rryy	rrYy	rryy

4 types of seeds were produced from F_1 generation.:

- Round and yellow seeds
- Wrinkle and tallow seeds
- Round and green seeds
- Wrinkle and green seeds

The phenotype is 9 : 3 : 3 : 1

Interpretation of Mendel's Results

Gregor Mendel's meticulous work with pea plants led to the formulation of fundamental principles that govern how traits are passed from one generation to the next. These principles, often referred to as Mendel's Laws, alongside specific types of genetic crosses, are crucial for understanding inheritance patterns and determining the genetic makeup of individuals.

Mendel's Laws of Inheritance

1. **The Law of Dominance:** This law posits that when an individual possesses two different alleles for a single inherited trait, one allele (the dominant allele) will mask the expression of the other

allele (the recessive allele), determining the observable characteristic or phenotype. The recessive allele remains present in the genotype but is not expressed phenotypically. This principle is evident in the F_1 generation of a monohybrid cross between two true-breeding parents. For instance, when a true-breeding tall pea plant (TT) is crossed with a true-breeding dwarf pea plant (tt), all F_1 offspring are tall (Tt). The allele for tallness (T) is dominant and completely suppresses the expression of the allele for dwarfness (t) in the heterozygous state.

2. **The Law of Segregation:** This law states that during the formation of gametes (sperm and egg cells) in sexually reproducing organisms, the two alleles for a heritable character (e.g., T and t) separate (segregate) from each other so that each gamete receives only one allele. This segregation occurs during meiosis. For example, a heterozygous F_1 plant (Tt) will produce two types of gametes: 50% carrying the 'T' allele and 50% carrying the 't' allele. The alleles do not blend or permanently influence each other; they remain discrete units and simply separate during gamete formation. This random segregation ensures that each offspring receives a unique combination of alleles, leading to the re-appearance of recessive traits in the F_2 generation.

3. **The Law of Independent Assortment:** This law states that alleles for different genes (i.e., genes controlling different traits) segregate independently of each other during gamete formation. This means that the inheritance of one trait does not influence the inheritance of another distinct trait. This principle applies to dihybrid crosses (where two or more traits are studied simultaneously). For example, in a cross involving seed colour (yellow/green) and seed shape (round/wrinkled), the way the alleles for colour separate into gametes is independent of how the alleles for shape separate. An individual heterozygous for both traits (RrYy) will produce gametes containing all possible combinations of alleles (RY, Ry, rY, ry) in equal proportions, as if each gene were inherited alone. This independence leads to greater genetic variation in offspring.

Determining Parental Genotypes: Back Cross and Test Cross

In genetics, it is often crucial to determine the specific genotype of an individual, particularly if they exhibit a dominant phenotype, as this phenotype can result from either a homozygous dominant (e.g., TT) or a heterozygous (e.g., Tt) genotype. This uncertainty can be resolved using specific types of genetic crosses.

1. **Back Cross:** A back cross is a general term for a cross where the F_1 progeny (first filial generation offspring) is mated back to either one of its parentals (P) genotypes. This is aimed at creating offspring with a genetic makeup more similar to that parent. Back crosses are commonly used in breeding programs to introduce a specific desirable trait from a wild relative into a cultivated crop, or to rapidly develop inbred lines (a group of genetically identical homozygous organisms produced by repeated self-fertilization between close relatives over several generations).

   F_1 x Dominant Parent (e.g., Tt x TT): This type of back cross is used to quickly increase the proportion of offspring carrying the dominant allele, often seen in livestock breeding to improve desirable traits.

   F_1 x Recessive Parent (e.g., Tt x tt): This specific type of back cross is also known as a Test Cross (see below) and is particularly informative for determining genotype.

2. **Test Cross:** A test cross is a specialised type of back cross where an individual displaying the dominant phenotype (but of unknown genotype, e.g., T?) is crossed with a homozygous recessive individual (e.g., tt) for the same trait. The primary purpose of a test cross is to determine the unknown genotype (whether homozygous dominant or heterozygous) of the parent exhibiting the dominant phenotype. If the unknown parent is homozygous dominant (TT), all F_1 offspring from the test cross (TT x tt) will be heterozygous (Tt) and will express the dominant phenotype (100%

dominant phenotype). If the unknown parent is heterozygous (Tt), then crossing Tt x tt will produce offspring in a 1:1 phenotypic ratio of dominant to recessive traits (e.g., 50% tall (Tt) and 50% dwarf (tt)). The appearance of any recessive offspring immediately reveals that the unknown parent must have been heterozygous. Test crosses are widely used in agriculture (plant and animal breeding) to confirm the genetic purity of breeding lines or to identify desirable heterozygotes.

Polygenic Inheritance

Polygenic Inheritance: The Basis of Continuous Variation

Beyond the simple inheritance patterns described by Mendel's monohybrid and dihybrid crosses, many complex traits in organisms are influenced by the combined action of multiple genes. This phenomenon is known as polygenic inheritance. (A continuous phenotypic trait is controlled by multiple genes and often influenced by environmental factors)

Polygenic inheritance occurs when the expression of a single phenotypic trait is controlled by the cumulative effect of more than one gene. These genes are often located at different loci (positions) on the same or different chromosomes. As multiple genes are involved, this mode of inheritance is also referred to as quantitative inheritance or multiple factor inheritance. It produces a range of variation rather than discrete categories.

Characteristics of Polygenic Traits

Polygenic traits exhibit several distinctive features that differentiate them from Mendelian traits (which are typically controlled by a single gene):

1. Continuous Variation: Unlike Mendelian traits that usually fall into distinct categories (e.g., tall or dwarf, yellow or green), polygenic traits show a continuous range or spectrum of phenotypes within a population. This variation can be measured and often follows a bell-shaped curve (normal distribution). There are many intermediate forms between the two extremes.
2. Additive Effect of Alleles: The genes involved in polygenic inheritance typically contribute to the phenotype in an additive manner. This means that each "contributing allele" (often the dominant allele) adds a small, incremental, or cumulative effect to the phenotype. The more contributing alleles an individual possesses, the more pronounced the trait becomes. There is generally no complete dominance or recessiveness among the individual alleles across all the genes involved; rather, their effects sum up.
3. Multifactorial Influence (Gene-Environment Interaction): Many polygenic traits are also multifactorial traits. This implies that while multiple genes play a significant role, environmental factors (such as nutrition, lifestyle, exposure to sunlight, disease) can also interact with the genetic predisposition to modify the final phenotype. The environment can either enhance or diminish the expression of the genetic potential.

Examples of Polygenic Inheritance in Humans

Human traits provide excellent illustrations of polygenic inheritance:

1. Height: Human height is a classic example of a polygenic trait. We do not observe just two distinct categories like "tall" and "short" in the population. Instead, there's a wide range of heights, from very short to very tall, with many intermediate measurements. This continuous variation reflects the influence of hundreds of genes, each contributing a small amount to an individual's adult height. An individual's height depends on the cumulative effect of the "tall" alleles inherited from both parents across these numerous genes (Additive Effect). While genetics sets the potential range,

environmental factors like adequate nutrition during growth, lack of chronic illness, and general health significantly influence whether an individual reaches their full genetic height potential (Environmental Influence).

2. Skin Colour: Human skin pigmentation is another well-known example of polygenic inheritance, determined by the amount and type of melanin produced in the skin. It is influenced by multiple gene pairs (often modelled with three, but potentially up to six or more genes in reality) that contribute to melanin production. Using a simplified model with three gene pairs (A/a, B/b, C/c), where uppercase alleles (A, B, C) contribute to darker skin (more melanin) and lowercase alleles (a, b, c) contribute to lighter skin (less melanin):

   The genotype aabbcc would represent the very lightest skin colour (zero contributing alleles). The genotype AABBCC would represent the very darkest skin colour (six contributing alleles). All other combinations represent intermediate shades. For example, a person with genotype AaBbCc (three contributing alleles) would have a medium skin tone. A person with AABbCc (four contributing alleles) would be darker than medium but lighter than AABBCC. The effect of each contributing allele is additive, meaning the total number of uppercase alleles directly correlates with the degree of skin pigmentation. This additive effect across multiple genes results in the vast and continuous spectrum of human skin colours observed globally, from very light to very dark, with countless intermediate shades (Continuous Spectrum). Environmental factors like sun exposure (tanning) can further modify the expressed phenotype of skin colour, highlighting its multifactorial nature.

Learning Tasks

1. Discuss similarities and differences in traits among humans
2. Describe hereditary features in humans
3. Analyse and describe patterns of inheritance in human families

Pedagogical Exemplars

1. **Collaborative learning**

   a. Put learners in mixed-ability groups to review reproduction in humans (SHS 2).

   b. In mixed ability groups assign each group specific hereditary terminologies for learners to research define and explain for the present to the class.

   c. Encourage peer critiquing and discussion as learners share their findings and clarify any misunderstandings about the terminology.

2. **Concept mapping**

   a. Guide learners to use concept mapping to organise the terms and their relationships visually. Start with broader concepts like “genes” and “traits” and branch out to more specific terms and their definitions.

   b. Assign collaborative projects to learners to research specific inheritable traits and present their findings to the class.

   c. Provide examples of Punnett squares or pedigrees for simple Mendelian traits (e.g., dominant/recessive traits) and guide learners through the process of determining genotypic and phenotypic ratios

	R	r
r	Rr	rr
r	Rr	rr

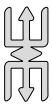
Key Assessment Level 2: Homework

1. Explain how Mendel's laws of inheritance apply to the transmission of traits from parents to offspring. Use examples from pea plant experiments. **(10 marks)**
2. Describe the difference between dominant and recessive traits and explain how these influence the appearance of traits in offspring. **(8 marks)**

PLC Session 14

45 minutes | **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to
   a. explain the week's concepts in a practical way that will make it easier for learners to understand
   b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject specific app to plan your lesson. Ask the app to
   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
   b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
   c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Plan the week's key assessment with your app
   a. The key assessment for the week is ***homework***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the homework (NTS 3k-3q).

10 minutes | **Content Exploration**

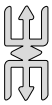
5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)

b. all teachers in the group work through a similar problem individually for 3–4 minutes

c. the group then works through the problem together step by step

d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- *This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?*
- *If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.*
- *Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.*

30 minutes Enactment

6. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).

   a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.

   b. After the enactment, ask for structured feedback from the group

      i. was the concept explained in a way that a learner with no prior knowledge could follow?

      ii. were the examples grounded in contexts familiar to Ghanaian learners?

      iii. did any misconceptions surface and if so, how were they addressed?

5 minutes Reflection

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).

8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).

9. Remember to

   a. transfer your chats into your learning planner template.

   b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).

   c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 15

Learning Indicator: *Discuss hereditary diseases in humans*

Focal Area: Understanding Hereditary Diseases in Humans

Overview

In the modern world, the emergence and discovery of new diseases have become increasingly common due to advancements in medical research and technology. Among the wide array of diseases affecting humans, a significant number fall under the category of hereditary diseases. These are disorders that are passed down genetically from one generation to another and are rooted in the biological makeup of individuals.

Hereditary diseases, also known as genetic disorders, are conditions that are transmitted from parents to their offspring through genes. According to Dictionary.com (2014), a hereditary disease is defined as a disorder that can naturally be passed from one generation to the next via genetic inheritance. These diseases are usually caused by abnormalities in an individual's DNA, particularly chromosomal or gene mutations. Every human inherits a unique combination of genes from their biological mother and father, and this genetic blueprint plays a crucial role in shaping not only physical traits but also predispositions to certain diseases.

The Role of Genes in Heredity

Genes are segments of DNA that act as instructions for building proteins and determining the functioning of cells. They are responsible for visible traits such as eye colour, skin tone, and height, as well as less visible factors like susceptibility to certain illnesses, metabolic functions, and the production of hormones and enzymes. Each person typically inherits two copies of each gene, one from the mother's egg and one from the father's sperm.

Although these gene copies usually work together to ensure normal development, they are not always identical. Small variations between the two can lead to unique combinations of traits. In some cases, these differences are harmless and contribute to natural human diversity. However, when one or both genes carry a harmful mutation, it may result in a hereditary disease.

How Genetic Disorders Are Inherited

There are various inheritance patterns that determine how hereditary diseases are passed on. In some cases, a person can carry a gene with a defect without experiencing any symptoms, this is known as being a carrier. This happens because the normal version of the gene can compensate for the defective one. However, if a child inherits two defective copies of a gene (one from each parent), they are likely to develop the associated disorder.

This explains why sometimes a child can be born with a genetic disease even when neither parent shows any signs of illness. The condition only manifests when both parents unknowingly carry the same defective gene and pass it on to their child. This pattern is common in recessive genetic disorders.

Examples of Hereditary Diseases

There are many well-known examples of hereditary diseases. These include:

1. Hereditary Hemochromatosis: a disorder causing the body to absorb too much iron, leading to organ damage.
2. Down Syndrome: a chromosomal condition caused by an extra copy of chromosome 21, leading to developmental delays and physical characteristics.
3. Sickle Cell Anaemia: a blood disorder where red blood cells are abnormally shaped, leading to pain and reduced oxygen transport.
4. Turner Syndrome: a chromosomal condition affecting females, where one of the X chromosomes is missing or incomplete, impacting growth and development.

Types of Hereditary Diseases
Cystic Fibrosis

Cystic Fibrosis (CF), also known as mucoviscidosis, is a serious, inherited genetic disorder that profoundly impacts the body's exocrine glands. It leads to the production of abnormally thick, sticky mucus and excessively salty sweat. This viscous mucus obstructs various ducts and passageways, particularly in the respiratory, digestive, and reproductive systems, leading to a range of complications. CF is caused by a defect in the Cystic Fibrosis Transmembrane Conductance Regulator (CFTR) gene. This gene provides instructions for creating the CFTR protein, which acts as a channel controlling the movement of chloride ions and water in and out of cells. In individuals with CF, the mutated CFTR gene produces a faulty protein that either doesn't work correctly or isn't produced at all. This dysfunction disrupts the delicate balance of salt and water transport, causing secretions (like mucus, sweat, and digestive juices) to become dehydrated, thick, and sticky. Instead of acting as lubricants, these secretions plug up tubes and ducts, leading to significant organ damage over time.

Organs affected

1. Lungs: The thick mucus clogs the small airways, making it difficult to breathe and creating an ideal environment for bacterial infections. This leads to chronic lung infections, inflammation, and progressive lung damage, including bronchiectasis (widening of the airways).
2. Pancreas: The mucus blocks the ducts that carry digestive enzymes from the pancreas to the small intestine. This prevents proper digestion and absorption of fats, proteins, and vitamins, leading to malnutrition, poor growth, and sometimes cystic fibrosis-related diabetes (CFRD).
3. Intestines: Blockages can occur, particularly in new borns (meconium ileus) and older children/adults (distal intestinal obstruction syndrome), causing severe constipation and abdominal pain.
4. Liver: Blockage of bile ducts can lead to inflammation and scarring (cirrhosis) in a small percentage of individuals.
5. Sweat Glands: The faulty CFTR protein also affects sweat glands, leading to abnormally salty sweat. This is a key diagnostic indicator.
6. Reproductive System: In men, thick mucus can block or cause the absence of the vas deferens (the tube that carries sperm), leading to infertility in almost all cases. Women with CF may experience reduced fertility but can often conceive and have successful pregnancies.

Down Syndrome

Down syndrome, also known as Trisomy 21, is a genetic condition caused by the presence of extra genetic material from chromosome 21. This chromosomal abnormality results in a unique set of physical characteristics, intellectual disabilities, and developmental delays, the severity of which can vary significantly among individuals. It is the most common chromosomal disorder leading to intellectual disability in children.

Causes of Down Syndrome

Down syndrome is caused by abnormal cell division that leads to an extra full or partial copy of chromosome 21. While the exact reason for these cell division errors is not fully understood, they can occur in one of three ways:

1. **Trisomy 21 (Nondisjunction):** This is the most common cause, accounting for about 95% of Down syndrome cases. In Trisomy 21, an individual has three copies of chromosome 21 in every cell of their body, instead of the usual two. This occurs due to an error in cell division during the formation of the sperm or egg cell (meiosis), where a pair of chromosome 21 fails to separate. When this egg or sperm fuses with a normal gamete, the resulting embryo has three copies of chromosome 21.
2. **Mosaic Down Syndrome:** This is a rare form of Down syndrome, affecting about 1% of individuals with the condition. In mosaic Down syndrome, a person has a mix of cells, some with the usual two copies of chromosome 21 and others with three copies. This "mosaic" pattern is caused by an abnormal cell division error that occurs after fertilisation, early in embryonic development. Individuals with mosaic Down syndrome may have fewer characteristics of Down syndrome than those with Trisomy 21 because of the presence of some normal cells.
3. **Translocation Down Syndrome:** This form accounts for about 4% of Down syndrome cases. In translocation Down syndrome, part of chromosome 21 breaks off during cell division and attaches (translocate) to another chromosome, most commonly chromosome 14, 21, or 22. Individuals with translocation Down syndrome have the usual two full copies of chromosome 21, but they also have extra genetic material from chromosome 21 attached to another chromosome. This can occur spontaneously or, rarely, can be inherited from a parent who is a "balanced carrier" of the translocation. A balanced carrier has the rearranged chromosome but no extra or missing genetic material, so they do not have Down syndrome themselves, but they can pass on the unbalanced translocation to their children. Only about one-third of translocation Down syndrome cases are inherited.

Asthma

Asthma is a chronic (long-term) respiratory condition characterised by inflammation and narrowing of the airways, which are the tubes that carry air in and out of your lungs. This inflammation makes the airways overly sensitive and prone to react to various triggers. When exposed to these triggers, the muscles around the airways tighten (bronchoconstriction), the lining of the airway's swells, and extra mucus is produced. These changes collectively make breathing difficult, leading to characteristic symptoms such as coughing, wheezing, shortness of breath, and chest tightness.

Types of Asthma

Asthma is not a single condition, and its manifestation can vary greatly among individuals. While the underlying mechanism of airway inflammation is common, different "types" or "phenotypes" of

asthma are recognised based on their triggers, severity, and response to treatment. Some common types include:

1. Allergic (Extrinsic) Asthma: This is the most common type, often starting in childhood. It's triggered by exposure to specific allergens like pollen, dust mites, pet dander, mould spores, or cockroach droppings. People with allergic asthma often have a history of other allergic conditions like hay fever (allergic rhinitis) or eczema.
2. Non-Allergic (Intrinsic) Asthma: This type is not triggered by allergens and typically develops later in life. Triggers can include respiratory infections (colds, flu), stress, exercise, cold air, or irritants.
3. Exercise-Induced Bronchoconstriction (EIB): Formerly known as exercise-induced asthma, this occurs during or shortly after physical activity. It can affect people with or without underlying asthma. Symptoms typically improve with rest or specific pre-exercise medications.
4. Occupational Asthma: This type develops as a result of exposure to irritants or allergens in the workplace, such as chemicals, dusts, fumes, or animal proteins.
5. Cough-Variant Asthma (CVA): The primary symptom of CVA is a chronic, dry cough, often without the typical wheezing. It can be challenging to diagnose.
6. Nocturnal Asthma: Symptoms, particularly coughing and wheezing, worsen at night, often disrupting sleep.
7. Severe Asthma: This refers to asthma that remains uncontrolled despite optimal high-dose conventional treatments. It may require specialised therapies like biologics.
8. Aspirin-Exacerbated Respiratory Disease (AERD): A specific type of asthma triggered by aspirin and other nonsteroidal anti-inflammatory drugs (NSAIDs).

Asthma Triggers

Asthma symptoms are often brought on by exposure to specific triggers, which can vary from person to person. Identifying and avoiding triggers is a crucial part of asthma management. Common triggers include:

1. Airborne allergens, pollen (from trees, grasses, weeds), animal dander (skin flakes, saliva, urine of pets), mould spores, dust mites (microscopic insects found in dust) and cockroach droppings
2. Respiratory Infections: Viruses like the common cold, flu, and other respiratory infections can inflame the airways and trigger asthma symptoms.
3. Irritants and Pollutants: Tobacco smoke (first-hand and second hand), air pollution (e.g., smog, industrial emissions, vehicle exhaust), chemical fumes (from cleaning products, paints, strong scents), wood smoke from fireplaces or bushfires
4. Weather Conditions: Cold, dry air, changes in weather or humidity and thunderstorms (can cause pollen grains to burst into smaller, more easily inhaled particles)
5. Physical Activity: Exercise can be a significant trigger for many individuals with asthma, especially in cold or dry environments.

Diabetes Mellitus

Diabetes mellitus, commonly referred to as diabetes, is a group of chronic metabolic diseases characterised by elevated blood sugar (glucose) levels. Glucose is a crucial source of energy for the cells that make up muscles, tissues, and the brain. In diabetes, the body either doesn't produce enough

insulin, or it can't effectively use the insulin it produces, leading to an accumulation of glucose in the bloodstream. Over time, persistently high blood glucose can lead to serious health complications affecting the heart, blood vessels, eyes, kidneys, and nerves.

The Role of Insulin

Insulin is a hormone produced by specialised cells called beta cells in the pancreas, a gland located behind and below the stomach. Insulin acts like a key, unlocking cells to allow glucose from the bloodstream to enter and be used for energy. When blood glucose levels rise (for example, after a meal), the pancreas releases insulin. As glucose moves into the cells, blood sugar levels drop, and the pancreas reduces insulin secretion. In people with diabetes, this finely tuned process is disrupted.

Types of Diabetes

There are several types of diabetes, with the most common being Type 1, Type 2, Prediabetes, and Gestational Diabetes.

1. **Type 1 Diabetes**

   Type 1 diabetes, previously known as juvenile diabetes or insulin-dependent diabetes, is an autoimmune condition where the body's immune system mistakenly attacks and destroys the insulin-producing beta cells in the pancreas. As a result, the pancreas produces little to no insulin. Without insulin, glucose cannot enter the cells and builds up in the bloodstream.

- Cause: The exact cause of type 1 diabetes is unknown. It is believed to be caused by a combination of genetic susceptibility and environmental factors. While certain genes increase the risk, not everyone with those genes develops type 1 diabetes. Environmental triggers, such as viral infections, are thought to play a role in initiating the autoimmune response in genetically predisposed individuals. Type 1 diabetes is not linked to lifestyle factors like diet or exercise.
- Onset: It can develop at any age, but it most commonly appears in children, adolescents, and young adults.
- Management: Individuals with type 1 diabetes require lifelong insulin therapy, administered via injections or an insulin pump, to replace the insulin their body no longer produces.

2. **Type 2 Diabetes**

   Type 2 diabetes is the most common form of diabetes, accounting for the vast majority of cases. In type 2 diabetes, the body either doesn't produce enough insulin, or the cells become resistant to the effects of insulin (known as insulin resistance). This means that even if insulin is present, it cannot effectively move glucose into the cells, leading to high blood sugar levels.

   Cause: The development of type 2 diabetes is complex and often involves a combination of genetic and lifestyle factors.

   - Insulin Resistance: This is a hallmark of type 2 diabetes, where muscle, fat, and liver cells don't respond adequately to insulin. The pancreas initially tries to compensate by producing more insulin, but over time, it may not be able to keep up with the body's demand, leading to elevated blood glucose.
     - Genetics: Having a family history of type 2 diabetes significantly increases an individual's risk.
     - Lifestyle Factors: Key contributors include:

- Being overweight or obese: Excess body fat, particularly around the abdomen, is strongly linked to insulin resistance.
- Physical inactivity: Lack of regular physical activity contributes to insulin resistance and weight gain.
- Unhealthy diet: Diets high in processed foods, sugary drinks, and unhealthy fats can increase the risk.

Sickle cell disease

Sickle cell disease (SCD), also known as sickle cell anaemia, is a group of inherited blood disorders. This means it's passed down from parents to their children through genes. At its core, SCD affects haemoglobin, the protein in red blood cells responsible for carrying oxygen throughout the body. SCD is caused by a mutation (a change) in the *HBB* gene. This gene provides instructions for making beta-globin, a component of haemoglobin. A specific mutation in the *HBB* gene leads to the production of an abnormal form of haemoglobin called haemoglobin S (HbS).

Normally, healthy red blood cells contain normal haemoglobin (HbA), are round, flexible, and can easily move through even the smallest blood vessels to deliver oxygen. In individuals with SCD, the presence of HbS causes red blood cells to become rigid, sticky, and take on a characteristic "sickle" or C-shape, especially when they release oxygen.

These sickled cells have several problems:

1. They are stiff and sticky: They cannot move easily through small blood vessels and tend to clump together, blocking blood flow.
2. They die prematurely: Sickled cells have a much shorter lifespan (10-20 days) compared to normal red blood cells (100-120 days). This leads to a chronic shortage of red blood cells, a condition called anaemia.

The blockage of blood flow and the chronic anaemia are responsible for the wide range of symptoms and complications associated with SCD, including severe pain episodes (vaso-occlusive crises), organ damage (spleen, kidney, liver, lungs), increased risk of infection, and stroke.

Inheritance Pattern: Autosomal Recessive

Sickle cell disease is inherited in an autosomal recessive pattern. This means that a child will only develop SCD if they inherit *two* copies of the mutated *HBB* gene, one copy from each parent.

1. Normal Gene (HbA): Represents the gene for normal haemoglobin.
2. Sickle Cell Gene (HbS): Represents the gene for abnormal haemoglobin.
3. If both parents have Sickle Cell Trait (HbAS):
    a. Each parent carries one normal gene (HbA) and one sickle cell gene (HbS). They do not have SCD themselves, but they are "carriers" of the gene. People with sickle cell trait usually do not experience symptoms, except in rare extreme conditions like severe dehydration or intense physical activity.
    b. For each child they have, there is a:
        - 25% chance (1 in 4) that the child will inherit two normal genes (HbAA) and will not have SCD or be a carrier.

- 50% chance (1 in 2) that the child will inherit one normal gene and one sickle cell gene (HbAS), meaning they will also have sickle cell trait and be a carrier.
- 25% chance (1 in 4) that the child will inherit two sickle cell genes (HbSS), meaning they will have sickle cell disease.

This is the most common way SCD is inherited.

1. If one parent has Sickle Cell Disease (HbSS) and the other has Sickle Cell Trait (HbAS)
   a. The parent with SCD has two sickle cell genes (HbSS).
   b. The parent with sickle cell trait has one normal and one sickle cell gene (HbAS).
   c. For each child they have, there is a:
      - 50% chance (1 in 2) that the child will inherit one HbS gene from the parent with SCD and one HbS gene from the carrier parent, resulting in HbSS (sickle cell disease).
      - 50% chance (1 in 2) that the child will inherit one HbS gene from the parent with SCD and one HbA gene from the carrier parent, resulting in HbAS (sickle cell trait).
      - No children will be completely unaffected (HbAA) in this scenario.
2. If one parent has Sickle Cell Disease (HbSS) and the other has normal hemoglobin (HbAA):
   a. The parent with SCD has two sickle cell genes (HbSS).
   b. The parent with normal haemoglobin has two normal genes (HbAA).
   c. All children (100% chance) will inherit one HbS gene from the affected parent and one HbA gene from the unaffected parent, meaning all their children will have sickle cell trait (HbAS). None will have SCD.
3. If both parents have normal haemoglobin (HbAA):

All children (100% chance) will have normal haemoglobin (HbAA) and will not have SCD or be carriers.

Spinal Muscular Atrophy (SMA)

The term “progressive muscular atrophies” can be broad, but the description provided strongly points to Spinal Muscular Atrophy (SMA) as a key example of a severe, heritable muscle disorder affecting infants. Atrophy refers to the wasting away or decreases in the size of a body part, in this case, muscles, due to a lack of normal development or use. SMA is a group of genetic diseases that affect the motor neurons in the spinal cord. Motor neurons are nerve cells that send signals from the brain and spinal cord to the muscles, controlling muscle movement. In SMA, these motor neurons progressively degenerate and die, leading to muscle weakness and wasting (atrophy).

Spinal Muscular Atrophy (SMA): A Closer Look

1. Genetic Cause: SMA is primarily caused by a mutation in the Survival Motor Neuron 1 (SMN1) gene. This gene is responsible for producing the SMN protein, which is crucial for the health and survival of motor neurons. When the SMN1 gene is mutated or missing, insufficient SMN protein is produced, leading to the degeneration of motor neurons.
2. Inheritance Pattern: SMA is an autosomal recessive disorder. This means that an individual must inherit two copies of the mutated SMN1 gene (one from each parent) to develop the condition. If a person inherits only one mutated copy, they are a carrier and typically do not show symptoms, but they can pass the gene on to their children.

Albinism

Albinism is another group of recessively inherited genetic disorders that affects the production of melanin, the pigment responsible for the colour of skin, hair, and eyes. It is not contagious and does not inherently affect intelligence or physical health beyond the issues directly related to pigmentation.

Genetic Basis and Types of Albinism

Albinism results from mutations in specific genes that are involved in the production of melanin. There are different types of albinism, classified based on the gene affected and the degree of pigment reduction. The most common type is oculocutaneous albinism (OCA), which affects the skin, hair, and eyes. Ocular albinism (OA) primarily affects the eyes.

1. Inheritance Pattern: Most forms of albinism, including the common types of OCA, are inherited in an autosomal recessive pattern. This means that both parents must be carriers of the mutated gene (each having one normal copy and one mutated copy) for their child to have albinism. If a child inherits two copies of the mutated gene (one from each carrier parent), they will develop albinism.
2. Melanocytes: The disorder affects melanocytes, which are specialised cells located primarily in the skin, hair follicles, and eyes. These cells produce melanin. In albinism, either the melanocytes cannot produce melanin at all, or the amount of melanin produced is significantly reduced, or the quality of melanin is altered.

Characteristics and Associated Issues

Individuals with albinism typically exhibit striking physical characteristics due to the lack or reduction of melanin:

1. Skin Colour: The skin can appear very pale or strikingly white, sometimes with a pinkish hue due to visible blood vessels. It does not tan and remains abnormally sensitive to sunlight. It may indeed appear wrinkled due prematurely due to sun damage.
2. Hair Colour: Hair can range from very white to light yellow, light brown, or reddish, depending on the type of albinism and the individual's ethnic background.
3. Eye Colour: Eyes can appear very light blue, grey, green, or, less commonly, reddish-pink (due to the visible blood vessels in the iris when pigment is absent).
4. Vision Problems: This is a hallmark of albinism and is often the most impactful health concern. Melanin plays a crucial role in the normal development of the optic nerves and retina.

Predicting Genetic Outcomes: Punnett Squares, Test Crosses, and Pedigree Analysis

Genetics, the study of heredity, relies on predictable patterns of inheritance. Understanding these patterns is crucial for predicting traits in offspring, analysing genetic disorders, and informing breeding strategies. Tools like Punnett squares, test crosses, and pedigree analysis are fundamental in achieving this understanding.

Punnett Squares: Visualising Genetic Crosses

Punnett squares, a tabular method devised by the British geneticist Reginald Punnett, are powerful tools used to predict the possible genotypes and phenotypes of offspring resulting from a genetic cross. They provide a clear visual representation of how parental alleles combine during fertilisation.

Constructing a Punnett Square

The process of constructing and interpreting a Punnett square involves a few systematic steps:

Identify Parental Genotypes: Determine the genetic makeup (genotypes) of the two parents involved in the cross. For instance, in a monohybrid cross (a cross involving a single genetic trait), if we consider pea plants, true-breeding yellow seeds might have a genotype of YY, and true-breeding green seeds might have a genotype of yy.

Determine Parental Gametes: Based on the principle of segregation (Mendel's First Law), each parent's alleles for a specific trait separate during meiosis, so that each gamete (sperm or egg) receives only one allele. List all the possible unique haploid gametes each parent can produce.

For a parent with genotype YY, all gametes will carry the Y allele.

For a parent with genotype yy, all gametes will carry the y allele.

For a heterozygous parent (Yy), gametes will carry either the Y allele or the y allele, in approximately equal proportions.

Create the Grid: Draw an empty grid (Punnett square). The number of columns typically corresponds to the number of unique gametes from one parent (conventionally, the male parent's gametes are placed across the top), and the number of rows corresponds to the number of unique gametes from the other parent (conventionally, the female parent's gametes are placed along the side).

Fill the Boxes: In each empty box within the grid, combine the alleles from the corresponding row and column. Each filled box represents a possible diploid genotype of a zygote (fertilised egg) that could result from the mating.

Determine Ratios

Genotypic Ratios: Count the frequency of each unique genotype (e.g., YY, Yy, yy) within the filled boxes. Since each box represents an equally likely outcome, these counts directly provide the genotypic ratio.

Phenotypic Ratios: To determine the phenotypic ratios, apply the known dominance relationship between the alleles. For example, if Y (yellow) is dominant to y (green), then genotypes YY and Yy will both express the yellow phenotype, while yy will express the green phenotype.

Examples of Monohybrid Crosses:

Cross 1: True-breeding Parents (Homozygous Dominant x Homozygous Recessive)

Parental Genotypes: Yellow (YY) x Green (yy)

Gametes: Y from the yellow parent; y from the green parent.

Punnett Square (2x2)

X	Y	Y
y	Yy	Yy
y	Yy	Yy

Offspring Genotypes: All Yy (100% heterozygous)

Offspring Phenotypes: All Yellow (100% expressing the dominant trait)

Cross 2: Self-Cross of Heterozygous Offspring (F_1 x F_1)

Parental Genotypes: Yellow (Yy) x Yellow (Yy)

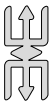
Gametes: Y, y from each parent.

Punnett Square (2x2)

X	Y	y
Y	YY	Yy
y	Yy	yy

Offspring Genotypes: 1 YY : 2 Yy : 1 yy (1:2:1 ratio)

Offspring Phenotypes: 3 Yellow : 1 Green (3:1 ratio).



Note

The genotypes Yy and yY are functionally identical, representing the same heterozygous combination. This phenotypic ratio (3:1) was famously observed by Mendel in the F_2 generation of his pea plant crosses, validating the principles of segregation and independent assortment.

2. The Test Cross: Determining Unknown Genotypes

Beyond predicting offspring from known parents, Punnett's work (and Mendel's prior insights) also provided a method to determine the genotype of an organism that displays a dominant phenotype but whose underlying genotype is unknown (e.g., is a yellow-seeded pea plant YY or Yy). This method is called the test cross.

Principle: A test cross involves crossing the individual with the unknown dominant phenotype with an individual that is homozygous recessive for the same characteristic. The homozygous recessive individual's genotype (yy) is known, and it will only contribute recessive alleles (y) to its gametes.

Scenario 1: Unknown Dominant Individual is Homozygous Dominant (YY)

Cross: YY (unknown) x yy (test cross parent)

Punnett Square: All offspring will be Yy.

Phenotypes: All F_1 offspring will express the dominant trait (e.g., all yellow seeds). This indicates the unknown parent was YY.

Scenario 2: Unknown Dominant Individual is Heterozygous (Yy)

Cross: Yy (unknown) x yy (test cross parent)

Punnett Square: Offspring will be 50% Yy and 50% yy.

Phenotypes: The F_1 offspring will exhibit a 1:1 ratio of the dominant phenotype to the recessive phenotype (e.g., 1 yellow seed: 1 green seed). This indicates the unknown parent was Yy.

The test cross is a powerful analytical tool that further supports Mendel's postulate of segregation, as the appearance of recessive offspring directly reveals the presence of a recessive allele in the previously unknown parent. This technique is widely used in plant and animal breeding to ensure desired genetic lines.

3. **Pedigree Analysis: Tracing Inheritance in Humans**

While test crosses are valuable in experimental settings, they are unethical and impractical for humans. Instead, geneticists use pedigree analysis to study the inheritance patterns of human genetic diseases and other traits within families.

Organisation and Symbols of a Pedigree

A pedigree is a standardised diagram that represents the ancestral history of a genetic trait within a family.

Generations: Each horizontal row represents a single generation, with the oldest generation at the top of the pedigree and the most recent generation at the bottom. Generations are typically numbered with Roman numerals (I, II, III...).

Individuals

Males: Represented by squares (☐).

Females: Represented by circles (○).

Affected Individuals: Shaded (or filled) shapes (e.g., blue or black) indicate individuals who express the trait or disease.

Unaffected Individuals: Unshaded (or clear) shapes indicate individuals who do not express the trait.

Carriers: Half-shaded or a dot within the shape can sometimes indicate individuals who are heterozygous carriers for a recessive trait but do not show the phenotype.

Relationships

Marriage/Mating: A single horizontal line connects individuals who have had children together.

Offspring: Children are connected to their parents' horizontal mating line by a vertical line, typically arranged in birth order from left to right.

Twins: Indicated by two vertical lines diverging from the same point on the parental line. Identical (monozygotic) twins have a horizontal line connecting their two vertical lines.

Analysing Inheritance Patterns with Pedigrees

Geneticists use pedigree analysis to deduce genotypes and predict the likelihood of a trait appearing in future generations. Key patterns emerge:

Recessive Traits: Affected individuals often have unaffected parents (who must be carriers).

The trait may skip generations. Affected individuals are usually homozygous recessive (aa).

Example: Alkaptonuria: Individuals with alkaptonuria cannot properly metabolise phenylalanine and tyrosine, leading to symptoms like darkened skin, brown urine, and joint damage. In a pedigree, unaffected individuals (e.g., AA or Aa) might have affected offspring (aa), indicating that both unaffected parents must be heterozygous carriers (Aa). If an individual is unaffected but has an affected sibling, their genotype could be AA or Aa, often represented as A?.

Dominant Traits: Affected individuals usually have at least one affected parent. The trait appears in every generation. Affected individuals transmit the trait to approximately half their offspring if heterozygous.

Learning Tasks

1. Analyse of hereditary diseases and their impact on Ghanaian communities
2. Analyse of sickle cell disease as a major hereditary condition in Ghana
3. Compare multiple hereditary diseases and their management approaches

4. Develop comprehensive policy recommendations for hereditary disease management in Ghana

Pedagogical Exemplars

1. **Research Projects and Presentations**
   a. Assign research projects to learners in mixed ability groups to investigate specific hereditary diseases and present their findings to the class.
   b. Present case studies or patient stories that illustrate the symptoms, progression, and impact of hereditary diseases on individuals and families and guide learners to identify hereditary diseases.
   c. Using multimedia presentations, videos, and visual aids to guide learners to understand hereditary diseases and their impact on individuals and populations.

Key Assessment Level 3: Case study

Haemophilia is a recessive X-linked disorder that impairs blood clotting. In the Taylor family, the grandfather had haemophilia. His daughter, Sarah, does not show symptoms but is a carrier. Sarah is married to Mark, who does not have haemophiliac. They are expecting their first child and want to understand the inheritance risk. Sarah's brother also has haemophiliac.

1. Using a Punnett square, determine the possible genotypes and phenotypes of the offspring between Sarah (carrier) and Mark (normal). **(4 marks)**
2. What is the probability that:
   a. A son will have haemophilia?
   b. A daughter will be a carrier? **(4 marks)**
3. Explain why haemophilia is more common in males than in females. Use genetic principles and inheritance patterns in your explanation **(5 marks)**

PLC Session 15

45 minutes | **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to
   a. explain the week's concepts in a practical way that will make it easier for learners to understand
   b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject specific app to plan your lesson. Ask the app to
   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
   b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
   c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).

Note

- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Plan the week's key assessment with your app
   a. The key assessment for the week is ***case study***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the case study (NTS 3k-3q).

10 minutes **Content Exploration**

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
   a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
   b. all teachers in the group work through a similar problem individually for 3–4 minutes
   c. the group then works through the problem together step by step
   d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).

Note

- *This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?*
- *If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.*
- *Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.*

30 minutes **Enactment**

6. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).
   a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
   b. After the enactment, ask for structured feedback from the group
      i. was the concept explained in a way that a learner with no prior knowledge could follow?
      ii. were the examples grounded in contexts familiar to Ghanaian learners?
      iii. did any misconceptions surface and if so, how were they addressed?

5 minutes **Reflection**

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
    a. transfer your chats into your learning planner template.
    b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
    c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 8 Review

During Weeks 14 and 15, learners explored key concepts in heredity with a focus on observable human traits and hereditary diseases. In Week 14, the focus was on understanding heredity, the passing of traits from parents to offspring, using real-life examples such as tongue rolling, dimples, earlobe attachment, and the ability to roll the tongue. Learners were introduced to the basic principles of dominant and recessive genes, Punnett squares, and how traits can vary even among siblings due to combinations of alleles inherited from both parents. By the end of the week, each learner should have been able to identify common inherited traits in humans, use a simple genetic cross to predict trait outcomes, and explain how heredity contributes to variation in a population.

In Week 15, the focus shifted to hereditary diseases, where learners discussed how certain genetic disorders, such as sickle cell anaemia, albinism, haemophilia, and cystic fibrosis—are passed from parents to children through genes. They learned the difference between inherited conditions and those caused by environmental factors. Through case studies and class discussions, learners examined how faulty genes lead to specific symptoms, and the importance of genetic counselling in families with a history of such conditions. By the end of this week, each learner should have been able to define hereditary diseases, give examples, describe how they are inherited, and explain the social and emotional impact these conditions may have on individuals and families.

Overall, this two-week section aimed to build a foundational understanding of genetics and inheritance while encouraging empathy and awareness of genetic conditions in real-life contexts.

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 14

Question 1

1. Identification of Mendel's Law of Segregation (1 marks)
2. Description of segregation of alleles during gamete formation (2 mark)
3. Identification of Mendel's Law of Independent Assortment (1 marks)
4. Explanation of independent inheritance of traits (2 mark)
5. Use of a clear example from Mendel's pea plant experiments (e.g., tall vs. short) (2 marks)
6. Scientific accuracy in explanation (2 marks)

(Total 10 marks)

Question 2

1. Definition of that differentiate dominant trait and recessive trait (2 marks)
2. Explanation of how dominant alleles mask recessive ones (2 marks)
3. Correct use of genotype examples (e.g., TT, Tt = tall; tt = short) (2 marks)
4. Logical structure, grammar, and scientific accuracy (2 marks)

(Total 8 marks)

WEEK 15

1.

	X^H	Y
X^H	X^HX^H	X^HY
X^h	X^HX^h	X^hY

Marking Breakdown

1. Correctly identifies Sarah as X^HX^h (carrier) (1 mark)
2. Correctly identifies Mark as X^HY (normal) (1 mark)
3. Correct setup of Punnett square. (1 mark)
4. All four offspring genotypes correctly derived and interpreted. (1 mark)

(Total of 4 marks)

1. **a) Probability that a son will have haemophilia (2 marks)**
   - i. States correct probability: **50%** (1 mark)
   - ii. Justifies based on Punnett square: Half of sons (X^HY, X^hY) have haemophile (1 mark)

   b) Probability that a daughter will be a carrier (2 marks)
   - i. States correct probability: **50%** (1 mark)
   - ii. Justifies based on Punnett square: Half of daughters (X^HX^h) are carriers. (1 mark)

(Total of 4 marks)

2) Explanation of why haemophile is more common in males (2 marks)

i. Correctly explains that males have only one X chromosome, so one recessive allele causes disease. (1 mark)

ii. Females have two X chromosomes, so a second normal allele can mask the effect (carriers). (1 mark)

Scientific Explanation & Genetics Principles (3 marks)

i. Correct use of X-linked inheritance. (1 mark)

ii. Understanding of dominant vs. recessive allele behaviour. (1 mark)

iii. Recognises males are hemizygous for X-linked genes (have only one X) (1 mark)

iv. Coherent, biologically accurate explanation integrating Punnett square with inheritance pattern. (1 mark)

v. Notes or infers that Sarah's father must have been X^hY, and her mother X^HX^H or X^HX^h, reinforcing her carrier status. (1 mark)

Any three for 3 marks (Total of 5 marks)

SECTION 9: GENETICS

STRAND: RELATIONSHIPS WITH THE ENVIRONMENT

Sub-Strand: The human body and health

Learning Outcome: *Design mind maps and concept maps of some Mendelian crossing to sex determination in humans*

Content Standard: *Explore and model sex determination in humans*

INTRODUCTION AND SECTION SUMMARY

In this section, learners study how traits are inherited in humans through the principles of Mendelian genetics, focusing on sex determination and selected human traits. They explore how sex is determined by the combination of X and Y chromosomes from parents, using Punnett squares to visually represent and predict outcomes. Learners also investigate traits such as tongue rolling, dimples, and attached earlobes, identifying dominant and recessive alleles and applying Mendelian crossings to determine possible genotypes and phenotypes of offspring. By the end of the section, learners are expected to know key genetic terms, understand how traits are passed from parents to children, and demonstrate the ability to use genetic tools like Punnett squares to solve simple inheritance problems and explain variation in human traits.

The weeks and the indicators covered by the section are:

- **Week 16:** Draw Mendelian crossings to explain sex determination in humans
- **Week 17:** Explore selected traits in humans using applications of Mendelian crossing.

SUMMARY OF Pedagogical Exemplars

To effectively teach the concepts of inheritance, sex determination, and sex-linked traits, teachers are encouraged to use collaborative and talk/sign-for-learning strategies that promote learner engagement, critical thinking, and peer-to-peer explanation. In mixed-ability groups, learners conduct research on Gregor Mendel's pea plant experiments and explore the historical background of sex chromosome discovery through guided discussions. Teachers should support understanding by using diagrams, visual aids, and karyotypes to help learners illustrate the structure and function of sex chromosomes and distinguish between male (XY) and female (XX) chromosomal patterns.

To deepen conceptual understanding, teachers guide learners in discussing sex-linked traits and disorders such as colour blindness and haemophilia, using Punnett squares and pedigree charts to analyse how such traits are inherited and to predict probabilities. Learners are expected to know the foundational principles of Mendelian genetics, the role of sex chromosomes, and examples of sex-linked traits; they should understand how genetic information is passed from parents to offspring; and they should be able to apply Punnett square techniques, analyse pedigree data, and interpret visual genetic models.

Through hands-on simulation activities, observation of human traits, and analysis of expected versus observed phenotypic ratios, learners actively engage with the content while developing collaboration and analytical skills. This pedagogical approach ensures that learning is inclusive, student-centred, and connected to real-world biological phenomena.

ASSESSMENT SUMMARY

In this assessment, learners will demonstrate strategic reasoning by applying Mendelian genetics to real-life human inheritance patterns. For the first task, learners will use Punnett squares to draw and interpret Mendelian crossings to explain sex determination in humans, showing how the combination of X and Y chromosomes from the parents determines the sex of the offspring. This will involve computational thinking and accurate use of genetic symbols to justify the biological outcomes. In the second task, learners will explore selected human traits such as dimples, tongue rolling, and earlobe attachment using Mendelian crossing in the context of a scenario or case study. They will analyse given parental genotypes, predict offspring traits, and explain the inheritance patterns based on dominant and recessive alleles. By completing these tasks, learners are expected to demonstrate an understanding of inheritance, use genetic tools strategically, and apply their knowledge to realistic genetic situations.

Indicators	DOK Level	Assessment Strategy and/or Mode
Draw Mendelian crossings to explain sex determination in humans.	Level 3: Strategic reasoning	Computation
Explore selected traits in humans using applications of Mendelian crossing.	Level 3: Strategic reasoning	Scenario and case study

WEEK 16

Learning Indicator: *Draw Mendelian crossings to explain sex determination in humans*

Focal Area: Mendelian Crossings in Human Sex Determination

Overview

Sex determination is the biological system that dictates the development of sexual characteristics in an organism, leading to the designation of male or female. This process is crucial for reproduction and varies across different species. In many organisms, including humans, the mechanism is under genetic control, meaning it's determined by specific genes or chromosomes.

Genetic Control of Sex Determination

In higher organisms, such as humans, sex is typically determined at the moment of fertilisation. This is primarily due to the presence of sex chromosomes, which carry genes that regulate sexual development.

While some organisms, like many fish species, have independent genes located on different non-sex chromosomes (autosomes) that influence sex determination, the most widely understood and prevalent mechanism in complex organisms is chromosomal sex determination.

The XX-XY System in Humans

Humans possess 23 pairs of chromosomes, totalling 46 chromosomes in each somatic (non-sex) cell. Of these 22 pairs are autosomes: These chromosomes carry genes for all other traits and are identical in males and females. 1 pair is the sex chromosomes: This pair determines an individual's biological sex.

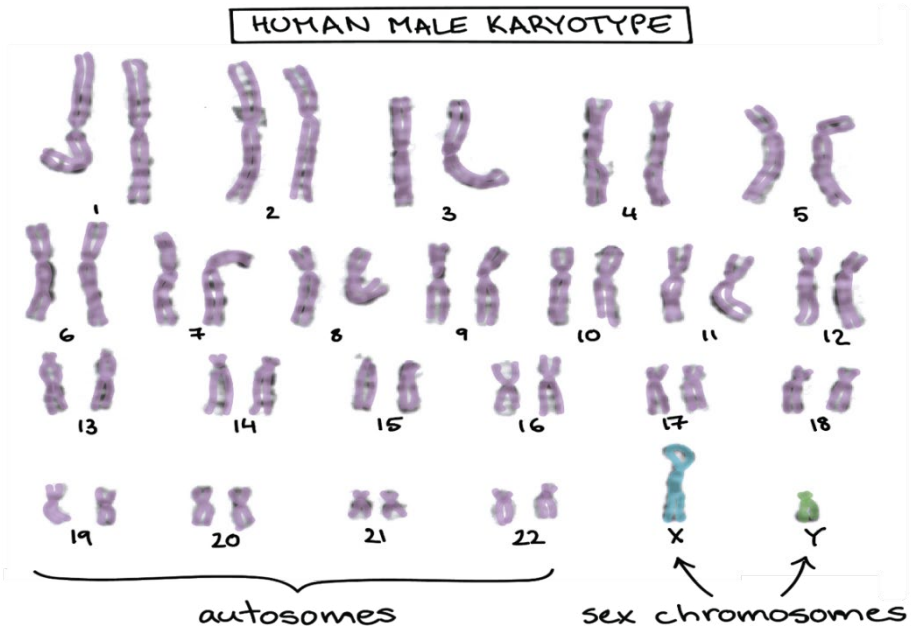


Figure 9.0: *Shows human male karyotype*

In the XX-XY system, which is characteristic of humans and many other mammals, the sex chromosomes are: Females: Have two X chromosomes (XX) and Males: Have one **X** chromosome and one Y chromosome (XY).

How Sex is Determined at Fertilisation

During the formation of gametes (sperm and egg cells) through a process called meiosis, the sex chromosomes separate: Female (XX) gametes: Eggs always carry a single X chromosome and Male (XY) gametes: Sperm can carry either an X chromosome or a Y chromosome.

The two types of sperm are produced in roughly equal proportions. When fertilisation occurs, the sex of the resulting zygote (the first cell of a new organism) is determined by which type of sperm fertilises the egg:

1. If an X-carrying sperm fertilises an X-egg, the offspring will be XX (female).
2. If a Y-carrying sperm fertilises an X-egg, the offspring will be XY (male).

This clearly illustrates that the father's sperm determines the sex of the child. This scientific understanding refutes historical beliefs that incorrectly placed responsibility on the mother for the sex of the offspring. There is approximately a 50% chance of having a male child and a 50% chance of having a female child with each pregnancy.

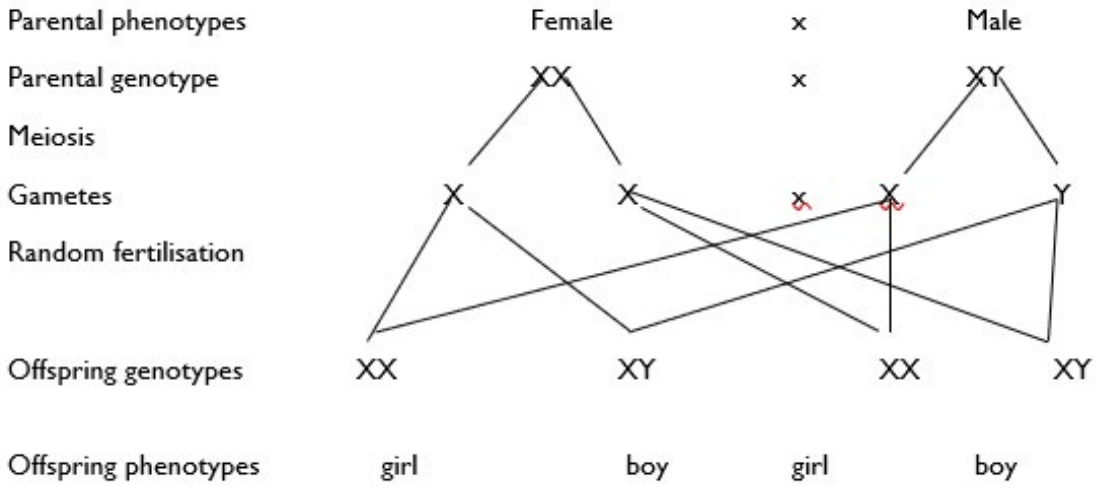


Figure 9.1: *Shows human male karyotype*

Other Types of Sex Determination Systems

While the XX-XY system is common, other mechanisms exist:

1. ZW-ZZ System**:** Found in birds, some fish, and some insects (e.g., butterflies). In this system, females are the heterogametic sex (ZW) and males are homogametic (ZZ).
2. XO System: Seen in many insects (e.g., grasshoppers). Females are XX, but males have only one X chromosome (XO), lacking a Y chromosome.
3. Haplodiploidy System: Characteristic of social insects like bees, ants, and wasps. Males develop from unfertilised eggs (haploid, having one set of chromosomes), while females develop from fertilised eggs (diploid, having two sets of chromosomes).
4. Environmental Sex Determination**:** In some reptiles (e.g., crocodiles, turtles), the temperature during egg incubation determines the sex of the offspring.

Sex-Linked Inheritance: Genes on Sex Chromosomes

Sex linkage refers to the inheritance patterns of genes located specifically on the sex chromosomes (X or Y), rather than on the autosomes. These genes are called sex-linked genes or **X-linked/Y-linked genes,** and their inheritance patterns differ significantly from autosomal traits because males and females have different numbers of X and Y chromosomes.

X-Linked Inheritance

The X chromosome is much larger than the Y chromosome and contains a significantly greater number of genes (over 900 genes). Genes found on the X chromosome can affect both males and females. X-linked traits can be either recessive or dominant.

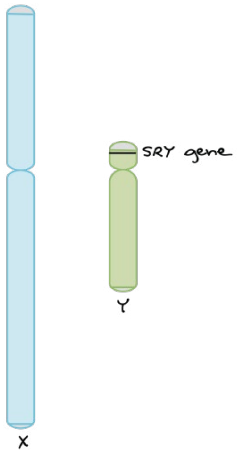


Figure 9.2: *Showing X-Linked Inheritance*

X-Linked Recessive Inheritance

1. **Common in Males:** X-linked recessive conditions are much more prevalent in males than in females. This is because males have only one X chromosome. If a male inherits a mutated recessive allele on his X chromosome, he will express the trait because he has no second X chromosome to provide a normal, dominant allele to mask it.
2. **Females as Carriers:** Females have two X chromosomes. If a female inherits one mutated recessive allele on one X chromosome and a normal, dominant allele on the other X chromosome, she will usually be a carrier. She typically won't show symptoms herself (or may have milder symptoms due to skewed X-inactivation, where one of the X chromosomes is preferentially inactivated), but she can pass the mutated allele to her children.

Inheritance Patterns

- **Affected Son from a Carrier Mother:** A son born to a carrier mother and an unaffected father has a 50% chance of inheriting the mutated and thus being affected.
    - **Daughters of Carrier Mothers:** Daughters of a carrier mother have a 50% chance of being carriers themselves. They rarely show the full condition unless they inherit the recessive allele from both parents (which is rare, requiring an affected father and a carrier/affected mother) or exhibit skewed X-inactivation.
    - **Affected Father:** An affected father cannot pass the X-linked trait to his sons (as sons inherit the Y chromosome from their father). However, all his daughters will be carriers because they inherit his X chromosome.

Examples of X-linked recessive conditions include

1. Red-green colour blindness: Difficulty distinguishing between shades of red and green.
2. Haemophilia A and B: Blood-clotting disorders where the blood does not clot properly.
3. Duchenne Muscular Dystrophy: A progressive muscle-wasting disease.
4. Glucose-6-phosphate dehydrogenase (G6PD) deficiency: A condition that can lead to haemolytic anaemia, often triggered by certain foods, drugs, or infections.

Example: Inheritance of Haemophilia

Let's use the Punnett square you provided to illustrate haemophilia inheritance: (X_H = normal allele, Xh = haemophilia allele)

X	X^H	X^h
X^H	X^H X^H	X^H X^h
Y	X^HY	X^hY

This Punnett square shows that if the mother is a carrier and the father is unaffected:

1. There's a 50% chance for daughters to be carriers and a 50% chance to be unaffected.
2. There's a 50% chance for sons to be affected and a 50% chance to be unaffected. This explains why it primarily affects males.

X-Linked Dominant Inheritance

1. Rare: X-linked dominant conditions are less common than X-linked recessive ones.
2. Inheritance Patterns:
   a. Affected Mother: If an affected mother has children with an unaffected father, there is a 50% chance for both sons and daughters to be affected. However, some X-linked dominant conditions can be lethal to male embryos, making them appear almost exclusively in females.
   b. Affected Father**:** If an affected father has children with an unaffected mother, all his daughters will be affected because they inherit his X chromosome. None of his sons will be affected, as they inherit his Y chromosome.

Examples of X-linked dominant conditions include:

1. Rett syndrome: A severe neurodevelopmental disorder (often lethal in males).
2. Fragile X syndrome (in some cases): While primarily X-linked recessive, some female carriers can show milder symptoms due to X-inactivation.
3. Vitamin D-resistant rickets (X-linked hypophosphatemia).

Y-Linked Inheritance (Holandric Inheritance)

Y-linked traits, also known as holandric traits, are determined by genes located exclusively on the Y chromosome. The Y chromosome is much smaller than the X chromosome and contains very few genes (estimated around 200).

1. Inheritance Pattern: Y-linked conditions are passed only from father to son and will affect all sons of an affected father. Daughters will never be affected and cannot be carriers, as they do not inherit a Y chromosome.
2. Limited Recombination: The Y chromosome generally does not undergo genetic recombination (crossing over) with other chromosomes, except for small regions called pseudo autosomal regions. This means that Y-linked genes are typically passed down unchanged from father to son through generations.
3. Difficulty in Detection: Due to the Y chromosome's small size and limited gene content, Y-linked traits were historically difficult to confirm. However, advancements in DNA sequencing have allowed for more accurate identification of Y-linked genes.
4. Examples: Most well-established Y-linked genes are involved in male sex determination and fertility. A common example is the SRY gene (Sex-determining Region Y gene), which triggers male development. Other Y-linked genes are associated with conditions like certain forms of male infertility due to Y-chromosome deletions.
5. Hypertrichosis pinnae auris (hairy ears): Was once thought to be a Y-linked trait but later discredited. This highlights the challenges in definitively confirming Y-linkage without modern genetic tools.

Characteristics of Y-linked inheritance

1. Occurs only in males.
2. Appears in all sons of males who exhibit the trait.
3. Is absent from daughters of trait carriers.

Other Complex Inheritance Patterns

Beyond simple Mendelian inheritance and sex-linked patterns, many traits are influenced by multiple genes and environmental factors.

Sex-Influenced Traits

Sex-influenced traits are autosomal traits whose expression or dominance is influenced by an individual's biological sex. This means an allele might be dominant in one sex but recessive in the other, often due to differences in sex hormones.

Example: Pattern Baldness in Humans: The gene for pattern baldness is located on an autosome. It acts as a dominant trait in males (requiring only one copy of the allele for expression) but a recessive trait in females (requiring two copies for significant expression, and even then, expression may be less severe than in males). This is influenced by the presence of male hormones like testosterone.

Sex-Limited Traits

Sex-limited traits are autosomal traits that are expressed in only one of the sexes, even though the genes for these traits are present in both males and females. The expression is effectively "limited" by the presence or absence of specific sex hormones or anatomical structures.

1. Example: Milk Production in Mammals: Genes for milk production are present in both male and female mammals. However, only females express the trait of lactation, as it's dependent on female hormones and mammary gland development.

2. Other Examples: Age of onset of menstruation, width of pelvis, and specific patterns of body hair distribution.

Polygenic Inheritance (Multifactorial Traits)

Polygenic inheritance describes traits that are determined by the cumulative effects of multiple genes (alleles at many loci) rather than a single gene. These traits often show continuous variation within a population, meaning there's a gradual range of phenotypes rather than distinct categories.

1. Continuous Traits: Unlike "discontinuous traits" (like blood types A, B, O, AB, which fall into clear categories), polygenic traits are "continuous." You can't easily put individuals into distinct groups.
2. Additive Effect: In polygenic inheritance, the effect of individual alleles is often small, and they typically do not display simple dominance or recessiveness. Instead, each "contributing allele" adds a small, additive effect to the phenotype.
3. Multifactorial Traits: Many polygenic traits are also multifactorial, meaning they are influenced by both multiple genes and environmental factors. Environmental factors can significantly modify the expression of these genetic predispositions.

Examples of Polygenic Inheritance

1. Skin Colour: Human skin colour is primarily determined by at least three, and likely more, genes that control the production of melanin. Individuals inherit a combination of "contributing" alleles (leading to darker skin) and "non-contributing" alleles (leading to lighter skin). The additive effect of these alleles results in the wide spectrum of human skin tones.
2. Human Height: Height is an incredibly complex multifactorial trait controlled by over 400 genes. This complexity makes predicting an offspring's height challenging. Environmental factors during growth, such as nutrition, health, and exposure to disease, also play a significant role in determining final adult height. Two short parents can have a tall child, and vice versa, due to the complex interplay of numerous genes and environmental influences.
3. Weight, Body Build, Intelligence: These are also examples of complex multifactorial traits influenced by many genes and environmental factors.

Learning Tasks

1. Analyse the concepts of related to Mendelian crossing and sex determination
2. Analyse genetic crossing diagrams through comparative evaluation
3. Analyse sex determination through multiple crossing scenarios
4. Develop comprehensive genetic counselling strategies using Mendelian crossing principles

Pedagogical Exemplars

1. **Collaborative and talk/sign for learning**
   a. In mixed ability groups, learners research Gregor Mendel's experiments with pea plants and how his findings laid the foundation for our understanding of inheritance for a class discussion.

b. Discuss with learners the historical background of sex chromosome discovery and the pioneering work of researchers such as Nettie Stevens and Thomas Hunt Morgan.

c. Use diagrams to guide learners in illustrating the structure and function of sex chromosomes.

d. Using visual representations guides learners to understand the human karyotypes, highlighting the differences between male (XY) and female (XX) sex chromosomes.

e. In mixed-ability groups, learners discuss the inheritance patterns of sex-linked traits and disorders, such as colour blindness, haemophilia, and present their findings for the class discussion.

f. Use Punnett squares and pedigree analysis to guide learners in illustrating how sex-linked traits are passed down from parents to offspring and predict the probability of trait expression.

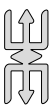
Key Assessment Level 3: Computation

1. In a family, the mother is a carrier for an X-linked disorder, and the father is normal. They already have one daughter who is a carrier and one son who is affected.
   a. What are the genotypes of the parents? **(1 mark)**
   b. What is the probability that their third child will be a normal son? **(3 marks)**
2. A woman who is not a carrier marries a man who has haemophilia (X^hY).
   c. What is the probability that their children will have haemophilia? **(4 marks)**
   d. If they have a child with haemophilia, what is the probability that the child is male? **(4 marks)**

PLC Session 16

45 minutes | **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to
   a. explain the week's concepts in a practical way that will make it easier for learners to understand
   b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject specific app to plan your lesson. Ask the app to
   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
   b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
   c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

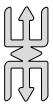
- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Plan the week's key assessment with your app

a. The key assessment for the week is ***computation***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the computation (NTS 3k-3q).

10 minutes Content Exploration

5. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
   a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
   b. all teachers in the group work through a similar problem individually for 3–4 minutes
   c. the group then works through the problem together step by step
   d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- *This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?*
- *If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.*
- *Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.*

30 minutes Enactment

6. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).
   a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
   b. After the enactment, ask for structured feedback from the group
      i. was the concept explained in a way that a learner with no prior knowledge could follow?
      ii. were the examples grounded in contexts familiar to Ghanaian learners?
      iii. did any misconceptions surface and if so, how were they addressed?

5 minutes Reflection

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
   a. transfer your chats into your learning planner template.
   b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
   c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

WEEK 17

Learning Indicator: *Explore selected traits in humans using applications of Mendelian crossing*

Focal Area: Understanding Mendelian Inheritance through Human Traits

Overview

Have you ever wondered why you have your mother's eyes or your father's nose? Or why some siblings look so similar while others appear quite different? The answers lie in the fascinating field of genetics – the study of heredity, which is how traits are passed from parents to their offspring.

Centuries ago, a curious monk named Gregor Mendel conducted ground-breaking experiments with pea plants. His meticulous work, long before the discovery of DNA, laid the foundation for our understanding of how traits are inherited. His principles, now known as Mendelian genetics, provide a powerful framework for predicting the patterns of inheritance for many simple traits.

In this manual, we will dive into selected human traits that often follow Mendelian patterns of inheritance. Learners will be taught to use the tools of Mendelian crossing, like the Punnett Square**,** to predict the likelihood of offspring inheriting specific characteristics. By observing traits in themselves, their families, and their classmates, they will gain a deeper appreciation for the genetic blueprint that makes each of us unique.

Selected Mendelian Human Traits

Many human traits are complex and influenced by multiple genes and environmental factors (polygenic or multifactorial traits). However, some fascinating traits are widely accepted to follow simple Mendelian inheritance patterns, making them excellent examples for our study.

Some common examples:

Earlobe Attachment

1. Phenotypes: Free earlobes vs. Attached earlobes
2. Inheritance Pattern: Free earlobes are generally considered dominant over attached earlobes.
3. Alleles: F: Allele for Free earlobes (dominant) and f: Allele for Attached earlobes (recessive)
4. Genotypes & Phenotypes**:**
    a. FF: Free earlobes (homozygous dominant)
    b. Ff: Free earlobes (heterozygous)
    c. ff: Attached earlobes (homozygous recessive)

Widow's Peak Hairline

1. Phenotypes: Widow's Peak (V-shaped hairline) vs. Straight Hairline
2. Inheritance Pattern: Widow's Peak is generally considered dominant over a straight hairline.
3. Alleles
    a. W: Allele for Widow's Peak (dominant)

   b. w: Allele for Straight Hairline (recessive)
4. Genotypes & Phenotypes
   a. WW: Widow's Peak (homozygous dominant)
   b. Ww: Widow's Peak (heterozygous)
   c. ww: Straight Hairline (homozygous recessive)

Tongue Rolling

1. Phenotypes: Ability to roll tongue into a U-shape vs. Inability to roll tongue
2. Inheritance Pattern: Tongue rolling is generally considered dominant over non-rolling.
3. Alleles
   a. R: Allele for Tongue Rolling (dominant)
   b. r: Allele for Non-rolling (recessive)
4. Genotypes & Phenotypes
   a. RR: Tongue Rolling (homozygous dominant)
   b. Rr: Tongue Rolling (heterozygous)
   c. rr: Non-rolling (homozygous recessive)

Dimples

1. Phenotypes: Presence of dimples vs. Absence of dimples
2. Inheritance Pattern: Presence of dimples is generally considered dominant over the absence of dimples.
3. Alleles
   a. D: Allele for Dimples (dominant)
   b. d: Allele for No Dimples (recessive)
4. Genotypes & Phenotypes
   a. DD: Dimples (homozygous dominant)
   b. Dd: Dimples (heterozygous)
   c. dd: No Dimples (homozygous recessive)

PTC Tasting

1. Phenotypes: Ability to taste Phenylthiocarbamide (PTC) vs. Inability to taste PTC
2. Inheritance Pattern: Ability to taste PTC is generally considered dominant over non-tasting. (PTC is a harmless chemical often found on special paper strips used for testing).
3. Alleles
   - T: Allele for PTC Taster (dominant)
   - t: Allele for PTC Non-taster (recessive)
4. Genotypes & Phenotypes

- TT: PTC Taster (homozygous dominant)
- Tt: PTC Taster (heterozygous)
- tt: PTC Non-taster (homozygous recessive)

The Punnett Square is a simple yet powerful tool for visualising and predicting the outcomes of genetic crosses.

Steps for Performing a Monohybrid Cross

Use the example of earlobe attachment.

Scenario: A man who is heterozygous for free earlobes (Ff) marries a woman who is also heterozygous for free earlobes (Ff). What are the possible genotypes and phenotypes of their children, and what are the probabilities?

Step 1: Identify the trait and its alleles.

- Trait: Earlobe Attachment
- Alleles: F (Free earlobes - dominant), f (Attached earlobes - recessive)

Step 2: Determine the genotypes of the parents (P generation).

- Man's genotype: Ff
- Woman's genotype: Ff

Step 3: Determine the possible gametes each parent can produce.

- Each parent, being heterozygous (Ff), can produce two types of gametes: one carrying the F allele and one carrying the f allele.
  - Man's gametes: F, f
  - Woman's gametes: F, f

Step 4: Draw a Punnett Square and fill it in.

- Place the possible gametes from one parent along the top row.
- Place the possible gametes from the other parent along the left column.
- Fill in each box by combining the alleles from the corresponding row and column.

	F	**f**
F	FF	Ff
f	Ff	ff

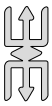
Step 5: Determine the predicted genotypes and phenotypes of the offspring (F_1 generation) and their ratios/probabilities.

- Genotypes
  - FF: 1 out of 4 squares (1/4 or 25%)
  - Ff: 2 out of 4 squares (2/4 or 1/2 or 50%)
  - ff: 1 out of 4 squares (1/4 or 25%)
  - Genotypic Ratio: 1 FF : 2 Ff : 1 ff
- Phenotypes

- Free earlobes (FF and Ff): 3 out of 4 squares (3/4 or 75%)
- Attached earlobes (ff): 1 out of 4 squares (1/4 or 25%)
- Phenotypic Ratio: 3 Free earlobes : 1 Attached earlobes

My Family's Genetic Traits

Mendelian genetics to observable traits in yourself and your family.



Important Ethical Note

This activity is for educational purposes only. Do not attempt to diagnose any medical conditions or make judgments about individuals based on these simple traits. Always ask for permission before observing or discussing traits with family members and respect their privacy.

Materials

Pen/pencil, this manual, observation skills, optional: PTC taste strips (if available for testing PTC tasting)

Instructions

1. Observe Your Own Traits: For each trait listed in the table below, determine your own phenotype.
2. Observe Family Traits: With permission, observe the same traits in your parents and siblings. If you don't know or cannot observe a trait for a family member, leave it blank.
3. Fill in the Table: Record your observations in the "Phenotype" column.

Trait	Dominant Phenotype	Recessive Phenotype	My Phenotype (Circle one)	Parent 1 Phenotype	Parent 2 Phenotype	Sibling 1 Phenotype	Sibling 2 Phenotype
Earlobe Attachment	Free Earlobe	Attached Earlobe	Free / Attached				
Widow's Peak	Widow's Peak	Straight Hairline	Widow's Peak / Straight				
Tongue Rolling	Can Roll Tongue	Cannot Roll Tongue	Can / Cannot				
Dimples	Dimples Present	Dimples Absent	Present / Absent				
PTC Tasting	Can Taste PTC	Cannot Taste PTC	Can / Cannot				

Analysis Questions

Using the information from week 14 and week 16, answer the following questions. If you need to make assumptions about genotypes (e.g., if a parent has a dominant phenotype but their genotype isn't known from observations), state your assumptions clearly.

1. Your Genotypes: Based on your phenotype and your parents' phenotypes, try to determine your most likely genotype for each trait. Explain your reasoning.
    a. Example: If you have attached earlobes (ff), both your parents must carry the 'f' allele. If they both have free earlobes, they must both be heterozygous (Ff).
2. Parental Genotypes: For any trait where you and your parents have a dominant phenotype, but an offspring has a recessive phenotype (e.g., parents both free earlobes, but a sibling has attached), what must the parents' genotypes be? Show a Punnett Square to support your answer.
3. Predicting Offspring: If two individuals, both heterozygous for tongue rolling (Rr x Rr), were to have children, what is the probability that their child would not be able to roll their tongue? Show your Punnett Square.
4. Class Data (Optional)**:** If your teacher facilitates, collect class data for each trait and discuss the observed frequencies versus the Mendelian ratios (e.g., why might the 3:1 ratio not be perfectly observed in a small sample like your class?).

While Mendelian crosses are powerful for understanding basic inheritance, it's important to remember that human genetics is often more complex.

- Polygenic Traits: Many human traits (like height, skin colour, and intelligence) are influenced by multiple genes acting together, not just one.
- Environmental Influences: The environment can also play a significant role in how genes are expressed (e.g., nutrition affecting height potential).
- Incomplete Dominance: In some cases, the heterozygous phenotype is an intermediate blend of the two homozygous phenotypes (e.g., red and white flowers producing pink offspring).
- Codominance: Both alleles are fully expressed in the heterozygous phenotype (e.g., ABO blood groups, where A and B alleles are codominant).
- Sex-Linked Traits: Traits determined by genes located on the sex chromosomes (X or Y), leading to different inheritance patterns in males and females (e.g., colour blindness, haemophilia).

Height (Tall vs. Short) – Dominant/Recessive Trait

1. Assumption: Tall (T) is dominant and short (t) is recessive.
2. A heterozygous tall person (Tt) is crossed with another heterozygous tall person (Tt).

Punnett Square

	T	**t**
T	TT	Tt
t	Tt	tt

Genotypes: 1 TT (homozygous dominant): 2 Tt (heterozygous): 1 tt (homozygous recessive)

Phenotypes: 3 Tall: 1 Short

Interpretation

There is a 75% chance of a tall child and 25% chance of a short child.

Explanation of Height as Polygenic Inheritance using Punnet Square

Let us assume 2 gene pairs, each with a dominant and recessive allele:

1. A = tall, a = short
2. B = tall, b = short

Each dominant allele contributes to tallness. The more dominant alleles, the taller the individual.

Parent Genotypes: AaBb × AaBb

We will create a 16-square Punnett Square using all combinations.

Step 1: Possible gametes from each parent

Parent: AaBb → Gametes: AB, Ab, aB, ab

Step 2: Punnett Square

	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb

Count Dominant Alleles and Interpret Phenotype

Genotype	Dominant Alleles	Phenotype
AABB	4	Very tall
AABb	3	Tall
AaBB	3	Tall
AaBb	2	Medium height
AAbb	2	Medium height
Aabb	1	Short
aaBB	2	Medium height
aaBb	2	Short
aabb	0	Very short

2. Skin Colour – simplified model using one gene pair

Note

*In reality, skin colour is a **polygenic trait**, influenced by multiple genes. But for teaching Mendelian basics, a simplified dominant/recessive model is used.*

- Assumption: Dark skin (D) is dominant, light skin (d) is recessive.
- Cross: Heterozygous parents (Dd × Dd)

Punnett Square

	D	d
D	DD	Dd
d	Dd	dd

Genotypes:1 DD (homozygous dark): 2 Dd (heterozygous dark): 1 dd (homozygous light)

Phenotypes

3 Dark-skinned: 1 Light-skinned

Interpretation
Dark skin appears more frequently due to dominant allele

Explanation of Skin colour as Polygenic Inheritance Using Punnett Squares

We will assume:

- Two genes (A and B) control skin pigment.
- Dominant alleles (A and B) contribute dark pigment.
- Recessive alleles (a and b) contribute light pigment.
- The total number of dominant alleles determines skin shade.

Parental Genotypes: AaBb × AaBb

Each parent can pass on four possible gametes:
AB, **Ab**, **aB**, **ab**

16-Square Punnett Grid

	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb

Dominant Allele Count and Phenotype

Genotype	Dominant Alleles	Skin Colour Phenotype
AABB	4	Very dark
AABb	3	Dark
AaBB	3	Dark
AaBb	2	Medium tone
AAbb	2	Medium tone
aaBB	2	Medium tone
Aabb	1	Light
aaBb	1	Light
aabb	0	Very light

Interpretation for Learners

1. Skin colour shows a range, not just light or dark.
2. Most offspring are expected to fall into the middle tones (2 dominant alleles).
3. More dominant alleles = more melanin = darker skin.

Baldness – Sex-Influenced Trait

- Assumption: Baldness is dominant in males (B), recessive in females.
- Genotypes:
  - BB = bald in both sexes
  - Bb = bald in males, not bald in females
  - bb = not bald in both sexes

Example: A heterozygous bald man (Bb) marries a heterozygous woman (Bb).

Punnett Square

	B	b
B	BB	Bb
b	Bb	bb

Genotypes:1 BB: 2 Bb: 1 bb

Phenotypes

- Males
  - BB and Bb = Bald (3 out of 4)
  - bb = Not bald (1 out of 4)

- Females
  - BB = Bald (1 out of 4)
  - Bb = Not bald (2 out of 4)
  - bb = Not bald (1 out of 4)

Interpretation

This shows how the same genotype (Bb) expresses differently in males and females, due to influence of sex hormones.

Explanation of Haemophilia Using a Punnett Square

Haemophilia is a sex-linked recessive genetic disorder, most commonly carried on the X chromosome. It affects blood clotting and occurs more frequently in males because they have only one X chromosome (XY), while females have two (XX).

Key Points

- The haemophilia gene is represented by X^h (affected) and a normal X by X.
- Since males inherit only one X from their mother, if that X carries the haemophilia gene, they will have the disorder.
- Females need two copies of the haemophilia gene to be affected (X^hX^h), which is rare. If they have one affected X (X^hX), they are carriers.

Example Punnett Square:

Let's consider a carrier mother (X^hX) and a normal father (XY).

	X^h	**X**
X	**X^h X**	XX
Y	**X^h Y**	XY

Offspring Outcomes

1. XX (normal girl) – not affected
2. X^hX (carrier girl) – not affected, but carries the gene
3. XY (normal boy) – not affected
4. X^hY (haemophilic boy) – affected

Learning Tasks

1. Analyse complex inheritance patterns by strategically selecting and applying genetic notation systems.
2. Analyse complex polygenic inheritance patterns using skin colour, height as a model system
3. Analyse complex sex-linked inheritance patterns with hormonal and age-related factors

Pedagogical Exemplars

Collaborative learning

1. Provide learners in their mixed groups with images, diagrams, and videos illustrating underlying trait expression and inheritance. Learners observed and recorded examples of human traits.
2. Provide hands-on crossing activities for learners to simulate genetic crosses using Punnett squares or other visual aids.
3. Guide learners in calculating and comparing the observed phenotypic ratios to the expected ratios based on Mendelian inheritance.

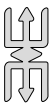
Key Assessment Level 3: Case study

1. Given a scenario where two parents—one tall (heterozygous) and one short (homozygous recessive)—have children, draw a Mendelian cross and determine the possible genotypes and phenotypes of their offspring. Explain your reasoning. **(10 marks)**
2. You are provided with a case where both parents have normal hair but one of their children is bald. Using a Punnett square, determine the likely genotypes of the parents and explain how baldness is inherited. **(10 marks)**

PLC Session 17

45 minutes | **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous year/session/week, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to
   a. explain the week's concepts in a practical way that will make it easier for learners to understand
   b. identify two or three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners. (NTS 3a, 3g and 3m).
3. Use your subject specific app to plan your lesson. Ask the app to
   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.
   b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q)
   c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

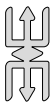
- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Plan the week's key assessment with your app

a. The key assessment for the week is ***case study***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the case study (NTS 3k-3q).

10 minutes Content Exploration

4. As a subject group, select one problem or idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then
   a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)
   b. all teachers in the group work through a similar problem individually for 3–4 minutes
   c. the group then works through the problem together step by step
   d. highlight the most common errors made at each step and discuss (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- *This part is not just about 'How do I teach this?' but how do I teach it for learners to understand?*
- *If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.*
- *Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.*

30 minutes Enactment

5. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).
   a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.
   b. After the enactment, ask for structured feedback from the group
      i. was the concept explained in a way that a learner with no prior knowledge could follow?
      ii. were the examples grounded in contexts familiar to Ghanaian learners?
      iii. did any misconceptions surface and if so, how were they addressed?

5 minutes Reflection

6. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
7. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
8. Remember to
   a. transfer your chats into your learning planner template.
   b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
   c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 9 Review

In Week 16, learners studied sex determination in humans using Mendelian crossing. They were taught that biological sex is determined by the combination of sex chromosomes inherited from the parents, XX for females and XY for males. Through Punnett square exercises, learners demonstrated how the mother always contributes an X chromosome, while the father contributes either an X or a Y chromosome, ultimately determining the sex of the offspring. By the end of the week, each learner should have been able to draw and interpret a Punnett square for sex determination, explain the genetic basis of male and female offspring, and understand that the father's contribution determines the child's sex.

In Week 17, learners built on this knowledge by applying Mendelian genetics to explore selected human traits, such as tongue rolling, dimples, hitchhiker's thumb, and attached earlobes. They reviewed dominant and recessive traits, learned how to represent genotypes using allele symbols (e.g., Rr, rr), and used Punnett squares to predict the probability of inheriting certain traits. Learners also practiced identifying phenotypes and genotypes from given crosses. By the end of the week, each learner should have been able to apply Mendelian principles to solve problems involving human traits, explain how traits are passed from parents to offspring, and interpret genetic crosses in real-life contexts.

Together, these two weeks deepened learners' understanding of inheritance through visual tools, critical thinking, and practical applications of Mendelian laws.

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 16

Question 1

a) Parental genotypes – 1 mark

Mother = X^NX^c (carrier), Father = X^NY (normal) – 1 mark (each ½ mark mother and father)

(Total of 1 mark)

b) Probability of normal son – 3 marks

i. Showing of crossing: 1 mark

ii. Son genotypes: X^NY (normal), X^cY (affected) – 1 mark

iii. Probability son is normal = 1 mark

(Total of 4 marks)

Question 2

c) Probability of haemophilic child – (4 marks)

- Father: X^hY; Mother: X^HX^H – (each ½ mark =1marks)
- Correct crossing: (1 mark)
- Offspring: All daughters are carriers; all sons normal – (2 marks)

(Total 4 marks)

d) Probability child with haemophilia is male – (2 marks)

- No child can have haemophilia – (1 marks)
- Conditional statement (if a child does, it's not male) – (1 marks)

(Total 4 marks)

WEEK 17

Question 1

a. **Identify the alleles and parent genotypes (2 marks)**
Let T = Tall (dominant trait), and t = short (recessive trait).

- The tall parent is heterozygous (Tt). (1 marks)
- The short parent is homozygous recessive (tt). (1 marks)

b. **Construct the Punnett Square (2 marks)**

x	**t**	**T**
t	tt	Tt
t	tt	Tt

Correct crossing ½ mark each =1/2*4= 2marks

c. **Identified genotypes with accurate ratio or count (2 marks)**

E.g.,: From the Punnett square, the offspring genotypes are:

2 Tt (heterozygous tall) (1 mark): 2 tt (homozygous short) (1 mark)

d. **Identification of phenotypes with logical ratio (2 marks)**

- 50% of the offspring will be Tall (Tt) (1 mark)
- 50% will be Short (tt) (1 mark)

e. **Explanation of genetic probability based on inheritance patterns (2 marks)**
E.g.: Because the tall parent has one dominant (T) and one recessive (t) allele, and the short parent has only recessive (t) alleles, each child has a 50% chance of inheriting a Tt (tall) or a tt (short) combination. The Punnett square clearly shows this equal probability.

(Total of 10 marks)

Question 2

1. Baldness Inheritance (5 marks)

Baldness in this case is assumed to be a **recessive trait.** (1 mark)

Let:

- **B** = allele for normal hair (dominant) (1mark)
- **b** = allele for baldness (recessive) (1mark)

If both parents have normal hair but have a bald child, they must both be carriers of the recessive gene. So, their genotypes are likely:

- **Parent 1: Bb** (1 mark)
- **Parent 2: Bb** (1 mark)

Accurately constructs and labels Punnett square (3 marks)

E.g., Punnett Square**:**

	B	b
B	BB	Bb
b	Bb	bb

Identifies genotypes correctly (1 mark)

E.g.: The genotypic ratio is: 1 BB (homozygous dominant): 2 Bb (heterozygous carriers): 1 bb (homozygous recessive)

Explains phenotypes and carrier concept (2 marks)

E.g.: The phenotypic ratio is:

- 3 with normal hair (BB and Bb) (1 mark)
- 1 bald (bb) (1 mark)

Explanation: (2 marks)

- The parents both have the Bb genotype (normal but carriers).
- They can pass either the B or b allele.
- The child who is bald inherited b from both parents, making the genotype bb.
- This shows that baldness is inherited as a recessive trait, only expressed when both alleles are recessive.

Each point ½ mark = (2 marks)

(Total 10 marks)

SECTION 10: INDIGENOUS TEXTILE PRODUCTION

STRAND: RELATIONSHIPS WITH THE ENVIRONMENT

Sub-Strand: Technology in local industries

Learning Outcome: *Evaluate the scientific processes involved in the production of indigenous textiles and its economic importance*

Content Standard: *Demonstrate knowledge of the scientific processes involved in the production of indigenous textiles*

INTRODUCTION AND SECTION SUMMARY

In this section, learners explore the scientific processes involved in the production of indigenous textiles such as tie-dye, batik, and adire. These traditional methods use the principles of resist dyeing, where certain parts of the fabric are protected from dye to create patterns using techniques like tying, waxing, or starching. Learners will investigate how materials interact through processes such as absorption, diffusion, solubility, and chemical fixation. They will also learn the role of heat, natural and synthetic dyes, and fixatives in setting colours permanently. By the end of the section, learners should be able to describe the step-by-step processes used in tie-dye, batik, and adire production, identify the scientific concepts applied at each stage, and explain how traditional textile art is grounded in scientific principles. They will also be expected to observe or engage in simple textile dyeing activities and analyse the outcomes using scientific reasoning.

The weeks and the indicators covered by the section are:

Week 18: Analyse the scientific processes involved in indigenous textiles production (such as tie-dye, batik, adire)

SUMMARY OF Pedagogical Exemplars

To effectively teach the scientific and socio-economic aspects of indigenous textile production, teachers should use strategies like talk-for-learning, project-based learning, collaborative learning, and critical thinking activities such as the Diamond Nine. Learners should work in pairs or groups to discuss various indigenous textiles, highlighting their cultural significance, traditional production methods, and the scientific principles involved (e.g., dye absorption and heat setting). Teachers should guide learners in creating visual aids such as posters or digital presentations to communicate their findings. Field trips to local textile producers should be planned with clear objectives, where learners prepare questions, observe processes, interact with materials and professionals, and document their experiences. Back in the classroom, learners analyse their observations collaboratively and present their findings using multimedia formats. These presentations are followed by group discussions to compare insights, explore challenges, and propose improvements. Learners are also tasked to research sustainable practices and community impacts of textile industries. Using the Diamond Nine approach, learners rank the economic benefits of indigenous textile production and display their ideas through poster presentations and gallery walks.

By the end of the section, learners should know the cultural and economic relevance of indigenous textiles, understand the science behind the processes, and be able to analyse, communicate, and apply their knowledge to real-world situations.

ASSESSMENT SUMMARY

In this assessment, learners are expected to demonstrate their conceptual understanding of the scientific processes involved in the production of indigenous textiles such as tie-dye, batik, and adire. Through essay-type questions, learners should explain how materials, dyes, heat, and resist techniques are used to achieve different patterns and colours. They should be able to describe the roles of soaking, boiling, waxing, and chemical reactions in the production process. The assessment aims to evaluate the learner's ability to connect traditional textile methods with relevant scientific principles (e.g., absorption, colour fixation, and the role of mordants). By the end of the task, learners should show a clear understanding of how indigenous knowledge integrates with science in textile production and be able to communicate these ideas using appropriate scientific vocabulary in written form.

Indicators	DOK Level	Assessment Strategy and/or Mode
Analyse the scientific processes involved in indigenous textiles production (such as tie-dye, batik, adire)	Level 2: Conceptual understanding	Essay-type questions

WEEK 18

Learning Indicator: *Analyse the scientific processes involved in indigenous textiles production (such as tie-dye, batik, adire)*

Focal Area: The science involved in the production of indigenous textiles

Analyse the scientific processes involved in indigenous textiles production (such as tie-dye, batik, adire)

Textile design, far beyond mere aesthetics, profoundly impacts the social, cultural, and economic well-being of individuals, communities, and nations. As a form of **mobile cultural** heritage, textiles serve as vital repositories of identity, history, and belief systems, making their preservation, documentation, and study for future generations, research, and public education an imperative.

Defining Indigenous Ghanaian Textiles

In Ghana, indigenous textiles are more than just clothing; they are deeply woven into the fabric of society, representing the attire specific to various ethnic groups with strong historical and cultural roots. While elements like colour palettes, forms, and the yarns and fibre types used may have undergone some modifications across successive generations, the foundational ideas, underlying philosophies, intricate techniques, and rich histories embedded within these textiles have largely remained consistent.

Ghana is a vibrant hub for traditional African fabrics, showcasing a remarkable diversity of indigenous textiles. Examples found in Ghana include, but are not limited to:

1. **Bogolanfini:** Hailing from Mali, its mud-dyed patterns reflect natural earth tones and abstract designs. It is made from cotton

Figure 10.0: *Bogolanfini Cloth*

2. **Adinkra Cloth:** A renowned Ghanaian fabric characterised by its stamped symbols, which is hand-printed using calabash stamps and natural black dye (adinkra aduro) derived from the bark of badie tree. Each of the symbols carry deep philosophical meanings and proverbs. It is made from cotton.

Figure 10.1: *Adinkra Cloth*

3. **Kuba Cloth:** Originally from the Democratic Republic of Congo, known for its intricate geometric patterns created from raffia fibre.

Figure 10.2: *Kuba Cloth*

4. **Adire:** A Yoruba resist-dyed textile from Nigeria, employing techniques like tying, stitching, or starch resist. It is made from 100% cotton.

Figure 10.3: *Adire*

5. **Kente:** Perhaps the most iconic Ghanaian textile, woven from silk and cotton strips in vibrant, complex geometric patterns, each with specific names and meanings. It originated from the Akan (Ashanti) and Ewe people

Figure 10.4: *Kente*

6. **Akwete Cloth:** A hand-woven fabric from Igbo Community, Nigeria, similar to Kente, known for its bold patterns and vibrant colours. It is made from cotton, rafia and sisal hemp.

Figure 10.5: *Akwete Cloth*

7. **Aso-Oke:** A hand-loomed cloth from the Yoruba people of Nigeria, often used for special occasions. It is made from cotton, silk or rayon

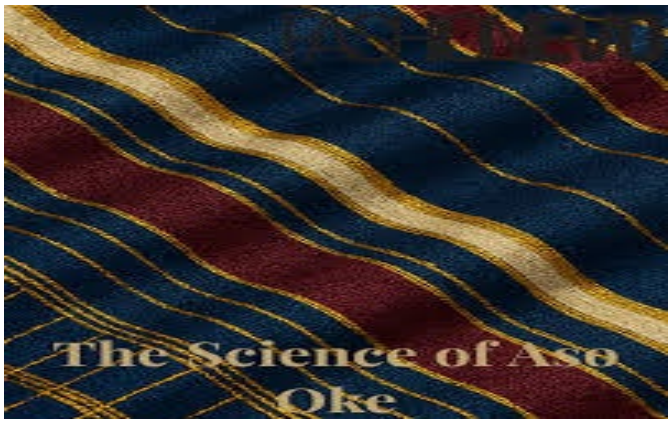


Figure 10.6: *Aso-Oke*

These exquisite textiles are traditionally crafted from natural fibres like cotton, silk, and raffia, and dyed with pigments derived from plants, minerals, or insects. However, a critical challenge lies in their inherent susceptibility to degradation; the natural colours tend to fade over time**,** making these precious artifacts vulnerable to extinction if not actively preserved.

Indigenous textiles are far more than just handicrafts; they are living cultural artifacts that encapsulate the very history, philosophies, and beliefs of a people. Their intricate designs, chosen colours, and production techniques symbolise a rich cultural history that must be safeguarded to uphold fundamental feelings of self, community, and belonging.

Indigenous Ghanaian textiles can be broadly divided into the following groups:

Traditional Textiles Made by Hand (Kente)

The complete history of Kente cloth, one of Ghana's most iconic textiles, is not definitively settled, with various accounts combining legend and historical evidence. Asante mythology attributes the origin of Kente weaving to Ota Kraban and Ameyaw in Bonwire, who reputedly drew inspiration from a spider's web, a narrative supported by the prevalence of woven lace and needlework during that era. However, historical accounts often trace Kente's roots to ancient weaving traditions in prosperous West African Kingdoms, flourishing between 300 and 1600 AD, pointing to archaeological findings of narrow-strip cloths from Mali dating back to the 11th century AD.

Regardless of its exact genesis, weaving appears to have been established in West Africa long before the formal creation of Kente as we know it. Evidence of early weaving, such as spindle whorls and loom weights, has been found in ancient empires like Meroe (500 BC to 300 AD).

In Ghana, weaving reportedly began in the northern regions, initially using rough raffia and later local cotton provided by farmers. By the 17th century, weaving became established in Bonwire, Ashanti. Traditionally, women prepared the fibres by spinning cotton, while men handled the weaving process, setting the warp and weft on a four-heddle loom. Early Kente also incorporated local Okanantan spider silk, which was later supplemented or replaced by imported European silk, sometimes mixed with cotton yarns. The intricate design and production methods, including the use of specific loom components, highlight Kente's profound historical and cultural significance as a mobile cultural heritage item essential for preservation, study, and public education.

Traditional Textiles with Handmade Prints (Adinkra)

Adinkra motifs serve as a powerful form of cultural expression, imbued with deep symbolic meaning derived from both representational natural objects and abstract concepts. These designs, traditionally stamped onto fabric, communicate profound philosophical ideas and proverbs. For example, specific shapes like the oval convey concepts of holiness, femininity, and beauty, while a half-circle or crescent is associated with fertility. Other symbols carry equally significant messages: the cross embodies compassion, and the arrow signifies a new beginning. Beyond general cultural meaning, Adinkra cloth was historically tailored to express a monarch's personal philosophy; a king's choice of aya (fern-patterned) fabric, for instance, specifically communicated his fearlessness. Through this intricate visual language, Adinkra textiles become wearable declarations of identity and wisdom.

Processes involved in the production of indigenous Adinkra textiles

Fabric Sourcing and Preparation: The foundation of Adinkra cloth is typically cotton fabric. Traditionally, this cotton would be woven locally. The fabric chosen can either be white (for a strong contrast with the dark stamp) or pre-dyed to a characteristic rusty brown colour. This brown hue is specifically known as "kuntunkuni," a name derived from the tree whose bark provides the dye.

Dye Preparation: The distinctive dark dye used for stamping Adinkra motifs is prepared from the bark of a specific indigenous tree: the kuntunkuni tree (scientifically known as *Bombax brevicuspe*). The process involves boiling or steeping the bark for an extended period to extract its rich dark pigments. This extract is then reduced and prepared into a thick, dark, inky dye solution that is suitable for stamping. The quality and depth of this dye are crucial for the clarity and longevity of the Adinkra symbols.

Motif Stamp Carving: Before stamping can begin, the Adinkra motifs themselves must be prepared. These intricate symbols are traditionally carved onto small, durable pieces of **calabash gourd** or wood. The carving process creates a raised relief of the desired symbol. Each specific Adinkra symbol has a predefined meaning and shape, requiring precise carving skills to ensure accuracy and detail when transferred to the fabric. Each stamp usually has a handle for easy gripping.

Stamping Process (Application): The chosen cotton fabric (white or kuntunkuni brown) is laid out smoothly, usually on a flat surface or a stretched frame. The carved Adinkra stamp is then dipped into the prepared dark dye solution, ensuring an even coating of dye on the raised pattern. The dye-laden stamp is then physically pressed firmly and carefully onto the fabric. This action transfers the dark motif onto the cloth. The artisan works systematically, repeating the stamping process across the entire fabric to create a coherent and often repetitive pattern, or to strategically place specific symbols.

Drying and Finishing: After the stamping is complete, the fabric is traditionally laid out to dry under the sun. The heat of the sun aids in fixing the dye to the cotton fibres, making it more permanent. Once completely dry, the Adinkra cloth may undergo a final rinsing to remove any excess dye or residue, which helps to further set the colour and ensures the patterns are crisp and clear.

Scientific principles involved in Adinkra textile production

1. **Dye Chemistry and Pigment Extraction**
    a. **Biochemical Extraction (Leaching):** The characteristic dark, rusty-brown dye for Adinkra is extracted from the bark of the **kuntunkuni tree** (*Bombax brevicuspe*). This process typically involves boiling or prolonged steeping of the bark in water. Scientifically, this is a form of leaching, where soluble organic compounds (the dye pigments, or chromophores) are extracted from the plant material into the hot water. The bark contains complex molecules, likely tannins (a class of polyphenols) and other natural organic pigments, which are responsible for the colour.
    b. **Dye Solution Formulation:** The extracted liquid is then processed into a thicker, inky consistency suitable for stamping. The stability and viscosity of this dye solution are critical for clear motif transfer.
    c. **Dye-Metal Interactions (Potential Mordanting):** While the provided text doesn't explicitly mention a mordant (a metallic salt used in dyeing to fix colour to fibres, creating a lasting connection between the dye and the fibre) for Adinkra dye, many natural brown dyes, particularly those rich in tannins, form stable complexes with metal ions. If the dye pots are made of iron, or if the water used contains dissolved iron, a chelation reaction could occur, where the dye forms insoluble coordination complexes with iron ions, enhancing colour fixation and contributing to the characteristic "rusty brown" or dark brown/black hue. This type of reaction significantly improves the dye's wash-fastness and light-fastness.
2. **Material Science of Fabric-Dye Interaction**
    a. **Cellulose Fibre Adsorption:** Adinkra predominantly uses cotton fabric, which is composed primarily of cellulose fibres. Cellulose fibres are hydrophilic (water-loving) due to their hydroxyl (-OH) groups. The dye molecules adhere to these cellulose fibres through various intermolecular forces, including hydrogen **bonding** and **van der Waals forces**, which allow the dye to be physically adsorbed onto and within the fibre structure.
    b. **Capillary Action:** When the liquid dye is applied to the fabric, it spreads outward from the point of contact into the surrounding fibres through capillary action. This phenomenon, driven by the surface tension of the liquid and the adhesive forces between the liquid and the narrow inter-fibre spaces, dictates the sharpness or slight bleeding of the stamped motif's edges.
3. **Physical Principles of Stamping (Direct Application)**
    a. **Pressure and Transfer:** The act of physically pressing the carved Adinkra stamp onto the fabric is governed by principles of pressure (Force per unit Area) and **adhesion**. The dye solution adheres to the raised surfaces of the stamp. When the stamp is pressed onto the fabric, the pressure ensures intimate contact, facilitating the direct transfer of dye from the stamp to the fabric.
    b. **Surface Tension Control:** The viscosity and surface tension of the dye solution are carefully balanced through traditional preparation methods to ensure the dye adheres well to the stamp without dripping excessively and transfers cleanly to the fabric without blurring the fine details of the motif.

4. **Drying and Dye Fixation**
    a. **Evaporation:** After the motifs are stamped, the fabric is typically laid out to dry. This process primarily involves the evaporation of the water (solvent) from the dye solution, leaving the solid dye particles physically trapped within the fabric fibres.
    b. **Photochemical Reactions (Sunlight):** Exposure to sunlight during drying can also play a role. The heat from the sun can further assist in the drying process, while ultraviolet (UV) radiation can induce photochemical reactions in some natural dyes, contributing to the final colour development and enhancing the dye's permanence and resistance to fading.

Processes involved in the production of indigenous Tie and Dye Textile

Tie-dye, a traditional textile art, boasts of a rich history spanning centuries and continents, found in diverse cultures across Asia, Africa, and potentially Latin America. This marvellous technique involves using thread to bind bundles of fabric tightly before dyeing, creating intricate designs through the resist method. Across West Africa, from Senegal to Nigeria, including countries like Ghana, Mali, and Sierra Leone, tie-dye traditions like Gara and Adire are integral to the cultural landscape, utilising either natural or synthetic dyes to produce their incredible patterns.

Fabric Preparation: The process typically begins with natural fibres, most commonly cotton, due to its absorbency and durability. Silk and rayon are also used in some traditions. The fabric is thoroughly washed to remove any impurities, sizing agents, or natural oils that might hinder dye absorption. It can then be left damp or dried, depending on the desired crispness or blending of the final pattern. For some Adire variations, the fabric might be pre-dyed to a base colour, such as the "kuntunkuni" brown.

Resist Application (Tying, Folding, Stitching, Waxing, or Pasting): This is the defining stage of tie-dye, where specific areas of the fabric are physically prevented from absorbing dye. Artisans employ a variety of ingenious methods:

1. **Tying (e.g., Adire Oniko, Gara):** Sections of the fabric are tightly bound with raffia, thread, string, or rubber bands. Small objects like stones, seeds, or corn kernels might be tied inside the fabric to create distinct circular or oval patterns. Folding the cloth into complex patterns (like a concertina or spiral) before tying creates geometric designs. The tightness and placement of the ties directly determine the pattern's sharpness and size.
    a. **Stitching (e.g., Adire Alabere):** Fine stitches are sewn into the fabric along a desired pattern line, and the thread is then pulled taut to gather and compress the fabric. This creates linear, curved, or more elaborate stitched resist patterns.
    b. **Starch Pasting (e.g., Adire Eleko):** A thick, viscous paste, traditionally made from cassava or maize flour, is hand-painted or stencilled onto the fabric. When this paste dries, it forms a physical barrier that the dye cannot penetrate.
    c. **Waxing (Batik):** Melted wax is applied to the fabric using specialised tools (like a *canting* for fine lines or a *cap* for stamping). The hydrophobic wax solidifies and creates a barrier against the water-based dye.

Dye Preparation

Natural Dye Extraction: Traditional tie-dye heavily relies on natural dyes.

a. **Indigo:** Leaves from the indigo plant (*Lonchocarpus cyanescens* or *Indigofera tinctoria*) are collected, often pounded, and then allowed to ferment in large earthenware dye pots, typically

partially sunk into the ground. This fermentation process is a crucial chemical reduction, transforming the insoluble blue indigo into a soluble, yellowish-green "leuco-indigo" form. Wood ashes or caustic soda might be added to soften water and maintain alkalinity, vital for the dyeing process.

b. **Kola Nut:** Kola nuts are finely crushed, usually with a mortar and pestle, and mixed with water and wood ashes (acting as a mordant/fixative) to produce a brown dye. This dye bath is labour-intensive to prepare and has a shorter usable life compared to indigo.

Dyeing (Immersion and Oxidation): The fabric, with its applied resists, is carefully immersed into the prepared dye bath. For indigo, the fabric is left in the soluble leuco-indigo solution to absorb the dye. Upon removal and exposure to air (oxygen), the leuco-indigo rapidly undergoes an oxidation reaction, reverting to its insoluble, vibrant blue form that is permanently trapped within the fabric fibres. The depth and richness of the blue hue are controlled by the number of times the fabric is dipped; the more immersions, the darker the indigo becomes.

For kola nut dye, the fabric absorbs the brown colour directly from the solution. Sometimes, fabrics are over-dyed (e.g., dipped in kola nut dye first, then in indigo) to create complex multi-tonal effects like dark greens or greenish-blacks.

Removal of Resist and Finishing: Once the dyeing process is complete and the dye is fixed (often by drying), the resist materials are removed. For tied fabrics, the strings, raffia, or rubber bands are untied. For stitched fabrics, the threads are carefully cut and pulled out. For starch-resist Adire Eleko, the dried cassava paste is scraped or washed off. For batik, the wax is typically removed by boiling the fabric in water, which melts the wax, allowing it to be skimmed off, followed by a thorough washing.

Scientific principles involved in Tie and Dye textile production

1. **Physical Principle of Resist Application**

   a. **Mechanical Barrier & Pressure:** The core of tie-dye involves physical manipulation of the fabric (tying, folding, twisting, knotting, stitching). These actions create a mechanical barrier by compressing and densifying the fabric in specific areas. The pressure exerted by the ties (e.g., raffia, string, rubber bands) physically blocks dye molecules from penetrating the tightly bound regions. This also reduces the pore space and hinders capillary action within those compressed areas.

   b. **Hydrophobicity (Wax Resist in Batik/related methods):** In techniques like Batik (which uses a similar resist principle), melted wax is applied. Wax is hydrophobic (water-repelling), creating an impermeable physical barrier against the aqueous dye solution.

   c. **Physical Blockade (Starch/Clay Resist):** In some forms, a thick paste (e.g., cassava starch) is applied. This paste dries to form a physical solid layer that mechanically blocks dye penetration.

2. **Fiber Chemistry and Dye Adsorption/Binding**

   a. **Cellulose Fiber Structure (Cotton):** Most traditional tie and dye fabrics are made from cotton, which is composed primarily of cellulose (a polymer of glucose units). Cellulose fibres contain numerous hydroxyl (-OH) groups, making them hydrophilic (water-attracting) and capable of interacting with dye molecules.

b. **Dye Molecule Properties (Chromophores & Auxochromes):** Dyes contain chromophores (chemical groups responsible for colour by absorbing certain wavelengths of light) and auxochromes (functional groups that enhance solubility and aid in binding to fibres).

c. **Dye-Fiber Bonding:** The permanence of the dye depends on the type of bond formed:

   - **Covalent Bonding:** Modern synthetic fibre-reactive dyes form strong, permanent covalent bonds with cellulose fibres under specific pH conditions (e.g., alkaline conditions created by soda ash). This is the most robust type of bonding, leading to high wash-fastness.
   - **Hydrogen Bonding & Van der Waals Forces:** Many natural dyes (like indigo or kola nut) and some synthetic dyes bind through weaker hydrogen bonds (between dye and cellulose hydroxyls) and van der Waals forces (general intermolecular attractions). These are less permanent than covalent bonds but still effective.

d. **Mordanting (Chemical Bridges):** For many natural dyes (e.g., kola nut dye), a **mordant** (e.g., wood ashes containing metal salts like aluminum or iron compounds) is crucial. Mordants act as chemical bridges by binding to both the dye molecule and the fibre, forming a stable coordination complex. This enhances the dye's adherence, lightfastness, and often modifies the final colour.

3. **Dye Bath Chemistry (pH, Reduction-Oxidation for Indigo)**

   a. **pH Control:** The pH of the dye bath is often critical for optimal dye uptake and reaction. For example, fibre-reactive dyes require an alkaline environment (high pH) for their reaction with cellulose. Acid dyes (used for protein fibres like wool/silk) require acidic conditions.

   b. **Redox Reactions (Indigo Dyeing):** Traditional indigo dyeing involves sophisticated **reduction-oxidation (redox) chemistry**.

      - **Reduction:** In its natural state, indigo (indigotin - the main colouring compound in indigo dye) is insoluble blue. To be used, it must be chemically reduced (e.g., through fermentation of leaves or by adding reducing agents like sodium hydrosulfite or Sodium dithionite) in an alkaline environment. This converts it into a soluble, yellowish-green form called **leuco-indigo** (or indigo-white).
      - **Oxidation:** The fabric is immersed in this soluble leuco-indigo solution. Upon removal from the dye bath and exposure to air (oxygen), the leuco-indigo rapidly oxidizes back to its insoluble blue form (indigotin), which then precipitates and becomes physically trapped within the fabric fibres, creating the permanent blue colour. This is why the colour develops upon exposure to air.

4. **Physical Processes During Dyeing and Finishing**

   a. **Diffusion & Capillary Action:** Dye molecules move from areas of high concentration (dye bath) into the fabric fibres (lower concentration) through **diffusion**. Within the fabric, dye solution spreads through the tiny spaces between fibres by **capillary action**.

   b. **Evaporation:** During drying, water evaporates from the dyed fabric, leaving the dye solids embedded within the fibres.

   c. **Mechanical Fixation:** Techniques like beating the cloth with a mallet (e.g., after indigo dyeing) can physically press dye particles deeper into the fibres and increase the fabric's sheen by compacting the fibres.

d. **Heat Transfer (Wax Removal):** In wax-resist methods (like Batik), removing the wax involves heat transfer (boiling water) to melt the wax, exploiting its lower density to separate it from the fabric.

Batik

Batik fabric-making is a wax-resist dyeing technique done by hand, usually in homes and small workshops by families or small groups of dealers.100% cotton fibre is used. From cotton grown in Ghana, (the dry, Savannah climate in the northern regions of the country is ideal for the cultivation of cotton) the plain fabric is made in factories there. Either calico or grey baft is used, the former being softer. The fabric dyes, though, are imported.

The cloth is pre-shrunk, due to the dyeing and washing and re-dyeing process. Hand-dyed & hand-printed they are suitable for a wide variety of projects. Sometimes light damask fabric is used and those have a slight shimmer to the finished product. They have strong, vibrant colours with abstract or Ghanaian designs.

Melted wax is applied to the fabric in a design of the batik maker's choice with a brush or pre-carved wooden block. Starting with a lighter colour the cloth is dipped in first dye and then dried. Wherever the wax has seeped through the fabric, the dye will not penetrate; the rest is the new colour.

More wax is applied for the next set of designs, followed by dyeing and drying until the complete number of colours and designs has been achieved. (Often several colours are used, with a series of waxing and dyeing steps.) The fabric is boiled to remove the wax for re-use, and to reveal the deep rich colours and the fine crinkle lines that give batik its character. The last stages involve a final drying and ironing for sale.

A few of them have two designs on the same piece, meant to complement each other. One fabric is an accent to the other.

Processes involved in the production of indigenous Batik

Fabric Preparation: The process typically begins with natural fabrics, most commonly cotton or sometimes silk, due to their absorbency and suitability for wax application. The fabric is thoroughly washed to remove any impurities, starches, or sizing agents that could interfere with dye absorption or wax adherence. It is then often stretched taut on a frame to ensure a smooth, stable surface for intricate wax application.

Design Planning & Transfer (Optional but Common): While some skilled artisans may apply wax freehand, designs are often sketched onto the fabric lightly with a pencil or charcoal. For complex or repetitive patterns, a pre-made design might be traced or stamped onto the fabric.

Wax Preparation and Application (The Resist)

1. **Wax Melting:** A blend of waxes (traditionally beeswax for flexibility and paraffin wax for its characteristic crackle effect) is melted in a wax pot over a heat source, maintaining it at a consistent, hot liquid state.
2. **Wax Application:** The melted wax is then applied to the fabric using specialized tools:
    a. **Canting (Tjanting):** A pen-like tool with a small copper reservoir and a fine spout, used for drawing intricate lines, dots, and detailed patterns by hand. This is known as *batik tulis* (written batik).

   b. **Cap (Tjap):** A copper stamp with a carved design, used for applying repetitive patterns more quickly and consistently over larger areas. This is known as *batik cap* (stamped batik).
   c. **Brushes:** Used for applying larger areas of wax or broader strokes.
3. **Resist Mechanism:** The wax, being hydrophobic (water-repelling), solidifies upon contact with the fabric, forming an impermeable barrier. This ensures that when the fabric is dyed, the areas covered by wax resist the dye and retain their original colour.
4. **Dyeing (Lightest Colour First):** Once the wax has hardened, the fabric is immersed in a dye bath. The dye molecules only penetrate and colour the unwaxed areas of the fabric.
5. **Colour Progression:** Batik dyeing typically proceeds from the lightest colours to the darkest. The first dye bath will be the lightest desired colour.
6. **Fixation:** Dyes are allowed to absorb, and for many synthetic dyes, a fixing agent (like soda ash) is used to create a permanent bond with the fabric fibers. Natural dyes (like indigo, kola nut) have their own specific preparation and fixation methods.
7. **Drying:** After dyeing, the fabric is carefully removed from the dye bath and hung to dry completely. Wringing or squeezing is avoided to prevent the wax from cracking prematurely (unless the crackle effect is desired at this stage).
8. **Repeated Waxing and Dyeing (for Multi-Colour Designs):** For multi-coloured batik, the process of waxing and dyeing is repeated in layers. After the first dye colour has dried, additional wax is applied to areas that are to remain that first colour. The fabric is then dyed in a darker colour. This process can be repeated multiple times, applying new wax to protect previously dyed areas and progressively introducing darker shades. The distinctive "crackle effect" often seen in batik is created by deliberately crinkling or manipulating the fabric after a layer of wax has hardened, causing the wax to crack. When the fabric is then dyed, the dye seeps into these fine cracks, creating a network of fine lines of the new colour within the waxed areas.
9. **De-waxing (Wax Removal):** Once all the desired colours have been applied and dried, the wax resist must be removed. The most common traditional method is to immerse the fabric in **boiling water**. The heat causes the wax to melt and separate from the fabric. Since wax is less dense than water, it floats to the surface, where it can be skimmed off (and often reused). In some methods, ironing the fabric between layers of absorbent paper (like newspaper) can also remove wax, as the paper absorbs the melted wax.
10. **Final Washing and Finishing:** After de-waxing, the fabric is thoroughly rinsed in warm water with soap to remove any residual wax and unbound dye. It is then dried and may be pressed or ironed to smooth out wrinkles and achieve the final desired finish.

Scientific principles involved in Batik textile production

1. **Physical Principle of Wax as a Resist**
   a. **Hydrophobicity:** The core principle of Batik. Wax is a hydrophobic (water-repelling) substance, meaning it does not mix with water. When applied to fabric, the melted wax solidifies and forms an impermeable physical barrier. This barrier prevents the aqueous dye solution from penetrating the waxed areas, leaving them undyed.
   b. **Melting and Solidification:** Wax has a relatively low melting point. It is applied to the fabric in its liquid (molten) state, allowing for intricate drawing or stamping. Upon cooling, it rapidly solidifies, creating a stable, physical mask on the fabric surface.

c. **Viscosity and Adhesion:** The consistency (viscosity) of the melted wax (often a blend of beeswax for flexibility and paraffin for brittleness/crackle) is crucial. It must be viscous enough to cling to the fabric without excessive spreading but fluid enough to flow smoothly from tools like the *canting* (for fine lines) or *tjap* (for stamping). It adheres to the fabric fibres through various intermolecular forces.

2. **Fabric Chemistry and Dye Adsorption/Binding**

   a. **Cellulose Fiber (Cotton):** Batik predominantly uses natural cellulose fibres like cotton. These fibers are hydrophilic (water-absorbing) and have numerous hydroxyl (-OH) groups that are receptive to dye molecules.

   b. **Dye-Fiber Interaction:** The way dyes bind to the fabric is chemical. Dyes contain **chromophores** (colour-bearing groups) and auxochromes (groups aiding solubility and binding).

      i. **Covalent Bonding:** For synthetic fiber-reactive dyes often used today, the dye forms strong, permanent covalent bonds with the cellulose fibres, typically in an alkaline environment (e.g., pH adjusted by soda ash).

      ii. **Hydrogen Bonding/Physical Adsorption:** Many natural dyes, and some synthetics, bind through weaker intermolecular forces like hydrogen **bonds** and **van der Waals forces**.

   a. **Capillary Action:** The dye solution is drawn into the unwaxed areas of the fabric through capillary action, filling the microscopic spaces between and within the fibres.

3. **Dye Chemistry (Especially for Traditional Dyes like Indigo)**

   a. **Solubility and Redox Reactions (Indigo):** If traditional indigo dye is used, complex reduction-oxidation (redox) chemistry is involved. Natural indigo (indigotin) is insoluble in water. It must be chemically reduced (e.g., through fermentation in an alkaline vat) to a soluble, yellowish-green form (leuco-indigo). When the fabric is removed from the vat and exposed to oxygen in the air, the leuco-indigo rapidly oxidizes back into its insoluble blue form, becoming permanently trapped within the fabric fibres.

   b. **Mordanting (for certain dyes):** While not universally required for all Batik dyes, some natural dyes need mordants (metal salts like alum or iron) to act as chemical "bridges" that help fix the dye permanently to the fabric, improving colourfastness by forming stable coordination complexes.

4. **Physical Processes During Dyeing and Layering**

   a. **Sequential Dyeing (Light to Dark):** The multi-colour effects in Batik are achieved by a precise sequence of waxing and dyeing, typically moving from the lightest dye colours to the darkest. Each colour is applied only to the unwaxed areas, and then new wax is applied to protect those newly dyed areas before immersing the fabric in a darker dye bath.

   b. **Drying and Evaporation:** After each dyeing stage, the fabric is dried, allowing the water to evaporate and leaving the dye solids embedded in the fibres.

5. **Wax Removal (De-waxing) and Finishing**

   a. **Heat Transfer and Phase Change:** The wax resist is removed, usually by immersing the fabric in boiling water. This applies heat, causing the wax to undergo a phase change from solid to liquid.

   b. **Density Difference:** Since melted wax is less dense than water, it floats to the surface, allowing it to be skimmed off (and often recycled).

c. **Solvent Removal (Alternative):** In some modern methods, chemical solvents might be used to dissolve the wax, which also relies on solubility principles.

d. **Final Washing:** A thorough wash with soap and hot water removes any residual wax and unbound dye particles, ensuring a clean, vibrant final product.

6. **Crackling Effect (Physics of Fracture)**

The distinctive "crackle" lines in some Batik designs are achieved by mechanically manipulating the fabric after the wax has been applied and hardened (e.g., crumpling or folding). This induces tiny fractures or cracks in the brittle wax layer. When the fabric is then dyed, the dye seeps into these fine cracks, creating the characteristic network of lines.

ADIRE TECHNIQUES

Adire are indigo-dyed cotton cloths decorated using a resist-dying technique to create striking patterns in blue and white. They were traditionally made and worn by women throughout the Ghana and West Africa. The cloths were usually made up of two strips of factory-produced cotton, sewn together to form a shape that was roughly square, and worn as wraps around the body. Cloths were made up of two strips of factory produced cotton shirting sewn together to form a shape that was roughly square. They were generally worn by women as wrappers. One of the most important factors in the popularity of adire during the 1960s was that a large number of cloths could be produced quickly and cheaply in response to changing customer demands. It has now however fallen out of favour.

Cloths were usually prepared and dyed, by women and treated in a variety of ways to create patterns that would be revealed after dying. Raffia and starch were the two most common forms of resist used in the production of adire.

The dyeing process

The cloths were usually prepared, and always dyed, by women. Their bright colour comes from imported indigo grains or locally grown indigo leaves, which were fermented and mixed with water softened with caustic soda to make a dye. The cloth would be dipped into a large pot of dye and then pulled out to allow it to oxidise – a process which could be repeated to make the colour darker. Sometimes after it had been dyed the cloth would be beaten with a mallet, so it took on a sheen.

Creating pattern

Before dyeing, the cloths would be treated in a variety of ways to prevent certain parts of the fabric from absorbing dye. This would create the patterns revealed after the dyeing process. Raffia and starch were the two most common forms of resist-dyeing used. Tying raffia around the cloth, a process known as àdìrẹ oniko, could produce a huge variety of patterns. For example, tying small stones or seeds into the cloth would create small circles, or larger circles could be made by lifting a point of fabric and binding the fabric beneath it tightly.

A pattern formed of a specific combination of circles might be given a name; the pattern names often varied from town to town or changed over time. One example made in Ibadan in the 1960s features five rows of large circles with small circles filling the rest of the cloth, a pattern known there as olosupaeleso, or 'moons and fruits'.

Adire The Art of Raffia Resist Dyeing

Adire represents a captivating facet of traditional textile production, where the humble raffia fibre is masterfully employed to create intricate resist-dyed patterns. This technique, a subcategory of the broader adire (tie-dye) tradition, is renowned for its versatility and the stunning array of designs it yields, often in vibrant indigo blue and contrasting white.

At its core, adire oniko is a mechanical resist dyeing method. This means that patterns are formed by physically binding or tying sections of the fabric very tightly with raffia (or sometimes thread) before the cloth is immersed in a dye bath. The tightly bound areas act as a physical barrier, preventing the dye solution from penetrating the fabric fibres underneath. This creates sharp, undyed patterns against the dyed background.

Crafting Patterns with Raffia: Techniques and Variations

A remarkable variety of patterns can be produced by varying the way the raffia is applied:

Creating Circles: Small Circles: Artisans often tie small stones or seeds directly into the cloth. The tightness of the knot around the object creates a small, defined circular resist, resulting in crisp white dots against the dyed background.

Larger Circles: For bigger circular motifs, a point of fabric is lifted, and the fabric directly beneath it is bound tightly with raffia. The size of the lifted and bound area determines the diameter of the resulting circle.

Achieving Linear and Geometric Patterns: Concertina Folding (Accordion Pleating): One highly effective technique involves meticulously folding the cloth from corner to corner like a concertina (an accordion-like pleat). Once folded, the entire length of the pleated cloth is then bound very tightly at various, evenly spaced points along its length.

When this tightly bound, folded cloth is dyed, the dye only saturates the exposed areas between the bindings. The bound sections remain undyed.

Upon unfurling and unbinding the cloth, this method creates a striking diamond-shaped pattern with alternating blue and white stripes.

The broadness of these stripes can be precisely controlled by adjusting the intervals at which the cloth is bound. Tighter, closer bindings produce finer stripes, while looser, more spaced bindings result in broader stripes.

Beyond Simple Shapes: The ingenuity of adire oniko extends to much more complex designs. Artisans might combine various tying methods, incorporate intricate knotting techniques, or strategically pleat and bind the fabric to achieve highly detailed geometric motifs, abstract compositions, or even figurative representations.

The Dyeing Process: Traditionally Indigo: While modern adire may use synthetic dyes, the traditional and most revered adire oniko employs natural indigo dye. This involves a multi-step chemical process:

Preparation of the Indigo Vat: Natural indigo dye is insoluble in water in its vibrant blue form. It must be chemically reduced in an alkaline solution (traditionally through fermentation using ingredients like ash, local sweeteners, and bacteria) to a soluble, yellowish-green form called leuco-indigo.

Dyeing Immersion: The raffia-bound cloth is carefully immersed in this leuco-indigo dye bath. The soluble dye penetrates the unwaxed/unbound fibres.

Oxidation: Upon removal from the dye bath, the leuco-indigo rapidly oxidizes when exposed to air (oxygen). This chemical reaction converts it back into its insoluble blue form, effectively trapping the colour within the fabric fibres.

Repeated Dipping: To achieve deeper and richer shades of blue, the fabric is typically dipped multiple times, allowing it to oxidize between each dip, sometimes requiring dozens of immersions.

Unbinding and Finishing: After the desired depth of colour is achieved and the fabric is fully oxidized and dried, the raffia bindings are carefully removed, revealing the intricate white patterns against the deep blue background. The cloth is then rinsed and washed to remove any excess dye.

The meticulous handwork involved in the tying and folding, combined with the transformative chemistry of the indigo vat, makes adire oniko a testament to the scientific and artistic heritage embedded in indigenous textile traditions. The popularity of specific designs, like the "cloth of the year" in 1964, further highlights the cultural significance and dynamic evolution of this ancient craft.

Stitch resist

The term adire alabare is used when sewing has been used as a means to resist the dye. If the sewing has been done with raffia then it would be a form of adire oniko. Both machine sewing and hand sewing could be used to produce patterns. Although adire cloths were usually made by women the cloths that used a sewing machine were made by men.

When the two pieces of dyed cloth were stitched together is created a diamond shaped pattern with alternating blue and white stripes. The broadness of the stripes can be varied by the intervals at which it is bound

Adire

Adire encompasses various resist-dyeing techniques primarily practiced by the Yoruba people of Southwestern Nigeria. It traditionally uses natural indigo dye and different resist materials.

Types of Adire and their Resist Mechanisms

Adire Oniko (Tying/Knotting): Involves tying raffia, thread, or individual corn kernels/pebbles tightly around sections of fabric. The fabric can also be twisted or folded and tied.

Scientific Process: Similar to tie-dye, this is a mechanical resist. The physical compression and tight wrapping create a barrier that prevents dye penetration or allows only limited seepage, resulting in circular, striped, or irregular patterns.

Adire Alabere (Stitching): Resist: Patterns are created by stitching raffia or thread tightly into the fabric in a specific design (e.g., lines, curves, motifs). The fabric is then gathered tightly along these stitched lines.

Scientific Process: This is also a mechanical resist based on physical tension and compression. The tightly stitched areas are inaccessible to the dye solution. After dyeing, the raffia/thread is removed, revealing the undyed pattern.

Adire Eleko (Starch Paste Resist): A paste made from cassava starch (or rice starch) and other ingredients (e.g., alum, copper sulfate) is painted onto the fabric. The paste hardens upon drying.

Scientific Process: This is a physical barrier resist**.** The thick, dried starch paste creates an impermeable layer that physically blocks the dye from reaching the fabric fibres underneath. The paste acts as a non-reactive coating.

Dyeing Process (Traditionally Indigo): Traditional Adire uses natural indigo dye, typically extracted from plants like *Lonchocarpus cyanescens*. Indigo is a vat dye.

Reduction: Indigo dye is insoluble in water in its natural (oxidized) blue form. To be used, it must be chemically reduced in an alkaline solution (e.g., with natural reducing agents like fermentation by bacteria in a traditional indigo vat, or synthetic reducing agents like sodium hydrosulfite in modern use). This turns it into a soluble, yellowish-green form called **leuco-indigo.**

Dyeing: The fabric (with resist applied) is immersed in this leuco-indigo dye bath. The leuco-indigo molecules penetrate the fibres.

Oxidation: When the fabric is removed from the dye bath and exposed to air (oxygen), the leuco-indigo rapidly oxidizes back to its insoluble blue form, becoming trapped within the fibres. This oxidation reaction is what "fixes" the blue colour.

Repeated Dyeing: To achieve deeper shades of blue, the fabric is repeatedly dipped into the indigo vat and exposed to air for oxidation, sometimes 25 or more times for a deep blue-black.

Removal of Resist: For Adire Eleko, the dried cassava paste is scraped or washed off after dyeing, revealing the undyed patterns.

Scientific principles involved in Adire textile production

1. **Physical Principles of Resist Application:** Adire employs various techniques to create patterns by physically preventing dye from reaching certain areas of the fabric.

    a. **Mechanical Compression (Adire Oniko & Adire Alabere):**

        - **Principle:** This relies on applying pressure and physical barriers to the fabric. In **Adire Oniko** (tying/knotting), sections of the fabric are tightly bound with raffia, thread, or string, often incorporating small objects like stones or seeds. In **Adire Alabere** (stitching), patterns are created by sewing intricate lines with raffia or thread, then pulling the threads taut to gather and compress the fabric.
        - **Mechanism:** The tight binding or stitching physically compresses the fabric fibres, significantly reducing the pore space between threads and fibres. This high local pressure and reduced porosity physically block the larger dye molecules from penetrating the treated areas. Additionally, the compressed fabric has less surface area exposed to the dye solution, hindering dye uptake.

2. **Physical Barrier/Adsorption (Adire Eleko - Starch Resist)**

    Principle: This method utilises a thick paste, traditionally made from cassava starch, as a physical block.

        - **Mechanism:** The starch paste is applied to the fabric, forming an impermeable, solid layer upon drying. Starch molecules (complex carbohydrates) form a dense network that physically obstructs the dye molecules from reaching the fabric fibres underneath. The paste adheres to the fabric but does not chemically react with it or the dye in a way that allows colour transfer. After dyeing, the dry paste is brittle and can be scraped off or washed away, revealing the undyed pattern.

3. **Dye Chemistry (Primarily Traditional Indigo Vat Dyeing):** Traditional Adire is renowned for its use of **natural indigo dye**, which involves a complex and fascinating series of chemical reactions.

    a. **Biochemical Reduction (Fermentation):** Natural indigo (indigotin), extracted from plants like *Lonchocarpus cyanescens* (Yoruba: *elu*) or *Indigofera tinctoria*, is insoluble in water in its vibrant blue form. To make it usable for dyeing, it must undergo a chemical reduction process. Traditionally, this is achieved through fermentation in a deep earthenware dye vat.

Microorganisms (bacteria) consume sugars and other organic matter in the vat, creating an anaerobic (oxygen-free), alkaline environment (often maintained with wood ash or caustic soda) and producing reducing agents. These agents chemically reduce the insoluble blue indigotin to a soluble, yellowish-green form called leuco-indigo (or indigo-white).

b. **Alkalinity:** The alkaline (high pH) environment of the indigo vat is crucial for both the reduction process and for keeping the leuco-indigo soluble and stable until it is absorbed by the fabric.

c. **Oxidation for Colour Fixation:** When the fabric is removed from the dye bath, the soluble leuco-indigo molecules that have penetrated the fibres are exposed to oxygen in the air. This triggers a rapid oxidation reaction, where the leuco-indigo is chemically converted back into its insoluble blue indigotin form. This insoluble pigment precipitates and becomes physically trapped within the fabric fibres, permanently colouring the cloth blue. The intensity of the blue colour is directly proportional to the number of times the fabric is dipped and exposed to air.

d. **Dye-Fibre Interaction:** The leuco-indigo molecules interact with the cellulose fibres of the cotton through various intermolecular forces while in the vat. Once oxidized, the insoluble indigotin is mechanically entrapped within the fibre matrix, making it highly wash-fast.

4. **Material Science (Fabric Properties)**

Cellulose Fibre Structure (Cotton): As with other natural fibre textiles, the cotton fabric's cellulose structure, with its numerous hydroxyl groups, plays a vital role in adsorbing the leuco-indigo solution. The porous nature of the woven fabric allows for efficient penetration of the dye into the unwaxed areas.

a. **Physical Processes in Application and Finishing**

i. **Diffusion and Capillary Action:** The dye solution spreads into the unwaxed portions of the fabric through diffusion (movement from high to low concentration) and capillary action (the wicking of liquid into the narrow spaces of the fabric).

ii. **Evaporation:** After dyeing, the fabric is dried, a process of evaporation that removes the water solvent, leaving the dye solids fixed.

iii. **Mechanical Compaction:** For some indigo-dyed fabrics, beating the cloth with a mallet after drying can help compact the fibres, enhance the dye's adherence, and impart a sheen.

Learning Tasks

1. Develop comprehensive investigation framework for analysing scientific processes in textile production
2. Analyse the economic importance of indigenous textile production

Pedagogical Exemplars

1. **Talk-for learning**

a. Guide learners in pairs to discuss some indigenous textiles and highlight their cultural significance, traditional methods, and scientific principles involved in production.

b. Task learners in their groups to create visual aids like posters, diagrams, or digital presentations to illustrate key concepts and findings.

2. **Project-based learning/field trip**
    a. Plan a visit to a local industry or where indigenous textiles are produced. Ensure necessary permissions, safety measures, and arrangements for observation and documentation.
    b. Encourage groups to come up with questions and hypotheses about the processes they expect to observe during the industry visit.
    c. During the visit, guide learners to observe and document the key processes involved in indigenous textile production.
    d. Encourage hands-on interactions with equipment, materials, and production personnel (if permitted), fostering a deeper understanding of real-world applications of scientific concepts.
3. **Collaborative Learning**
    a. In the classroom, provide time for groups to review their observations, photographs, notes, and any samples or materials collected during the visit. Let learners analyse the scientific principles behind each production step.
    b. Organise a session where each group presents their findings, observations, and analyses to the rest of the class. Encourage multimedia presentations, diagrams, and tangible examples to enhance understanding.
    c. Facilitate discussions among groups, allowing them to cross-share insights, compare processes across different indigenous textiles, discuss challenges faced by the industry, and propose innovative ideas or improvements.
    d. Task learners in groups to research sustainable practices, safety regulations, market trends, and community impacts related to local industries producing such textiles.
4. **Diamond nine**

    Using the Diamond 9 discussion, learners enumerate the economic importance of indigenous textile production and present ideas in class for poster presentation and gallery walk.

Key Assessment: Practice Paper 2

1. Explain how the resist-dyeing technique used in batik production demonstrates the principles of chemical reaction and fabric absorption. **(10 marks)**
2. Compare the processes involved in producing batik and tie-dye textiles. **(10 marks)**

HINT

*Conduct **Practice Paper 2**. It should cover contents taught from Year 1 to 3. Refer to the **Table of Specification and Structure of the Paper** at the end of this section. Learners' papers should be marked immediately and scores entered into the SAP.*

TABLE OF SPECIFICATION FOR PAPER 1,2&3
PAPER 1
(OBJECTIVE TEST)

Strand	Learning Indicator (LI)	DoK 1	DoK 2	DoK 3	Total
1. Exploring Materials	Explain the characteristics of science in nature.	1	–	–	1
	Apply the characteristics of science where appropriate.	–	2	–	2
	Distinguish between metals, non-metals and semi-metals using their physical and chemical properties.	1	2	1	4
	Justify the uses of metals, non-metals and semi-metals.	–	–	1	1
	Discuss the relationship between binary compounds, the composition of binary compounds and the names of the compounds.	–	–	1	1
	Differentiate among acids, bases and water.	1	1	1	3
	Apply the knowledge of acids and bases in analysing the formation of salts and their uses.	–	1	2	3
	Identify air as a mixture and explain the uses of the components of air.	2	3	–	5
	Prepare and test for the gases (Oxygen and Carbon Dioxide) in the laboratory.	–	–	2	2
2. Processes for Living	Explain the mechanism of breathing and respiration in humans.	1	2	2	5
	Analyse the structure and functions of the human excretory organs (Skin, lungs, liver, kidneys).	–	1	–	1
	Explain the processes for the removal of waste from the human body.	–	1	1	2
	Explain reproduction in plants and humans.	2	2	–	4
	Understand the nervous system.	1	2	–	3
	Model and discuss the structure of the skeleton and muscles.	1	1	1	3
3. Vigour Behind Life	Describe the generation of electricity from solar cells/panels.	1	1	1	3

	Explain the concept of electrical energy and power.	1	–	–	1
	Demonstrate the principle of operation of a transformer.	–	2	1	3
	Explain the uses of electronic components in household electronic devices and amplifiers.	–	1	–	1
	Explore Consumer Electronic careers.	1	–	–	1
	Analyse the concepts of speed, velocity and acceleration.	–	1	1	2
	Analyse light energy and its uses in nature.	–	–	1	1
4. Relationships with the Environment	Examine the scientific principles in local technology (Soap making).	1	–	1	2
	Analyse the scientific processes involved in indigenous food production.	3	1	1	5
TOTALS		**18**	**24**	**18**	**60**
PERCENTAGE		**30%**	**40%**	**30%**	**100%**

PAPER 2

Strand Name	Learning Indicator (LI)	DoK 1	DoK 2	DoK 3	DoK 4	Total
1. Exploring Materials	Discuss the relationship between binary compounds...	–	–	1	–	1
	Distinguish between metals, non-metals and semi-metals...	–	–	1	–	1
	Design and perform a project/ activity using the characteristics of science.	–	–	–	1	1
2. Processes for Living	Analyse the structure and functions of the human excretory organs...	–	–	1	–	1
	Explain the mechanism of breathing and respiration in humans.	–	1	1	–	2
3. Vigour Behind Life	Describe momentum and its application in everyday life.	–	–	1	–	1
	Describe the generation of electricity from solar cells/panels.	–	–	1	–	1
	Demonstrate the principle of operation of a transformer.	–	–	1	–	1

	Explain the principle of 'doping' behaviour in relation to semiconductors.	–	1	1	–	2
4. Relationships with the Environment	Examine the causes and prevention of some lifestyle diseases.	–	1	–	–	1
	Explain the science in the production of indigenous beverage.	–	1	–	–	1
	Analyse the attributes of drugs.	–	1	–	–	1
	Explore the features of heredity.	–	1	–	–	1
TOTALS		**0**	**6**	**8**	**1**	**15**

PAPER 3 (TEST OF PRACTICAL)

Strand Name	Learning Indicator (LI)	DoK 1	DoK 2	DoK 3	DoK 4	Total
1. Exploring Materials	Distinguish between metals, non-metals and semi-metals using their physical and chemical properties.	–	–	1	1	2
2. Processes for Living	Explain reproduction in plants and humans.	–	1	1	–	2
3. Vigour Behind Life	Explain the uses of electronic components in household electronic devices and amplifiers.	–	1	1	1	3
4. Relationships with the Environment	Design an experiment to produce a local beverage.	–	–	–	1	1
TOTALS		**0**	**2**	**3**	**3**	**8**

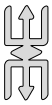
PLC Session 18

45 minutes **Planning & Reviewing the Learning Plan**

1. Begin the session by recapping lessons from the previous session, focusing on how learning was applied.
2. Use your subject specific app to explore the content before planning. Ask the app to
   a. explain the week's concepts in a practical way that will make it easier for learners to understand.
   b. identify three common misconceptions learners may have on the week's content and how to address them using contexts familiar to Ghanaian learners (NTS 3a, 3g and 3m).
3. Use your subject specific app to plan your lesson. Ask the app to
   a. suggest the most effective method for teaching the week's concepts to learners with diverse backgrounds.

b. suggest learning activities, differentiation and essential questions based on the method of teaching (NTS 3a-3q).

c. review your prepared learning plan and address any challenging issues you may have identified in your subject area (NTS 3a-3c).



Note

- *Take note of the recap topics linked to Years 1 and 2 while preparing for your lesson.*
- *Refer to the Values Learning Community Handbook and link the values for the week in your lesson to ensure that learners are applying what they learn.*

4. Use your app to plan and administer the mode of assessment for the Student Assessment Portal (SAP)

   a. The key assessment for the week is ***practice paper***. Chat with your app to plan this assessment by reviewing or developing the assessment items/tasks and marking schemes/rubrics for the practice paer (NTS 3k-3q).

10 minutes **Content Exploration**

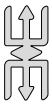
5. As a subject group, select one problem or topic/idea/term in the week's content that is challenging (not a routine procedural question, but one that requires conceptual understanding) and then

   a. use the app, ask it to solve the problem step by step and explain the reasoning behind each step (you may be assisted by a teacher who is strong in the content area)

   b. all teachers in the group work through the problem individually for 3–4 minutes

   c. the group then works through it together the problem, step by step

   d. highlight the most common errors made at each step (NTS 1c, 1e, 2c, 2e, 3e-3j).



Note

- *This part is not 'How do I teach this?' but how do I teach it for learners to understand?*
- *If the group still shares the same content gap, use the app: ask it to solve the problem step by step and explain the reasoning behind each step.*
- *Problems/ideas discussed should be sourced from the Teacher Manual content, not invented separately. This keeps the content exploration directly connected to what teachers will deliver.*

30 minutes **Enactment**

6. Enact a teaching activity based on your learning plan (NTS la-1b, 1e-lg, 2c, 2e, 2f, 3c-3j and 3o).

   a. Colleagues observe with specific attention to clarity of concept explanation, use of familiar Ghanaian examples and how misconceptions are handled if they arise.

   b. After the enactment, ask for structured feedback from the group

      i. was the concept explained in a way that a learner with no prior knowledge could follow?

      ii. were the examples grounded in contexts familiar to Ghanaian learners?

      iii. did any misconceptions surface and if so, how were they addressed?

5 minutes **Reflection**

7. Reflect and share your views on the session. One thing that worked well, what did not work well and what you will do differently. (NTS 1a, 1b).
8. Identify a critical friend to observe and provide feedback on your lesson in relation to the PLC Session conducted (NTS 1f, 1g).
9. Remember to
   a. transfer your chats into your learning planner template.
   b. read your Teacher Manual and related Learner Material in preparation for the next session. Take note of the recap weeks, which are linked to Years 1 and 2 (NTS 3a).
   c. integrate National Values, GESI, SEL, and 21st century skills into your learning activities, assessment tasks, and rubrics/mark schemes.

Section 10 Review

In Week 18, learners analysed the scientific processes involved in indigenous textile production, with a focus on traditional methods such as tie-dye, batik, and adire. The lesson explored how this cultural art forms use scientific concepts like absorption, resistance, solubility, and chemical reactions between dyes and fabrics. Learners observed how materials like wax or starch are used to create patterns by preventing dye from colouring certain areas of the fabric (resist-dyeing). They also discussed the properties of natural and synthetic dyes, the effect of temperature and time on colour intensity, and the role of fixatives (like alum or vinegar) in setting colours. By the end of the week, each learner should have been able to describe the step-by-step processes used in making tie-dye, batik, and adire, identify the scientific principles applied in each method, and appreciate the blend of traditional knowledge and science in textile production. This topic encouraged both scientific thinking and cultural appreciation.

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 18

Question 1

3. a. Identifies that batik uses wax to resist dye absorption (1 mark)

   b. Explains how wax prevents dye from entering fabric (resist technique) (1 mark)

   c. Mentions fabric absorption due to porous nature of cotton (1 mark)

   d. Identifies that untreated areas absorb dye (1 mark)

   e. Describes that reactive dyes (e.g., Procion MX) are used (2 marks)

   f. States that dyes form covalent bonds with cotton (chemical reaction) (2 marks)

   g. Describes removal of wax to reveal design (1 mark)

   h. Gives clear, specific example of batik design using wax-resist and reactive dyes (1 mark)

   (Total of 10 marks)

Question 2

a. Identification and accurate description of batik (e.g., use of wax, resist dyeing, layered colouring) (2 marks)

b. Identification and accurate description of tie-dye (e.g., tying, folding, dye soaking method) (2 marks)

c. First scientific difference explained clearly (e.g., resist agent: wax vs. physical ties) (2 marks)

d. Second scientific difference explained clearly (e.g., level of design control: precise vs. random) (2 marks)

e. Third scientific difference explained clearly (e.g., dye penetration patterns, heat use in batik) (2 marks)

(Total of 10 marks)

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