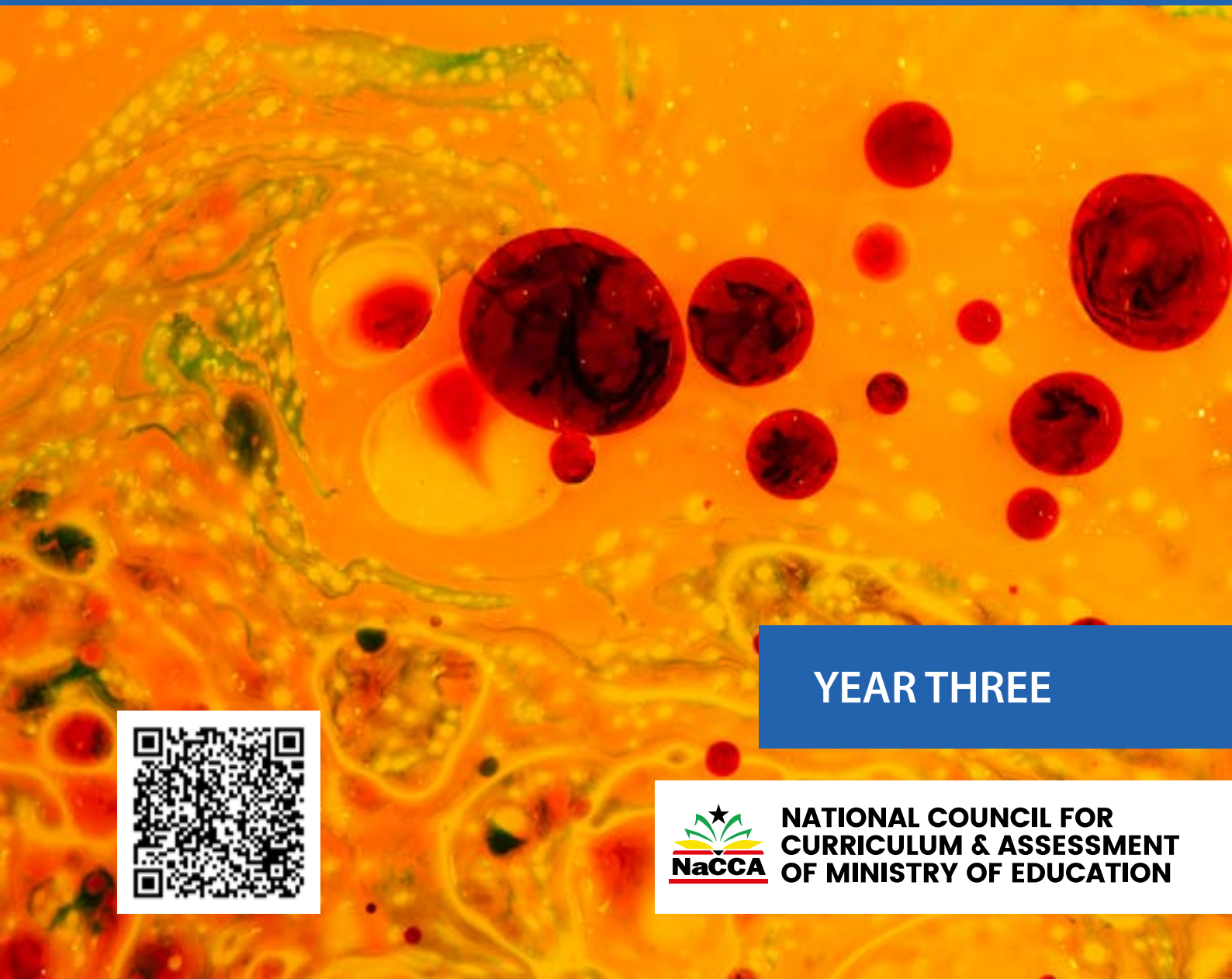
MINISTRY OF EDUCATION

Biomedical Science

for Senior High Schools

TEACHER MANUAL



YEAR THREE

NaCCA NATIONAL COUNCIL FOR CURRICULUM & ASSESSMENT OF MINISTRY OF EDUCATION

MINISTRY OF EDUCATION

REPUBLIC OF GHANA

Biomedical Science
for Senior High Schools

Teacher Manual

Year Three

NATIONAL COUNCIL FOR
CURRICULUM & ASSESSMENT
OF MINISTRY OF EDUCATION

BIOMEDICAL SCIENCE TEACHER MANUAL

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INTRODUCTION

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 Biomedical Science 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: PROFESSIONAL PRACTICE IN BIOMEDICAL SCIENCE

Strand: Biomedical Science in Society

Sub-Strand: Biomedical Science Practice

Learning Outcome: *Explain actions that can constitute malpractice, liability, and/or negligence, and how biomedical scientists can guard against them.*

Content Standard: Demonstrate knowledge of good professional practice as biomedical scientists.

INTRODUCTION AND SECTION SUMMARY

Biomedical science professionals work within strict legal and ethical frameworks. Understanding the boundaries of malpractice and negligence, and knowing how to mitigate risks, is essential for safeguarding patient safety, maintaining public trust, and upholding the integrity of scientific work. This section empowers biomedical science students to critically reflect on their conduct and apply best practices that minimize legal actions. The overall indicator for this section is the ability to explain actions that can constitute malpractice, liability, and/or negligence and how biomedical scientists can guard against them. Students will explore real-world scenarios and regulations that guide ethical decision-making and professional accountability in clinical and research settings.

The week covered by the section is:

Week 1:

Explain common practices that could result in malpractice, liability and/or negligence in the field of biomedical science.

Describe the purpose of informed consent from the patient and healthcare provider perspectives.

Identify and explain personal and long-term consequences of unethical or illegal behaviour in the workplace.

SUMMARY OF PEDAGOGICAL EXEMPLARS

To achieve the content standard for this section, the following pedagogical exemplars are recommended. Through initiating talk/sign for learning, learners discuss common causes of malpractice, such as ignoring Standard Operating Procedures (SOPs), safety breaches, or poor documentation. Using exploratory learning, they analyse videos, images, or scenarios to identify and differentiate between malpractice, negligence, and liability. In managing talk/sign for learning, the teacher guides class discussions on the code of ethics, code of conduct, and the purpose of informed consent, using sample forms for clarity. In mixed gender/ability groups, learners use activity-based learning to create an informed consent form including the condition,

proposed treatment, alternatives, risks, and confirmation of patient understanding. These strategies promote ethical thinking, professional awareness, and practical skills in biomedical science contexts.

ASSESSMENT SUMMARY

To assess learners' understanding of professional and ethical practices in biomedical science, DOK Level 3 assessment strategies are recommended. These assessments focus on learners' ability to apply strategic reasoning in analysing real-world scenarios involving malpractice, negligence, and liability in biomedical science practice. Learners are expected to examine situations where failure to follow professional standards leads to patient harm or legal consequences and evaluate the preventive role of established protocols. They are also tasked with explaining the concept and application of informed consent from both the patient and healthcare providers' perspectives, using realistic clinical or laboratory examples. Furthermore, learners analyse the personal and long-term consequences of unethical or illegal behaviour in the biomedical workplace, including damage to professional reputation, loss of employment, and reduced public trust. Through case studies, discussions, and presentations, learners are challenged to think critically about professional responsibility, informed consent, and the consequences of ethical lapses in healthcare and research settings.

Summary of the assessment used against the indicators

Indicators	DOK Level	Assessment Strategy and/or Mode
Explain common practices that could result in malpractice, liability, and/or negligence in the field of biomedical science.	3	Short answer individual class exercise
Describe the purpose of informed consent from the patient and healthcare provider perspectives	3	Short answer individual class exercise
Identify and explain personal and long-term consequences of unethical or illegal behaviour in the workplace.	3	Short answer individual class exercise

WEEK 1

Learning Indicators

1. *Explain common practices that could result in malpractice, liability, and/or negligence in the field of biomedical science*
2. *Describe the purpose of informed consent from the patient and healthcare provider perspectives*
3. *Identify and explain personal and long-term consequences of unethical or illegal behaviour in the workplace*

Recap Weeks

Year 1	**Week 1:** Describe what biomedical science is. **Week 6:** Analyse laboratory-acquired infections (LAIs), including some case studies.
Year 2	**Week 4:** Describe features of the biosafety levels and proper practice **Week 5:** a. Demonstrate proper setup of the biosafety cabinet and its environment. b. Demonstrate proper methods for donning and removal of personal protective equipment (PPE) such as gloves, lab coats, eye protection, and respiratory protection.

FOCAL AREA 1: AVOIDING MISTAKES - NEGLIGENCE, MALPRACTICE, AND LIABILITY

Definitions

Define negligence, malpractice, and liability as

Negligence is the failure to take reasonable care resulting in harm or injury to a patient, client or another person. It is when a health practitioner fails to exercise the standard level of care and that failure causes harm to a client or patient. For example, failure to clean up a spill, leading to an accident; a nurse at a district hospital failing to monitor a post-operative patient as required by protocol; using the wrong reagent because instructions were ignored; a laboratory technician failing to properly sterilize equipment before an experiment, leading to contamination of samples. This carelessness could result in incorrect test results, which may affect patient diagnosis and treatment.

Malpractice is specialized form of negligence that arises when a healthcare professional deviates from the accepted standard of care, causing harm to a patient. It usually involves a careless or harmful action during the performance of professional duties. Malpractice is a more serious form of negligence where a trained professional knowingly fails to follow accepted standards. For example, if a lab technician performs tests without adhering to standard operating protocols, or alters test results, or skips safety checks, if a doctor makes a serious mistake that harms a patient, or fakes medical reports.

Liability refers to the legal responsibility for harm caused to a patient through an act, omission, negligence, or failure to meet the accepted standard of care. It determines who is legally accountable when a patient suffers injury or damage during the provision of healthcare services.

Categories of Healthcare Liability

1. Individual Provider Liability

This occurs when a healthcare professional, such as a doctor, nurse, pharmacist, or midwife, is held personally responsible for harm resulting from negligent actions or failure to provide care according to professional standards.

2. Institutional or Hospital Liability

Healthcare institutions may be held liable when patient harm results from inadequate policies, poor supervision, unsafe facilities, insufficient staffing, or failure to provide appropriate resources for patient care.

3. Vicarious Liability

Under the principle of vicarious liability, an employer or healthcare institution may be held responsible for the negligent acts of its employees performed within the scope of their employment. However, liability may differ when the individual involved is an independent contractor.

4. Pharmaceutical and Product Liability

Manufacturers, distributors, or suppliers of medicines, medical devices, and healthcare products may be held liable when defective or unsafe products cause harm to patients.

5. Supervisory and Institutional Hierarchy Liability

Supervisors, department heads, and healthcare administrators may be held liable when failures in oversight, delegation, or monitoring contribute to patient harm.

Elements Required to Establish Liability

To establish liability in a healthcare setting, the following elements are generally considered:

Duty: A formal healthcare provider–patient relationship existed, creating a legal duty of care.

Breach: The healthcare provider failed to meet the accepted professional standard of care.

Causation: The breach of duty directly caused or significantly contributed to the patient's injury.

Damages: The patient suffered actual harm, injury, loss, or damages as a result.

Consequences of Liability

When liability is established, the responsible party may face:

- Payment of monetary compensation (damages) to the patient.
- Professional disciplinary actions by regulatory bodies.
- Suspension or revocation of professional licenses.
- Civil or, in some cases, criminal penalties.

In summary, negligence is the careless act, malpractice is the grave professional misconduct, and liability is the legal consequence that holds the healthcare professional accountable under Ghana's health and legal framework.

Discussions on common scenarios in a biomedical science setting that could lead to these issues should be based on the following

In biomedical science practice, maintaining professional and ethical standards is critical to protect patients, healthcare providers, and the public. Malpractice, negligence, and liability can arise when professionals fail to adhere to established protocols, leading to harm, inaccurate results, or legal consequences. Some common scenarios that can result in malpractice, negligence, and liability when standard procedures and protocols are not followed include:

1. **Mistakes in sample handling**: Accurate sample handling is a fundamental professional responsibility of biomedical scientists. Every stage of the laboratory process—from specimen collection and labelling to storage, transportation, and analysis—must be carried out according to established professional standards. Failure to adhere to these standards may compromise patient safety and expose the practitioner and healthcare institution to legal liability.

   For example, if a biomedical scientist incorrectly labels a blood sample, the specimen may be assigned to the wrong patient. Such an error can result in misdiagnosis, inappropriate treatment, or incorrect clinical decisions. The consequences can be particularly severe in situations involving blood transfusions, infectious disease screening, cancer diagnosis, or the long-term monitoring of chronic conditions.

   From a legal perspective, sample mishandling may constitute negligence when it can be shown that the biomedical scientist failed to exercise the level of care expected of a reasonably competent professional. Where patient harm results from such negligence, the practitioner may be held professionally and legally liable. In cases involving repeated, reckless, or systemic failures, liability may extend beyond the individual practitioner to include supervisors or the healthcare institution.

   To minimise these risks, biomedical scientists must strictly follow standard operating procedures, quality assurance measures, and professional guidelines throughout the laboratory workflow.

   Common Forms of Sample Mishandling

   a. **Contamination**

      Failure to use sterile techniques or maintain specimen integrity can contaminate biological samples, leading to inaccurate or unreliable test results.

   b. **Improper Storage**

      Incorrect storage conditions, such as inappropriate temperature, humidity, or transport conditions, may degrade specimens and compromise the validity of laboratory findings.

   c. **Mislabelling**

      Errors in specimen identification may result in patient samples being mixed up, potentially leading to incorrect diagnoses, treatments, or clinical interventions.

   d. **Expiration and Preservation Errors**

      The use of expired reagents or improperly preserved specimens can produce inaccurate test outcomes and affect patient management decisions.

2. **Inaccurate data analysis:** Another scenario arises when a scientist misinterprets laboratory results due to a lack of attention to detail, inaccurate equipment calibration, or failure to verify data. For instance, incorrectly interpreting test results for infectious diseases such

as tuberculosis or HIV may result in providing treatment to someone healthy or failing to treat a truly infected individual.

This not only endangers the patient but could also lead to public health risks. Where harm is established, the professional concerned may be held liable for damages, the extent of which will be determined by the nature and severity of the harm caused. In addition to civil liability, disciplinary proceedings may be instituted against the individual by the relevant regulatory or professional body. The likelihood and gravity of such disciplinary action will depend on the severity of the conduct in question and, critically, whether the adverse outcome was reasonably preventable through the exercise of due professional care. Some common examples of inaccurate data analysis include:

a. **Human measurement error**: Miscalculations or misinterpretations of results can cause incorrect conclusions, affecting patient care or research findings.
b. **Instrument calibration failures**: Using an uncalibrated or a malfunctioning instrument can produce inaccurate readings.
c. **Data manipulation or fraud**: Deliberately altering data for research or diagnostics may result in unethical outcomes and legal consequences.
d. **Lack of standardization**: Failure to adhere to standard protocols for analyzing results can introduce variability and reduce reliability.

3. **Failure to follow proper safety procedures**: Ignoring established biosafety protocols such as not wearing PPEs, mishandling hazardous samples, or failing to properly dispose of biohazardous waste can expose both staff and patients to infections or chemical hazards. In the case of laboratory-acquired infections (LAIs), failure to follow standard procedures can be seen as professional negligence, particularly if the laboratory worker had been trained but chose to disregard safety practices.
4. **Adherence to biosafety protocols** is a non-negotiable professional responsibility for all laboratory personnel. Where a biomedical scientist disregard established safety procedures, whether by failing to wear appropriate personal protective equipment, mishandling hazardous biological samples, or neglecting the proper disposal of biohazardous waste, the consequences may extend beyond the individual to colleagues, patients, and the broader healthcare environment. Such lapses create material risk of exposure to infectious agents or chemical hazards, with potentially serious implications for occupational and public health. A particular concern in this regard is the occurrence of laboratory-acquired infections. A worker may be held liable for professional negligence if an infection occurs because of their deliberate failure to follow the safety training provided to them. The intentional or habitual disregard of known safety standards significantly weakens their professional defence and might otherwise invite both civil liability and disciplinary sanction from the appropriate regulatory authority.

   Some examples of failure operational safety procedures include:

   a. **Exposure to hazardous materials:** Neglecting PPE use or improper disposal of biohazard waste poses risks to personnel.
   b. **Poor infection control:** Not following strict aseptic techniques increases the likelihood of laboratory-acquired infections.
   c. **Inadequate training**: Employees who lack proper training in handling dangerous chemicals or biological agents may unintentionally cause harm.

   d. **Failure to report incidents:** Ignoring or covering up safety violations can lead to repeated errors and increase liability.

These scenarios not only reflect poor judgment or carelessness but also raise important legal and ethical implications. When such lapses result in patient harm, the biomedical scientist or the institution may face legal liability, including compensation claims, suspension, revocation of professional licenses, or even criminal charges in extreme cases.

Discussion on how biomedical scientists can avoid these pitfalls.

Biomedical scientists must take deliberate steps to avoid the common pitfalls that lead to malpractice, negligence, and liability. This is vital not only for protecting the safety of patients and colleagues, but also for building public confidence in the healthcare system and upholding your own professional standing.

By following these steps, biomedical scientists can reduce errors and uphold high ethical and professional standards.

1. **Following standard procedures carefully**: Always adhere to approved protocols and standard operating procedures (SOPs) when handling samples, equipment, and data.
2. **Label and handle samples correctly**: Double-check patient names, test requests, and sample containers to avoid mix-ups or misidentification.
3. **Maintain accurate and complete records**: Record all test results, observations and actions clearly and promptly. Good documentation is essential for accountability.
4. **Use calibrated and well-maintained instruments/equipment**: Ensure they are functioning properly and are routinely serviced according to guidelines and by qualified personnel.
5. **Wear appropriate PPE**: Always use the correct PPE for the task to protect yourself and others and strictly follow all biosafety rules.
6. **Report errors or unsafe practices immediately**: Inform a supervisor or relevant authority as soon as a mistake or hazard is identified. Early reporting can prevent harm.
7. **Ask for clarification when unsure**: Never guess or assume. Always seek guidance from supervisors or experienced colleagues if something is unclear.
8. **Engage in regular training and professional development:** Remain current with emerging laboratory procedures, advancing technologies, and the evolving ethical standards that govern professional conduct via continued professional development.
9. **Work collaboratively and communicate clearly**: Maintain open and respectful communication with colleagues to ensure shared understanding and responsibility.

See **Table 1.1** for an overview of risk areas and their corresponding preventive strategies to avoid pitfalls.

Table 1.1 Key Takeaways for Avoiding Pitfalls

Risk Area	Preventive Strategies
Sample handling	Follow SOPs, use barcoding, and avoid cross-contamination
Data integrity	Document everything, use quality control checks

Safety breaches	Wear appropriate PPEs, report hazards immediately
Ethical violations	Train staff on consent and compliance

FOCAL AREA 2: INFORMED CONSENT – PROTECTING PATIENTS AND PROFESSIONALS

Explain the concept of informed consent

Informed consent is a legal and ethical requirement that ensures a patient or participant voluntarily agrees to a medical procedure, treatment, or participation in research after receiving clear, understandable information about:

1. The nature of the procedure or treatment, that is, what will be done.
2. Risks and benefits, that is, the potential harms and expected advantages.
3. Alternatives or other available options, including no treatment option.
4. Consequences of refusal, that is, what could happen if they decline.

Key principles of informed consent

Informed consent is built on three core principles: voluntariness, competence, and disclosure of information.

1. **Voluntary**: This means the individual gives permission freely, without any form of inducement, coercion, or manipulation. The decision to accept or decline a medical procedure or test must come from the patient alone, without any persuasion or pressure.
2. **Competent**: The patient must have the mental capacity to understand the information presented and make a logical or rational decision. This includes being of sound mind and, in most cases, being of legal age.
3. **Informed**: The provider must disclose all material risks in a way the patient can understand. This means the healthcare provider or biomedical scientist must explain all relevant details, such as the purpose, benefits, risks, and possible alternatives, in clear language that the patient can easily understand.

When is informed consent a requirement?

Informed consent is required any time a medical or biomedical procedure involves risk, choice, or personal impact. This includes before:

1. Conducting medical tests or procedures, such as drawing blood, scans, or surgeries.
2. Collecting or using biological samples (example, blood, tissue) for research or diagnosis.
3. Enrolling a person in a clinical or biomedical research study.
4. Disclosing sensitive health information, especially if it will be shared outside the care team.
5. Administering treatment, particularly when there are different treatment options or possible side effects.

In summary, informed consent is required whenever a patient's body, data, or decisions are involved, and is required to make a voluntary and informed choice about what happens next. See **Additional Reading** for sample patient informed consent forms.

Exceptions to informed consent

While informed consent is a legal and ethical requirement in most situations, there are a few recognised exceptions where it may not be required. These include:

1. **Emergencies**: When a patient is unconscious or unable to give consent, and immediate action is needed to save their life or prevent serious harm, treatment may proceed without consent.
2. **Incapacity without a legal guardian present**: If a patient lacks the mental capacity to consent and no legal representative or next of kin is available, healthcare providers may act in the best interest of the patient.
3. **Public health risks**: In cases involving contagious diseases (e.g., tuberculosis or COVID-19), some treatments or tests may be carried out without consent to protect the public.
4. **Therapeutic privilege (rare and controversial)**: A doctor may withhold full information if they believe that disclosing it would cause serious harm to the patient's mental or physical health. However, this must be used with extreme caution and is subject to ethical review.

These exceptions must always be handled carefully, with respect for the patient's rights and documented justification for any decision made without consent.

Importance of informed consent

Informed consent is a critical part of ethical and professional biomedical science practice. It ensures both patients and research participants are fully aware of what they are agreeing to before any procedure, treatment, or data collection begins. This process goes beyond simply signing a form. It involves clear communication, mutual understanding, and respect for individual rights. In biomedical science, informed consent is fundamental as it upholds the rights, autonomy, and dignity of every patient or research participant involved. It protects both the individual and the healthcare provider by ensuring that decisions are made openly, honestly, and without pressure. The importance of informed consent includes:

1. **Protecting patient rights**: It ensures individuals have control over what happens to their bodies or personal health information. (https://nyahomedical.com/2018/05/the-patient-charter-ghana).
2. **Promoting autonomy**: Respects the patient's right to make informed choices based on a full understanding of the procedure, risks, and alternatives.
3. **Building trust**: Encourages open and honest communication between healthcare providers and patients, strengthening the relationship between them.
4. **Upholding ethical practice**: Ensures professional and ethical standards in both clinical and research settings are upheld.
5. **Providing legal protection**: Safeguards the healthcare professionals from legal liability through documentation of the patient's voluntary agreement.
6. **Encouraging transparency and supporting patient safety**: Makes the medical or research process clear to the patient or participant, avoiding misunderstanding in the future.

It also helps patients to weigh the risks and benefits before agreeing to treatment or participation in research.

7. **Fulfilling legal and professional guidelines**: Informed consent is a legal and regulatory requirement in most healthcare systems, including Ghana.

Legal implications of failing to obtain informed consent

Failing to obtain proper informed consent can lead to serious legal consequences or liability for biomedical scientists and healthcare professionals. If a procedure is carried out without the patient's informed consent, it may lead to the following.

1. **Assault or unauthorised touching**: Carrying out a medical procedure without consent can be treated as an unlawful physical assault of the person.
2. **Negligence or malpractice**: If the patient is harmed because they were not fully informed about the risks or alternatives, the professional may be found legally liable.
3. **Breach of duty of care**: Healthcare professionals have a legal and ethical responsibility to protect patient rights. Ignoring this duty can result in professional disciplinary action.
4. **Loss of professional registration and licence**: Repeated or serious breaches related to consent can lead to suspension or removal from the professional register by regulatory bodies.

FOCAL AREA 3: POTENTIAL CONSEQUENCES OF UNETHICAL OR ILLEGAL BEHAVIOUR IN BIOMEDICAL SCIENCE PRACTICE

Discussion on the potential consequences of unethical or illegal behaviour in biomedical science practice

Unethical or illegal behaviour in the workplace refers to actions or decisions that violate moral principles, professional codes of conduct, organisational policies, or the law. In biomedical science, this could range from minor protocol breaches to serious offenses like falsifying data or compromising patient confidentiality. Understanding the potential consequences is crucial for maintaining professional integrity and ensuring patient safety. Potential short-term and long-term consequences are as follows:

Potential short-term consequences to the worker

1. **Immediate suspension from duty**: If the behaviour poses an immediate risk, such as improper handling of hazardous materials or potential manipulation of test results, the biomedical scientist may be suspended immediately.
2. **Formal investigation and questioning**: The worker will face investigation(s) by the employer or by a professional regulatory body, involving stressful interviews and scrutiny of their work.
3. **Damage to immediate reputation**: Colleagues may become apprehensive and hesitant to work with the individual, creating a difficult and isolated work environment.
4. **Increased scrutiny of work**: All the individual's subsequent tasks, documentation, and results may be subject to intense review and verification.

5. **Mandatory counselling or retraining**: Depending on the nature of the behaviour, the worker might be required to attend counselling or specific retraining programmes to address the issues.

Potential short-term consequences to the patient or participant

1. **Delayed or incorrect diagnosis**: Unethical practices like falsifying results or errors due to negligence can lead to patients receiving the wrong diagnosis.
2. **Inappropriate treatment**: Based on incorrect diagnostic information, clinicians may prescribe treatments that are ineffective or even harmful to the patient.
3. **Anxiety and distress**: Patients may experience significant worry and distress due to uncertain or conflicting test results or the impact of inappropriate treatment.
4. **Need for repeat testing or procedure**: Patients may have to undergo uncomfortable or inconvenient repeat blood draws or sample collections to obtain accurate results or corrective surgeries to avert long-term consequences.
5. **Delayed access to appropriate care**: The time lost due to initial incorrect results can delay the patient receiving the appropriate and necessary medical care.

Potential long-term consequences

These are the more enduring impacts that can persist over a longer period, significantly affecting the worker's career and the patient's health and trust.

To the worker

1. **Permanent loss of employment**: Serious breaches, such as fraud, gross negligence causing harm, or repeated ethical violations, may lead to permanent dismissal from the job.
2. **Revocation or suspension of professional licence**: Professional regulatory bodies can revoke or suspend the individual's license to practice biomedical science, making it illegal for them to work in the field.
3. **Legal action and financial ruin**: The worker could be personally named in civil lawsuits by affected patients or their families, potentially leading to substantial court-ordered payments that can cause financial hardship. Criminal charges are also likely for illegal actions.
4. **Permanent damage to professional reputation**: The individual's name and reputation may become associated with unethical behaviour, making it difficult to regain the trust of the professional community. A record of unethical behaviour or disciplinary action will make it exceptionally challenging to find work in any healthcare or scientific setting in the future.
5. **Psychological and emotional impact**: The stress of legal battles, professional ruin, and loss of livelihood can lead to long-term psychological distress, depression, and anxiety.

To the patient or participant

1. **Worsening of health condition**: Delayed or inappropriate treatment resulting from inaccurate laboratory information can lead to the progression of a disease, more severe symptoms, or irreversible health damage.

2. **Need for more intensive or costly treatment**: Correcting a delayed or incorrect diagnosis may require more aggressive, complex, and expensive medical interventions.
3. **Reduced trust in healthcare professionals**: Negative experiences due to unethical practices can erode a patient's trust in biomedical scientists and the wider healthcare system, potentially making them hesitant to seek necessary medical care in the future.
4. **Long-term health complications or disability**: In severe cases, the consequences of delayed or incorrect diagnosis and treatment may result in long-term health problems or permanent disability.
5. **Emotional trauma**: The experience of receiving incorrect information, undergoing unnecessary procedures, or suffering harm can cause lasting emotional trauma for the patient and their family.

Learning Tasks

1. Recap what biomedical science is, paying attention to the key characteristics of biomedical scientists, LAIs, biosafety levels, and proper practice.
2. Analyse a biomedical science case study that illustrates the significance of informed consent, ethical practice, and professional responsibility. Additionally, differentiate between malpractice, liability, and negligence using examples from the case and related biomedical scenarios.
3. Review real-world cases where unethical conduct led to legal actions, professional consequences, or patient harm. Discuss the lessons learnt.

Pedagogical Exemplars

Initiating Talk/Sign for Learning: Learners discuss possible sources, causes and examples of malpractice in the field of biomedical science, for example, not adhering to standard operating procedures (SOPs), ignoring biosafety levels and appropriate safety protocols that may result in injury or death; misdiagnosis due to errors in lab reports, patient injury or death during treatment, medication errors, inappropriate use of medical devices and poor documentation.

Exploratory Learning: Using videos, pictures, or listening to hypothetical scenarios, assist learners in identifying what constitutes malpractice, negligence, and liability. Learners critically analyse and differentiate between these actions. Refer to **Timms (2019, and scan QR Codes 1, 2, and 3** for more hypothetical scenarios.

Managing Talk/Sign for Learning: Engage learners in a whole-class discussion to explain what is meant by the code of ethics and code of conduct of biomedical science professionals and the implications of unethical or illegal behaviours in the workplace. Scan **QR Code 4** for more information on the Ghana Health Service (GHS) Code of Conduct and Disciplinary Procedure. With the aid of a sample informed consent form, engage learners in a whole-class discussion on what constitutes informed consent and its benefits (See **Additional Reading**; Sample Informed Consent Form).

Activity-Based Learning: Learners work in groups to develop an informed consent form and present it to the class. The forms should comprise of a description of a clinical problem, the proposed treatment, and alternatives including no treatment; discussions of the risk and benefits of the proposed treatment with comparisons to the risks and benefits of alternatives, and discussion of medical or clinical uncertainties regarding the proposed treatment; assessment of

the patient's understanding of the information provided by medical provider; and his/her preference and consent for treatment.

Key Assessment – Individual Class Exercise

Note: *For the visually impaired, get audio scenes, and for the hearing impaired, get videos with sign language available as alternatives for the videos used*

Key Assessment

1. **Level 3 (Strategic reasoning):** A newly employed biomedical scientist is working in a clinical diagnostic laboratory. Due to time pressure and poor adherence to biosafety protocols, the scientist accidentally exposed himself and a co-worker to a biological agent that should have been handled at a higher biosafety level. The incident was not reported immediately, and symptoms of infection appeared days later.
   - **a.** Analyse the scenario by identifying:
     - i. What professional roles and responsibilities were not fulfilled? Mention three. (3 marks)
     - ii. Discuss 2 ways the actions of the biomedical scientist may constitute malpractice, negligence, and liability. (4 marks)
     - iii. Evaluate 3 of the risks associated with the breach of safety, particularly in relation to biosafety levels and LAIs. (6 marks)
   - **b.** Based on your analysis, propose at least two professional and ethical actions that should have been taken to prevent the incident. (2 marks)
2. **Level 3 (Strategic reasoning):** A lab technician rushed through HIV testing and accidentally switched two patients' samples. A patient, who had not consented to the test, was wrongly told she was HIV positive. This mistake caused emotional harm and social stigma to her. Later, it was disclosed that she was HIV negative. The incident involved malpractice and negligence, and the hospital was held liable for the improper verification of informed consent.
   - **a.** How did the technician's actions reflect malpractice and negligence, and what were the effects on the patient? (6 marks)
   - **b.** In what ways was the hospital liable for the harm caused, and what policies should be changed to prevent this in the future? (4 marks)
   - **c.** Create a simple plan that ensures patients give informed consent before sensitive tests are conducted. Why is this important? (5 marks)
3. **Level 3 (Strategic Reasoning):** At a regional hospital in Ghana, a doctor performing abdominal surgery accidentally left a surgical blade inside a patient. This oversight went unnoticed during the routine post-surgical review. After several weeks, the patient returned to the hospital with intense abdominal pain and infection. An X-ray revealed the presence of the blade, requiring a second surgery to remove it. The patient experienced prolonged recovery and emotional distress. Legal action was taken, and the doctor faced disciplinary sanctions for negligence and breach of professional duty.
   - **a.** What are two short-term and two long-term consequences to:

i. The patient?

ii. The doctor?

iii. the hospital or healthcare system? (12 marks)

b. How does this incident affect public trust in healthcare professionals? (2 marks)

c. What legal or professional consequence may apply in such a situation? (1 mark)

PLC Session 1

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 ***individual class exercise***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the exercise (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 Review

This section reviews all the lessons taught for the previous week. A summary of what should have been taught and what each learner should have learnt if differentiation had been done.

1. Define and explain common practices that could result in malpractice, liability, and/or negligence in the field of biomedical science.
2. What are some actions and inactions that could constitute malpractice, negligence, or liability in biomedical science?
3. What is the purpose of informed consent from the patient and healthcare provider's perspective?
4. What are the personal and long-term consequences of unethical or illegal behaviour in the workplace?

Ethical and professional conduct forms the cornerstone of responsible biomedical science practice. Misconduct in the workplace, whether in the form of malpractice, negligence, or professional liability, carries far-reaching consequences that extend beyond the individual practitioner. In the short term, such lapses may result in job loss or legal proceedings, while the long-term repercussions include lasting damage to professional reputation and an erosion of patient trust. Collectively, these outcomes undermine the integrity of the broader healthcare system. This section develops learners' capacity for critical and applied reasoning, equipping them with the ethical grounding and sense of accountability necessary to navigate the complex professional demands of biomedical science in real-world clinical environments.

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 1

Question 1

a. Professional roles and responsibilities not fulfilled (Award 1 mark for each role/ responsibility)

i. Accept any 3 of these or any other relevant answers for 1 mark each.

- Failure to follow established biosafety protocols.
- Failure to report incidents promptly.
- Inadequate risk assessment before handling biological agents.
- Lack of adherence to professional duty of care.

ii. Discuss how the scientist's actions relate to malpractice, negligence, and liability. (2 marks for each of these actions correctly related to the case).

- Malpractice occurred because the biomedical scientist, a trained professional, knowingly disregarded established safety protocols, which constitutes professional misconduct.

- Negligence is evident in the failure to take reasonable precautions, leading to exposure of both the scientist and a co-worker to a potentially dangerous biological agent. This shows a lack of reasonable care in a high-risk environment.
- The scientist could be held liable for the harm caused. Liability refers to the legal responsibility to compensate for injury or damage. If the co-worker becomes seriously ill due to the exposure, the institution and possibly the scientist could face legal consequences.

The delayed reporting also increases liability risk, as it may have worsened the outcome by delaying medical intervention and containment.

iii. Evaluate risks, with specific reference to biosafety levels and LAIs. (Award 2 marks for each risk rightly referenced)

- The biological agent should have been handled at a higher biosafety level, implying that the lab was not equipped or authorised for such material.
- Biosafety levels (BSLs) are graded from 1 to 4, based on their level of risk to human health and the environment. Handling a higher BSL agent in a lower-level lab increased the risk of exposure and outbreak.
- This situation created the potential for LAIs, which are infections that affect laboratory workers because of occupational exposure to infectious agents or materials.
- Both the biomedical scientist and his co-worker became potential vectors for transmission, thereby becoming a risk to public health.
- Additionally, such an incident may trigger investigations, which may lead to loss of accreditation and damage the institution's reputation.

b. Preventive professional and ethical actions (Accept any two for 2 marks) Reference Year 2 Week 6

- Laboratories should be classified into appropriate BSLs based on the types of microorganisms being handled.
- Developing and following SOPs for all laboratory activities.
- Immediate reporting of incidents to supervisors.
- Proper training and education on laboratory safety practices and procedures for all laboratory personnel.
- Peer checks or supervision in high-risk areas.

Question 2

a. How did the technician's actions reflect malpractice and negligence, and what were the effects on the patient? (6 marks) Award 2 marks for each action correctly

- Malpractice (2 marks): Explains that the technician made a mistake by mixing up the samples and causing a wrong result. This is malpractice because he didn't follow proper procedures.

- Negligence (2 marks): Describes that the technician was careless by rushing and not checking the samples properly, which caused harm. This is negligence because he didn't do his job carefully.
- Effects on the patient (2 marks): Mentions how the mistake caused the patient emotional distress, fear, and social stigma because she was wrongly told she was HIV positive.

b. In what way was the hospital liable for the harm caused, and what policies should be changed to prevent this in the future? (4 marks)

- Hospital liability (2 marks): Explains that the hospital is responsible for making sure the testing is done correctly and that the patient gave consent.
- Policy changes (2 marks): Suggests a simple solution to prevent mistakes, such as double-checking samples and making sure patients give consent before tests.

c. Create a simple plan that ensures patients give informed consent before sensitive tests are conducted. Why is this important? (5 marks)

i. Plan (3 marks): Describes a simple plan:

- Explain the test clearly to the patient.
- Give the patient time to ask questions.
- Have a form for the patient to sign agreeing to the test.

ii. Importance (2 marks): Explains why informed consent is important:

- It protects the patient's rights.
- It helps avoid mistakes and ensures the patient understands what is happening.

Question 3

a. Short-term and long-term consequences (12 marks)

i. To the patient

Short-term: Severe abdominal pain, infection, need for a second surgery, prolonged hospitalization, and emotional distress.

Long-term: Possible chronic pain, psychological trauma (e.g., post-traumatic stress disorder), financial burden due to medical expenses, and diminished trust in the healthcare system.

ii. To the doctor

Short-term: Immediate disciplinary action, legal proceedings, and damage to professional reputation.

Long-term: Potential loss of medical license, financial liability, and difficulty in securing future employment.

iii. The hospital or healthcare system

Short-term: Legal liability, financial compensation claims, and reputational damage.

Long-term: Loss of public trust, increased scrutiny from regulatory bodies, and potential policy changes to prevent future errors.

b. Surgical negligence significantly reduces public trust in healthcare professionals. Patients may become hesitant to seek medical care, fearing similar errors might occur. The credibility of the healthcare system is compromised, leading to increased malpractice claims and stricter regulations and policy reforms. (Accept any two for 2 marks).

c. Legal: The doctor may face lawsuits for medical malpractice, financial compensation claims, and possible criminal charges if gross negligence is proven.

Professional: Disciplinary actions such as suspension, revocation of medical license, and mandatory retraining. (Accept any 1 for 1 mark)

Additional Reading

QR Code 1: *Video 1 Medical malpractice*

https://www.youtube.com/watch?v=PyTYZEbgoDM

QR Code 2: *Video 2 Case of malpractice*

https://youtu.be/L0-0VfGCMdI?si=lXer86bpZiOHibMb

QR Code 3: *Video 3 Case Medical Negligence*

https://youtu.be/S1G7LoJXMW4?si=XcCMc30M9J1iehs1

QR Code 4: *Video 4 GHS Code of Conduct*

https://youtu.be/0vzwkVQVm5A?si=qtVHJbQVvchVVLda

SAMPLE INFORMED CONSENT FORM

[Name of Hospital or Health Facility]

Address: [Insert hospital address]
Telephone Number: [Insert contact number]

INFORMED CONSENT FORM FOR MEDICAL TREATMENT / PROCEDURE

Patient's Full Name: _____

Hospital Number: _____

Date of Birth/Age: _____

Gender: ☐ Male ☐ Female

Address: _____

Phone Number: _____

Procedure/Treatment Name:

Explanation of Procedure/Treatment

I, Dr. _____, have explained to the patient (or their legal guardian) the nature of the procedure/treatment, its purpose, and the potential benefits and risks involved. These include, but are not limited to:

- Reason for the procedure
- Steps involved
- Common and serious risks/complications
- Alternative treatment options (if any)
- Expected outcome and recovery process

Patient Acknowledgement and Consent

I confirm that:

1. I have been given adequate information in a language I understand about the proposed treatment/procedure.
2. I have had the opportunity to ask questions, and all my questions have been answered to my satisfaction.
3. I understand that I have the right to refuse or postpone the treatment/procedure.

4. I understand the potential risks and benefits involved, and I accept them.
5. I voluntarily agree to undergo the treatment/procedure.

Signature of Patient/Guardian: _____

Date: _____

Name of Guardian (if applicable): _____

Relationship to Patient: _____

Signature of Healthcare Provider: _____

Name (Print): _____

Designation: _____

Date: _____

Interpreter's Statement (if applicable):

I have interpreted the information provided to the patient in a language they understand.

Name of Interpreter: _____

Signature: _____

Date: _____

CONFIDENTIALITY NOTICE

All information shared during this process will be kept confidential and used only for providing safe and effective care.

SECTION 2: BIOSAFETY

Strand: Biomedical Science in Society

Sub-Strand: Biosafety

Learning Outcome: *Apply the principles of biosafety to set up experiments.*

Content Standard: Demonstrate knowledge and understanding of principles of biosafety in setting up experiments.

INTRODUCTION AND SECTION SUMMARY

Biosafety ensures that biomedical science practices are safe and correct. The implementation of proper biosafety protocols when setting up and conducting experiments is important for preventing laboratory-acquired infections (LAIs), environmental contamination, and public health risks. This section equips students with essential knowledge and skills to apply biosafety principles throughout the experimental process, from planning and setting up to conducting the experiment and disposing of waste. The overall indicator for this section is the ability to plan experiments properly to avoid accidents, identify correct waste streams, and implement appropriate safety measures based on risk assessment.

The weeks covered by the section are:

Week 2: *Undertake proper planning of experiments to avoid accidents.*

Week 3: *Identify the correct waste stream and demonstrate proper disposal of hazardous waste in the laboratory*

Week 4: *Identify and describe the role of biosafety professionals in biomedical research laboratories*

SUMMARY OF PEDAGOGICAL EXEMPLARS

To achieve the content standard for this section, the following pedagogical exemplars are recommended. Through experiential learning, learners in mixed-ability groups plan and carry out a safe laboratory experiment by selecting a biological agent, identifying potential risks, and developing and evaluating mitigation strategies. Using exploratory learning, the teacher presents pictures of laboratory scenarios for learners to examine and identify safety breaches. Digital learning is integrated as learners watch videos on hospital waste streams and how to dispose of them properly. Through collaborative learning, learners share experiences of waste disposal at home and school, and brainstorm safe disposal methods for hazardous laboratory waste. Activity-based learning allows learners to role-play planning a safe experiment, assess risks, select PPE, and interact with a biosafety professional. Additionally, project-based learning engages learners in writing a report based on their research and interactions, highlighting the role of biosafety officers in ensuring laboratory safety and policy compliance.

ASSESSMENT SUMMARY

Evaluate students' understanding of laboratory safety through DOK Level 3 scenario-based tasks that require them to design safety protocols, examine waste management systems, and articulate the roles and responsibilities of biosafety professionals. These assessments build upon Year 1 indicators (1.1.2. LI.1-3) on biohazards and Year 2 indicators (2.1.2. LI.1-3) on biosafety practices. As recommended in the Assessment manual, combine practical demonstrations in the laboratory, featuring waste containers and PPE samples, with written explanations of the safety procedures. Record both quantitative scores and qualitative observations in transcripts, documenting specific competencies like "Correct selection of appropriate PPEs for different biohazard levels" and "Analysis of waste stream requirements with appropriate justification." Note areas requiring improvement and include evidence of progression from Year 1-2 foundational knowledge, focusing on students' ability to apply biosafety principles in the laboratory settings.

Summary of the assessment used against the indicators

Indicators	**DOK Level**	**Assessment Strategy and/or Mode**
Undertake proper planning of experiments to avoid accidents.	3	Short answer individual class exercise
Identify the correct waste stream and demonstrate proper disposal of hazardous waste in the laboratory	3	Case study analysis and in-class written assessment
Identify and describe the role of biosafety professionals in biomedical research laboratories	3	Individual written report with recommendations

WEEK 2

Learning Indicator: *Undertake proper planning of experiments to avoid accidents*

Recap Weeks

Year 1	**Week 4:** Discuss the various biohazards as well as the risk groups
Year 2	**Week 4:** Describe features of the biosafety levels and proper practice **Week 5:** Demonstrate proper setup of the biosafety cabinet and its environment. **Week 6:** Demonstrate proper methods for donning and removing personal protective equipment (PPE), such as gloves, lab coats, eye protection, and respiratory protection.

FOCAL AREA 1: PLANNING FOR SAFE EXPERIMENTS

Discuss the importance of planning experiments with safety as a top priority.

Safety planning forms the basis of responsible scientific practice in biomedical science laboratories. Prioritising safety is not merely a regulatory requirement but a fundamental ethical obligation that protects laboratory personnel, the institution, and the public.

Discussions should centre on the principle that safety must be embedded into the experimental planning process from the outset, rather than treated as an afterthought once all other considerations have been addressed. The following are some of the reasons it is important to place safety first when planning experiments:

1. **Protection of personnel**: Biomedical science laboratories present many hazards such as infectious agents, harmful chemicals, radiation, electrical shocks, etc. Careful safety planning helps reduce the risk of exposure and prevents injuries and long-term health problems. Emphasis should be placed on the fact that laboratory accidents can cause serious and lasting harm.
2. **Scientific reliability and continuity:** Explain to students that unsafe laboratory practices can compromise data integrity and scientific validity. Accidents that require medical treatment, equipment repairs, decontamination procedures, or incident investigations may interrupt research activities and require experiments to be repeated from the beginning. Help students understand that safety protocols are not separate from scientific methodology but are essential to producing reliable and reproducible results.
3. **Institutional responsibility:** Educational and research institutions have both legal and ethical obligations to ensure laboratory safety. Safety incidents can have far-reaching consequences, including legal action, loss of research funding, suspension of laboratory activities, and significant damage to institutional reputation. Emphasise that the laboratory safety practices taught in the classroom reflect the professional standards students will be expected to follow in their future careers. Where possible, invite the school safety officer to provide a brief overview of the institution's safety framework, reporting procedures, and emergency response protocols.
4. **Regulatory compliance**: Familiarise students with the key regulatory bodies responsible for overseeing laboratory operations in Ghana, including the Ghana Standards Authority (GSA), the Environmental Protection Agency (EPA), and other relevant health and professional regulatory authorities. Explain that these organisations develop and enforce standards that protect laboratory workers, patients, the public, and the environment. Clarify that compliance with these regulations is mandatory and that failure to comply may result in fines, suspension of laboratory activities, withdrawal of licences, facility closure, or personal professional liability.
5. **Community protection:** Emphasise that laboratory safety extends beyond protecting workers to safeguarding the broader community and environment. Explain how improper management of hazardous materials (chemical, biological, or radioactive) poses public health risks and environmental threats. Connect this concept to students' professional ethics, highlighting that responsible scientists consider potential impacts beyond laboratory walls.

Figure 1 illustrates the Hierarchy of Controls Pyramid, a foundational concept in laboratory safety management. When teaching this model, draw students' attention to the importance of the pyramid structure, which visually illustrates the relative effectiveness of each control measure. Hazard elimination sits at the apex as the most effective strategy, while personal protective equipment forms the base, representing the least reliable line of defence.

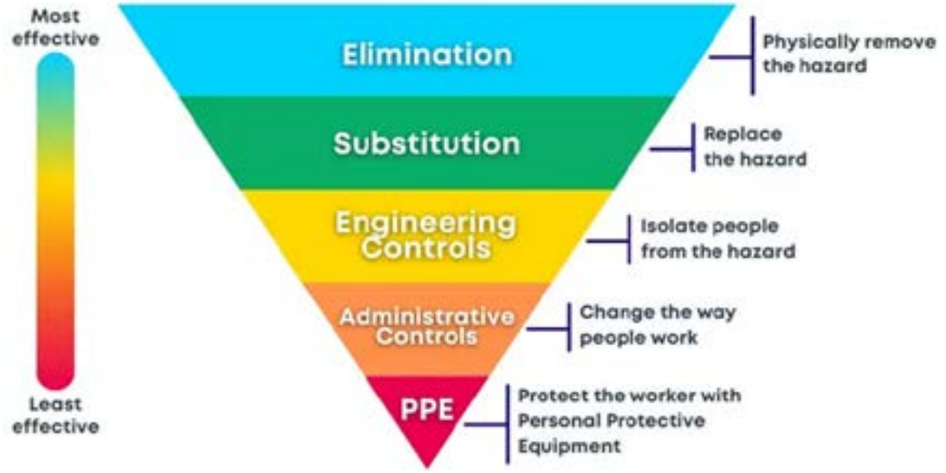


Figure 1: *Hierarchy of Laboratory Safety Controls*

Step-by-step approach to planning safe experiments

Planning safe laboratory experiments requires following the four essential steps. These are described as follows.

1. **Risk assessment**: Present risk assessment as the foundational element of laboratory safety planning, emphasising that it forms the critical first step in a four-part process. When teaching this concept, guide students through the standardised approach shown in **Figure 2**, which systematically identifies hazards, evaluates their potential consequences and likelihood, implements appropriate control measures, and reviews the control measures.



Figure 2: *Systematic Process of Risk Assessment*

The Risk Assessment Process

a. Hazard identification: Systematically identify all potential hazards associated with the experiment:

i. Biological hazards (microorganisms, human specimens, cell cultures)

ii. Chemical hazards (toxic, corrosive, flammable, reactive substances)

iii. Physical hazards (sharps, electrical equipment, extreme temperatures and radiation sources)

iv. Ergonomic hazards (repetitive motions, awkward postures)

b. Risk evaluation: Assess the likelihood and potential severity of harm for each identified hazard:

i. Consider exposure routes (inhalation, ingestion, skin contact, needlestick)

ii. Evaluate risk factors (concentration, quantity, duration of exposure)

iii. Assess potential consequences (minor injury to fatal outcome)

iv. Consider vulnerable populations (pregnant women, immunocompromised individuals)

v. Use the risk matrix (shown in **Figure 3**) to quantify and prioritise risks. The risk score is calculated by multiplying the probability (likelihood) and impact (severity) ratings (Risk Score = Likelihood × Severity)

c. Control measures: Apply the hierarchy of controls (See **Figure 1**) to mitigate risks:

i. **Elimination**: Remove the hazard entirely

ii. **Substitution**: Replace with a less hazardous alternative

iii. **Engineering controls**: Use fume hoods, biosafety cabinets, and equipment guards

iv. **Administrative controls**: Develop protocols, training, and signage

v. **Personal protective equipment**: Last line of defence

d. Review control measures: Regularly evaluate the effectiveness of implemented controls and make necessary adjustments:

i. Monitor incidents and near misses to identify areas for improvement

ii. Revise risk assessments when procedures or materials change

iii. Ensure ongoing training and communication with all laboratory personnel

iv. Periodically audit safety protocols to maintain compliance and readiness

Impact
How severe would the outcomes be if the risk occurred?

Probability
What is the probability the risk will happen?

	Insignificant 1	Minor 2	Significant 3	Major 4	Severe 5
5 Almost Certain	Medium 5	High 10	Very high 15	Extreme 20	Extreme 25
4 Likely	Medium 4	Medium 8	High 12	Very high 16	Extreme 20
3 Moderate	Low 3	Medium 6	Medium 9	High 12	Very high 15
2 Unlikely	Very low 2	Low 4	Medium 6	Medium 8	High 10
1 Rare	Very low 1	Very low 2	Low 3	Medium 4	Medium 5

Figure 3: *Risk matrix for risk evaluation*

Risk assessment form

The laboratory risk assessment form (see Additional Reading for a sample) serves as an essential teaching tool for developing students' safety analysis skills. It is structured around three critical sections that teachers should emphasise. The Hazard Identification section trains students to systematically recognise chemical, biological, physical, and other laboratory hazards. The Risk Evaluation Matrix introduces quantitative risk assessment by guiding students through the use of likelihood and severity scales. The Control Measures section reinforces preventative safety protocols, including the appropriate use of PPE. When teaching this form, emphasize the Waste Disposal Method checkboxes, which differentiate between yellow bins for infectious waste, yellow puncture-resistant containers for sharps, red bins for highly infectious materials, brown bins for chemical waste such as expired reagents, and black bins for general waste.

2. Personal protective equipment: When teaching about PPE, emphasise that selection must be directly informed by the specific hazards identified during risk assessment, not by convenience or habit. Guide students to understand PPE's proper position in the hierarchy of controls (**Figure 1**), as the final protective layer after other control measures have been implemented, not as a substitute for elimination, substitution, engineering controls or administrative procedures. Refer to **Figure 4** for an illustration of the primary categories of protective equipment (eye/face protection, respiratory protection, body/clothing protection, and hand protection) along with their appropriate applications and limitations. This presents an excellent opportunity to demonstrate proper donning and doffing procedures, particularly emphasising the sequence for removing potentially contaminated items to prevent cross-contamination.



Figure 4: *Basic types of PPE*

PPE selection process

1. **Identify required protection**
   - **a.** Eye and face protection: Safety glasses, goggles, face shields
   - **b.** Hand protection: Various glove types based on hazard (nitrile, latex, neoprene, butyl rubber)
   - **c.** Body protection: Laboratory coats, gowns, aprons
   - **d.** Respiratory protection: Surgical masks, respirators
   - **e.** Foot protection: Closed-toe shoes, safety footwear
   - **f.** Head protection: Caps, helmets (when necessary)
2. **Match PPE to specific hazards**
   - **a.** Chemical hazards: Chemical-resistant gloves, splash goggles, lab coat
   - **b.** Biological hazards: Appropriate gloves, eye protection, lab coat, possibly respiratory protection
   - **c.** Physical hazards: Cut-resistant gloves, impact protection, thermal protection
   - **d.** Radiation hazards: Lead aprons, thyroid shields, dosimeters
3. **Ensure proper fit and compatibility**
   - **a.** Verify correct sizing for all PPE
   - **b.** Ensure multiple PPE items can be worn together effectively
   - **c.** Consider comfort for extended wear
4. **Establish donning and doffing procedures**
   - **a.** Teach proper sequence for putting on PPE
   - **b.** Emphasise correct removal to prevent cross-contamination
   - **c.** Demonstrate proper disposal or decontamination methods

Table 2.1 shows how to choose the right personal protective equipment (PPE) for common laboratory hazards. It lists the type of hazard and the recommended protection, such as gloves, lab coats, goggles, face shields, or masks. This helps laboratory workers quickly find the correct PPE for working with biological, chemical, physical, or radiological dangers. The table promotes informed decision-making and contributes to the establishment of safe, consistent laboratory practices.

Table 2.1: PPE Selection Table

Hazard Type	Eye Protection	Hand Protection	Body Protection	Respiratory Protection
Corrosive chemicals	Chemical splash goggles	Chemical-resistant gloves (neoprene, butyl)	Lab coat and chemical-resistant apron	Not typically required unless vapours
Biological samples (BSL-2)	Safety glasses or goggles	Nitrile gloves (double if necessary)	Lab coat (preferably with knitted cuffs)	Surgical mask if aerosols possible
UV radiation	UV-protective face shield	Nitrile gloves	Lab coat with full coverage	Not required
Cryogenic materials	Face shield	Insulated cryogenic gloves	Lab coat and cryogenic apron	Not required
Sharps and dissection	Safety glasses	Cut-resistant gloves	Lab coat	Not required

3. **Safe handling procedures**: Guide students to understand that safe handling techniques encompass the correct procedures for working with laboratory materials and equipment, with the primary aim of preventing accidents and safeguarding both people and the environment. Emphasise that these methodical approaches apply to all laboratory activities, including chemicals, biological specimens, glassware, and specialized equipment. Demonstrate that proper handling serves multiple purposes: Preventing immediate hazards like spills and breakages, avoiding cross-contamination, protecting users from exposure, and maintaining experimental integrity. Guide students in understanding how hazards identified through risk assessment directly shape the specific handling protocols applied to common biomedical procedures, with particular focus on pipetting, aseptic technique, and chemical transfer methods.

Key principles of safe handling include:

- **a. Chemical handling**
  - i. Always add acid to water, never water to acid
  - ii. Use appropriate transfer tools (pipettes, funnels)
  - iii. Work in a fume hood when using volatile or hazardous chemicals
  - iv. Keep chemical containers closed when not in use
  - v. Label all containers clearly with contents and dates
  - vi. Never use mouth pipetting for any substance

vii. Store chemicals according to compatibility, not alphabetically

b. Biological material handling

i. Use aseptic technique when working with cultures
ii. Ensure all infectious materials are processed inside a biosafety cabinet
iii. Avoid creating aerosols or splashes
iv. Decontaminate work surfaces before and after use
v. Use appropriate disinfectants with adequate contact time
vi. Dispose of biological waste in designated containers
vii. Never recap needles; use sharps containers immediately

c. Equipment operation

i. Receive proper training before using new equipment
ii. Follow manufacturer's instructions and laboratory protocols
iii. Inspect equipment for damage before use
iv. Use equipment guards and safety features
v. Balance centrifuges properly
vi. Allow equipment to cool before maintenance
vii. Disconnect electrical equipment when not in use

d. Workspace management

i. Maintain a clear, uncluttered workspace
ii. Clean up spills immediately using appropriate methods
iii. Keep aisles and emergency exits clear
iv. Segregate incompatible activities and materials
v. Practice good personal hygiene (hand washing, no food/drink in the workspace)
vi. Designate clean and dirty areas to prevent cross-contamination

Figure 5 shows how to arrange laboratory spaces to prevent cross-contamination. When teaching this diagram, point out how clean areas are kept separate from dirty areas. Show students how the layout creates a one-way flow of work to prevent backward spread of contamination. Explain that different laboratory activities, such as sample preparation, diagnostic testing, and waste handling, each require designated areas equipped with appropriate safety features. Draw students' attention to the importance of proper storage arrangements for chemicals, biological samples, and equipment, particularly the separation of hazardous materials. Use this figure to illustrate how a well-organised laboratory layout helps prevent contamination, minimises the risk of accidents, and enhances overall workflow efficiency. This reinforces the understanding that thoughtful workspace planning is a fundamental component of laboratory safety.



Figure 5: *Proper organisation of laboratory space to prevent cross-contamination*

4. **Emergency procedures**: When teaching emergency preparedness, demonstrate how to use water buckets as temporary eyewash stations, identify the nearest water source for washing chemical exposures, and show the locations of first aid supplies. Review evacuation routes and gathering points specific to your school building. Practice emergency communication procedures, including contact information for the nearest health facility and transportation options if ambulance service is limited.

Key parts of emergency preparedness include:

a. Emergency response planning

i. Familiarise students with laboratory emergency plans
ii. Identify emergency exit routes and assembly points
iii. Locate and demonstrate use of emergency equipment:

- **Fire control**: Buckets of sand or soil (clearly labelled) can substitute for fire extinguishers; heavy cotton blankets can serve as fire blankets
- **Eye and skin decontamination**: In the absence of dedicated eyewash stations, clean water stored in designated plastic buckets with cups may be used for eye irrigation. Nearby water taps or large containers of stored clean water can serve as practical alternatives for skin decontamination following accidental exposure to hazardous substances.
- **First aid supplies**: Basic first-aid materials such as clean cloths, bandages, antiseptics, and other essential supplies should be stored in a dedicated, clearly labelled container that is readily accessible to all laboratory personnel. The contents should be inspected regularly and replenished as needed.
- **Spill management**: Local absorbent materials like sawdust, sand, or paper kept in labelled containers for chemical spills; diluted bleach solution in a spray bottle for biological contamination
- **Emergency power control**: Clearly mark main switches for quick manual shutdown; teach students to unplug equipment safely

b. Spill response procedures

i. Chemical spills

- Alert others in the area
- Assess spill size and hazard level of the spill
- For small spills: contain using appropriate materials from the spill kit
- For large spills: evacuate and call for assistance
- Clean up in a manner consistent with the chemical's properties
- Dispose of waste in designated containers

ii. **Biological spills**

- Alert others in the area
- Cover spill with absorbent material
- Apply and allow adequate contact time with the appropriate disinfectant
- Clean up and dispose of as biohazardous waste

c. Fire response

- Alert others by activating the fire alarm
- If you have been adequately trained and it is safe, use an appropriate fire extinguisher to fight the fire. Otherwise, evacuate immediately
- Close doors, but do not lock them
- Proceed to the designated assembly point
- Follow the emergency reporting protocol

d. Personal injury response:

i. Chemical exposure:

- Take off any clothes that have chemicals on them
- Wash the affected skin with clean water for at least 15 to 20 minutes. Use a bucket or stored water if there is no running water
- If the chemical got into the eyes, rinse them gently with clean water using a cup or bottle
- If a large area of the body is affected, use buckets of water to rinse the body well
- Go to a health centre or clinic for the chemical's safety sheet (if you have it) to help explain what happened

ii. Biological exposure:

- Wash the exposed area thoroughly with soap and water
- For needlesticks, encourage bleeding to flush the wound
- Document exposure details
- Seek medical evaluation

e. Documentation and reporting:

- Report all incidents, even minor ones

- Complete incident report forms
- Participate in incident investigations
- Contribute to preventive measures

Figure 6 displays a colour-coded decision tree that guides laboratory staff through emergency assessment and response protocols. When teaching this system, explain that yellow branches represent low-risk situations that can be handled in the lab for minor spills and equipment malfunctions without exposure. Orange represents moderate-risk incidents that require urgent attention and are possibly reported to safety personnel. They include non-injury chemical exposures and visible smoke without flames. Red represents high-risk emergencies that require evacuation and outside emergency services. Examples of such emergencies are fires, major chemical releases, and serious injuries.

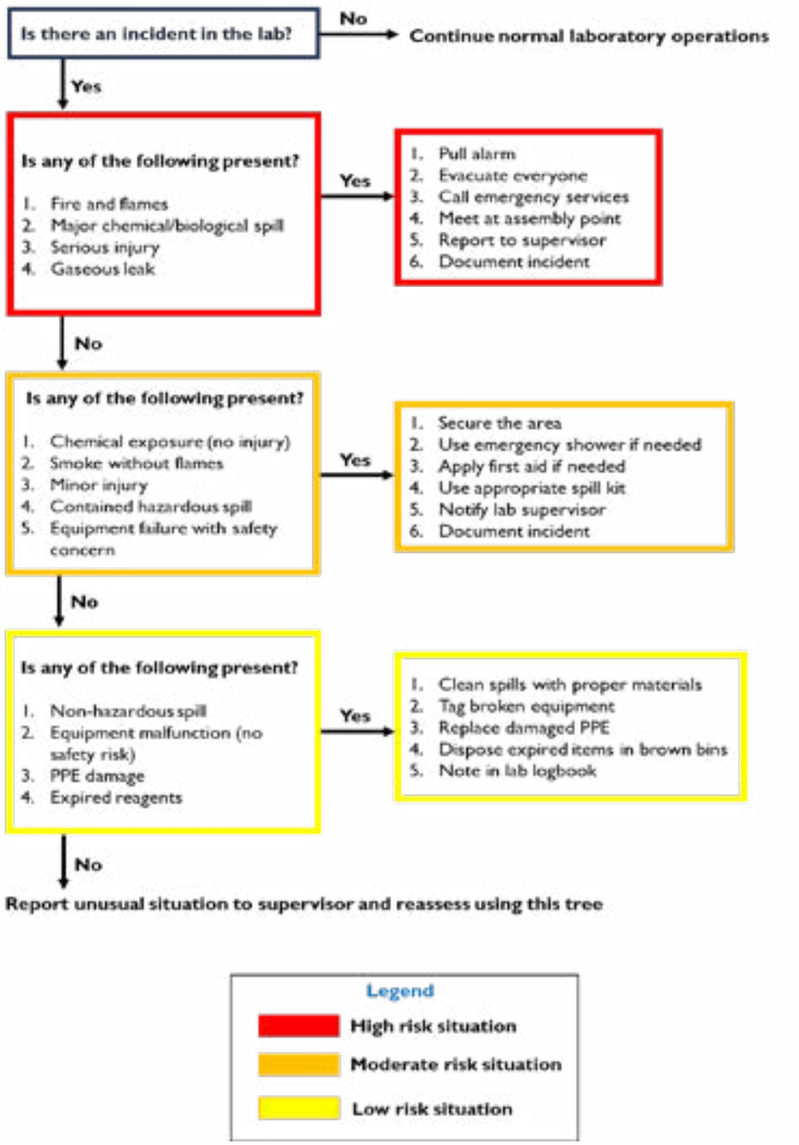


Figure 6: *Laboratory emergency response decision tree*

NOTE: When in doubt, answer "YES" and move to a higher risk level. Always wear appropriate PPE for any response.

Learning Tasks

1. Recap on the various biohazards, features of the biosafety levels, proper setup of the biosafety cabinet, and proper methods for donning and removal of PPEs.
2. Discuss the importance of planning experiments with safety as a priority.
3. Develop a step-by-step plan for conducting safe experiments by identifying potential risks, selecting appropriate PPE, reviewing safe handling procedures, and outlining emergency actions for accidents.

Pedagogical Exemplars

Experiential learning: Learners work in mixed-ability groups to design and carry out a simple science experiment. Each group starts by selecting a biological agent such as yeast, onion tissue, or leafy vegetables, and identify a basic procedure such as observing fermentation, testing osmosis, or examining how light affects plant growth. Learners identify possible hazards, including biological, physical, or chemical risks. They then develop a plan to reduce or prevent these risks and record their ideas using a laboratory risk assessment form (see **Additional Reading** for a sample). As part of this process, each group evaluates the other group's safety plan and gives suggestions for improvement. Once the risk control strategies are reviewed and approved by the teacher, learners carry out the experiment using appropriate safety measures, such as wearing personal protective equipment and using the correct waste disposal methods. After the activity, groups reflect on what happened, how safe the procedure was, and what they could do better next time.

Exploratory learning: The teacher shows several pictures or drawings of science laboratory setups, indicating safety errors that have been made. These images may show examples such as uncovered containers, unlabelled substances, eating in the lab, or inappropriate use of gloves or goggles. Working in pairs or small groups, learners study each image and identify what is wrong in the situation. The teacher supports the activity by asking guiding questions such as, "What danger is present here?" or "What should have been done differently?" Learners then explain what should be corrected and why it matters. After the discussion, the class reviews each image together, and the teacher highlights the key safety rules that apply. As a follow-up, learners can create a safety rule chart or a classroom poster using available materials to reinforce the lesson.

Key Assessment: Group Project

Level 3 (Strategic thinking): You are a laboratory scientist in a Ghanaian research facility, and your team is preparing to conduct an experiment involving chemical reactions with potentially hazardous substances (e.g., acids, flammable liquids, or biohazards). Using the four key safety components (Risk Assessment, PPE, Safe Handling, Emergency Procedures), develop a detailed, step-by-step safety protocol for your experiment. Justify each decision with scientific reasoning and real-world applicability. *(15 marks)*

Hint

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

PLC Session 2

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 3

Learning Indicator: *Identify the correct waste stream and demonstrate proper disposal of hazardous waste in the laboratory*

Recap Weeks

Year 1	**Week 4:** Discuss the various biohazards as well as the risk groups. **Week 6:** Analyse laboratory-acquired infections (LAIs), including some case studies.
Year 2	**Week 4:** Describe features of the biosafety levels and proper practice. **Week 6:** Demonstrate proper methods for donning and removal of personal protective equipment (PPE) such as gloves, lab coats, eye protection and respiratory protection.

FOCAL AREA 1: RESPONSIBLE WASTE MANAGEMENT

Discuss the importance of proper waste disposal in a laboratory setting

Teach students that proper waste disposal is a critical component of laboratory safety with significant implications beyond the immediate work environment. When introducing this concept, emphasise that biomedical laboratory waste often contains hazardous materials that pose serious threats to human health, environmental integrity, and community wellbeing if mismanaged. Describe how creating standard waste management protocols becomes especially crucial in Ghana, where laboratories operate with varied amounts of resources. Guide students through locally appropriate waste segregation systems, using available containers and clear labelling to distinguish between non-hazardous, infectious, chemical, and sharps waste streams.

Provide students with four key viewpoints that emphasise the significance of laboratory waste management when instructing them in this subject:

1. **Protection of laboratory workers**: Explain that incorrect waste handling directly endangers laboratory personnel through needlestick injuries, chemical burns, and exposure to infectious materials. Use simple examples relevant to students' laboratory experience to illustrate how improper disposal creates immediate safety hazards.
2. **Environmental safeguarding**: Describe how laboratory chemicals, heavy metals, and biological materials can persist in the environment, potentially contaminating soil and water. Help students understand that these contaminants can affect ecosystems long after disposal, emphasising the scientist's responsibility beyond the laboratory walls.
3. **Public safety**: Demonstrate that improper waste management endangers people outside the laboratory who lack appropriate training or protective equipment. Discuss common examples in which community members will encounter improperly disposed laboratory waste, consisting of through waste series structures or water assets.
4. **Regulatory requirements**: Introduce students to key Ghanaian regulatory bodies, including the Environmental Protection Agency (EPA), the Ghana Standard Authority (GSA), and the Ministry of Health (MoH), that govern laboratory waste management. Explain that compliance is not optional but a legal requirement with serious consequences for non-compliance.

Explore different types of hazardous waste generated in a lab

In discussing waste management, highlight that biomedical labs produce various waste types that necessitate unique handling and disposal techniques. Guide students to recognise that proper waste segregation begins with accurate identification using the standardised colour-coding system employed in healthcare settings throughout Ghana.

Direct students' attention to **Figure 7**, which illustrates the standard waste containers used nationally, highlighting how hazardous waste containers are distinctly marked with specific colours (red for highly infectious/ pathological waste, brown for chemical waste, yellow for infectious/biological waste, and yellow puncture-resistant containers for sharps), while non-hazardous general waste is collected in black containers.



Figure 7: *Colour-coded waste container guide*

Demonstrate proper disposal procedures for each waste type

Introduce students to **Figure 8** as an overview of the general waste management lifecycle that applies across all laboratory waste streams. Emphasize that this framework illustrates the universal journey of laboratory waste from generation during procedures, through proper segregation into colour-coded containers, containment with appropriate sealing and labelling, treatment according to hazard classification, and finally to approved disposal pathways. Although this general process applies to all types of waste, it's important to note that the specific procedures within each stage can differ greatly depending on how the waste is classified. Note that this foundational understanding prepares students for the detailed protocols for each waste category (infectious, chemical, sharps, and general waste). This structured approach helps students grasp the fundamental principles of waste management before addressing the

particular containment requirements, treatment methods, and documentation procedures unique to each waste classification.



Figure 8: *Laboratory waste management cycle*

Specific disposal procedures by waste type

When teaching laboratory waste disposal, demonstrate the specific procedures for each waste category:

1. Pathological & highly infectious waste (red)

Materials: Red biohazard bags, rigid containers with biohazard symbol, PPE, tracking forms

Key Procedures

- **a.** Line rigid container with red biohazard bag, folding top over rim
- **b.** Fill only to two-thirds capacity to allow secure closure
- **c.** Seal the bag with ties and the outer container tightly
- **d.** Label according to Ghana Health Service requirements
- **e.** Store in cool areas away from direct sunlight
- **f.** Arrange collection through approved waste handlers

2. Hazardous chemical & pharmaceutical waste (Brown)

Materials: Compatible containers, chemical waste labels, secondary containment, PPE

Key Procedures

- **a.** Select appropriate containers that won't degrade in storage
- **b.** Use secondary containment when filling to prevent contamination
- **c.** Fill allowing for potential expansion in hot weather
- **d.** Secure the cap tightly and seal with tape if necessary
- **e.** Record in the chemical register as required by the Ghana EPA
- **f.** Store in a ventilated, secure area protected from the weather

3. Infectious waste (Yellow)

Materials: Yellow biohazard bags, rigid containers, disinfectant, PPE

Key Procedures

a. Line waste bin with a yellow biohazard bag of appropriate thickness
b. Dispose of waste directly without sorting or handling
c. Apply appropriate disinfectant (typically 0.5% sodium hypochlorite)
d. Tie bag securely when two-thirds full
e. Label with department and date per local regulations
f. Record disposal in the facility waste management logbook

4. Sharps waste (Yellow puncture-resistant)

Materials: Yellow puncture-resistant containers, PPE, permanent marker

Key Procedures

a. Verify container meets puncture-resistance standards
b. Label clearly with "SHARPS" and biohazard symbol
c. Place in an accessible location near the point of use
d. Dispose of sharps directly without recapping needles
e. Fill only to three-quarters capacity
f. Secure lid when full and mark as "FULL", with date
g. Ensure final disposal through approved methods

5. General non-hazardous waste (Black)

Materials: Black bags, black bins, PPE if needed

Key Procedures

a. Line the black waste bin with a black bag
b. Dispose only of non-hazardous materials (paper, packaging, non-contaminated items)
c. Verify no hazardous materials are mistakenly included
d. Tie the bag securely when two-thirds full
e. Transport to regular waste collection points
f. Follow local recycling protocols where applicable
g. No special treatment required before final disposal

Learning tasks

1. Review of biohazards, LAIs, features of the biosafety levels, and the proper methods for donning and removal of PPE.
2. Explain the importance of proper waste disposal in laboratory settings by analysing its impact on health, safety, environment, and research integrity.

3. Sort common laboratory waste items into categories and match each one to its correct colour-coded disposal container, and provide reasoning for each classification based on the type of hazard it presents.
4. Demonstrate the proper disposal procedures for the various categories of laboratory waste identified in Step 3.

Pedagogical Exemplars

Digital learning: Introduce learners to healthcare-related waste management using online videos, digital images, or animations that show the different types of waste produced in hospitals. These may include infectious waste, sharps, chemical waste, and general waste. Learners watch the videos or study the images in class or at home using phones, tablets, or computers, depending on what is available. As they watch, they take notes on how each waste type is identified, handled, and safely disposed of. After viewing, learners discuss their observations in small groups and summarise the correct disposal methods for each waste stream. The teacher then guides a class discussion to reinforce key points and clarify any misconceptions.

Collaborative learning: Learners work in groups to share their personal experiences with waste collection and disposal in their homes, schools, or communities. They begin by listing the different types of waste they commonly see, such as plastic, food waste, glass, paper, or chemicals. Once each waste stream has been identified, groups discuss standard handling procedures and the challenges involved in managing them safely. The focus then moves to laboratory waste, with particular attention given to hazardous items such as broken glassware, chemical residues, and contaminated gloves. Together, learners brainstorm ideas on how best to dispose of these materials safely, based on what they have learned and what is practical in their environment. Each group presents its ideas to the class, and the teacher helps them refine their suggestions into clear, practical steps.

Key Assessment: Case Study

Level 3 (Strategic thinking): During your initial assessment of waste management in the Phlebotomy Laboratory (blood sample collection point in the hospital), you discovered that laboratory waste disposal practices need significant improvement.

1. Identify three potential lab waste and their corresponding risks when these wastes are improperly disposed of. (3 marks)
2. Categorise the laboratory wastes listed in **Question 1** and list the appropriate colour-coded disposal containers. Explain the rationale for each categorisation. (9 marks)
3. Explain two reasons why following biosafety rules is important in waste disposal. (3 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 ***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 4

Learning Indicator: *Identify and describe the role of biosafety professionals in biomedical research laboratories*

Recap Weeks

Year 1	**Week 4**: Discuss the various biohazards and the risk groups. **Week 6**: Analyse Laboratory-acquired infections, including some case studies.
Year 2	**Week 4**: Describe features of the biosafety levels and proper practice. **Week 6**: Demonstrate proper methods for donning and removal of personal protective equipment (PPE) such as gloves, lab coats, eye protection, and respiratory protection.

FOCAL AREA 1: ROLE OF BIOSAFETY PROFESSIONALS

Role of biosafety professionals in a biomedical research laboratory

Biosafety professionals are important healthcare workers who help prevent the spread of diseases by managing biological risks in laboratories and healthcare settings. They play a crucial role in protecting workers, patients, and the public from harmful biological agents. Their work draws on and extends the knowledge students developed in previous years regarding medical careers, biological hazards, and laboratory safety levels.

To facilitate this understanding, Table 2.2 presents various categories of biosafety professionals, detailing their functions, everyday tasks, and the necessary qualifications for each position. The table indicates that these experts merge scientific expertise with specialized safety training. Numerous careers in this field demand more than just a fundamental science degree; they frequently require further certifications in biosafety or related disciplines. The table further emphasizes the opportunities for professional advancement, ranging from initial entry-level roles to higher positions that entail considerable experience and training.

Table 2.2 Biosafety Professionals and Their Primary Functions

Professional title	Primary responsibilities	Required qualifications
Institutional Biosafety Officer	Oversee institutional biosafety program; develop policies; coordinate with regulatory bodies	Advanced degree in biological sciences; biosafety certification; 5+ years' experience
Laboratory Biosafety Manager	Implement daily safety protocols; supervise containment procedures; manage biological waste	Degree in biological sciences; laboratory experience; biosafety training
Biosafety Committee Member	Review research protocols; approve containment levels; ensure regulatory compliance	Scientific expertise; understanding of risk assessment
Biosafety Training Coordinator	Develop training programs; assess competency; create educational materials	Teaching experience; thorough knowledge of biosafety procedures

Biosafety Equipment Specialist	Certify containment equipment; validate sterilization; maintain safety infrastructure	Technical certification; equipment maintenance experience

Elaborate on how the planning steps and waste management practices contribute to a safe and responsible laboratory environment

This section revisits essential laboratory safety foundations introduced in earlier lessons. These include the four key planning steps: conducting a risk assessment, selecting appropriate personal protective equipment (PPE), following safe handling procedures, and establishing emergency protocols. In addition, students recall the five core waste management practices: waste generation, segregation, container preparation, treatment, and final disposal. The following points form a visual guide illustrating how experiment planning and waste management work together as one unified approach to achieving the highest standards of laboratory safety. Laboratory safety reaches its full potential when experimental planning and waste management are approached not as separate responsibilities, but as two sides of the same coin, each informing and reinforcing the other throughout the entire process. Before beginning any experiment, students must consider the types of waste that will be produced, whether chemical, biological, or sharps, the quantity of that waste, the potential hazards it may pose, and the proper disposal methods. Emphasis is placed on planning, where waste management is considered before the experiment begins, not after waste has already been generated. This proactive approach minimises laboratory-acquired infections (LAIs) and ensures the safety of all individuals in the laboratory environment. The following are examples of how experiment planning and waste management contribute to safe and responsible laboratory environments.

1. **Identifying and controlling hazards**: Risk assessment is essential for anticipating hazards associated with waste before they arise. For example, when using iodine solution for staining, understanding its potential to irritate skin and harm the environment allows students to prepare suitable waste containers in advance. Recognising such hazards helps ensure safe disposal and reduces health risks.
2. **Consistent safety measures**: Personal protective equipment must be worn during both experiments and waste handling. For instance, when a student uses bleach to disinfect surfaces, gloves should be worn both during cleaning and when disposing of bleach-soaked clothes, as these materials remain hazardous even after use.
3. **Continuity of safe practices**: Good laboratory technique applies equally during waste disposal. For example, when pouring used culture broth or liquid waste into disposal containers, careful handling is needed to avoid spills or splashes, just as when transferring samples during experiments. Poor handling at this stage can cause exposure to harmful agents.
4. **Complete emergency preparedness**: Emergency plans must cover both the experiment and waste management activities. Spill kits or absorbent materials such as sand or sawdust should be available not only near work areas but also at waste collection points. This ensures that spills involving hazardous substances such as formalin or strong disinfectants can be quickly contained, protecting everyone in the laboratory.

Learning Tasks

1. Revise key topics covered earlier, including classifying biohazards and their risk groups, analysing laboratory-acquired infection case studies, understanding biosafety level requirements, and demonstrating proper techniques for donning and removing personal protective equipment in laboratory settings.
2. Describe the key responsibilities of biosafety professionals in biomedical research laboratories, identifying at least three specific ways these professionals protect laboratory workers, the public, and the environment through the implementation of safety protocols and regulatory compliance measures.
3. Analyse how specific laboratory planning steps and waste management practices interconnect to create a comprehensive safety system, evaluating how each element contributes to protecting personnel, the community, and the environment from laboratory hazards.

Pedagogical Exemplars

Activity-based learning: Learners participate in a role-playing exercise where they plan a safe experiment step-by-step. This includes identifying hazards, conducting a risk assessment, and selecting appropriate personal protective equipment. To deepen understanding, a biosafety professional is invited to speak to the class about their work and the vital role of biosafety in research laboratories. Following the talk, learners research specific hazardous materials commonly found in labs and investigate the correct procedures for their disposal. This hands-on approach helps learners connect theory with real-world practices.

Exploratory learning: Learners visit a biomedical laboratory or attend a talk by a biosafety officer who explains how their role helps reduce the risk of infectious diseases. During the visit or session, learners observe laboratory practices and ask questions about biosafety protocols. This experience allows learners to see firsthand how biosafety officers work to protect staff and the community by enforcing safety measures and controlling hazards.

Project-based learning: Learners write detailed reports on the role of biosafety officers in maintaining safe laboratories. These reports draw from their interactions with the visiting professional as well as independent research using books, articles, or online resources. The focus is on how biosafety officers ensure compliance with safety policies, manage risks, and promote safe laboratory environments. This project develops learners' research, writing, and critical thinking skills while reinforcing the importance of biosafety in health sciences.

Key assessment: Report Writing

Level 3 (Strategic thinking): You are conducting a biosafety inspection of a biomedical research laboratory that works with moderate-risk infectious agents. During your inspection, you notice several concerns with their waste management system:

1. Sharps containers are frequently overfilled before disposal
2. Chemical waste bottles lack proper labelling
3. Biohazardous waste bags are not properly sealed before transport
4. PPE is sometimes discarded in the general waste

   a. State three specific safety risks and explain why each of these waste management practices poses to laboratory workers, the public, and the environment. (6 marks)
   b. Identify and explain two specific responsibilities of biosafety professionals that address these waste management issues. (4 marks)
   c. Describe how proper laboratory planning connects with effective waste management to create a comprehensive safety system. (5 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 ***report writing***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the assessment (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)

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

Section Review

This section reviews all the lessons taught for the last 3 weeks. A summary of what should have been taught and what each learner should have learnt if differentiation had been done.

1. What is the importance of planning experiments with safety as a priority, and how does this approach protect laboratory workers and research integrity?
2. What are the four essential steps for conducting safe experiments in the laboratory, from initial risk assessment to emergency preparedness?
3. Why is proper waste disposal critical in laboratory settings, and how does improper disposal impact human health, environmental safety, and research quality?
4. Identify the different colour-coded waste disposal containers used in laboratory settings, and what specific types of waste materials belong in each?
5. What are the key responsibilities of biosafety professionals in biomedical research laboratories, and how do they protect laboratory workers, the public, and the environment?
6. How do proper laboratory planning and waste management practices interconnect to create a comprehensive safety system?

Laboratory safety and biosafety principles form the foundation of responsible biomedical science practice. Failure to implement proper safety protocols, waste management procedures, and biosafety measures can lead to laboratory-acquired infections, environmental contamination, and public health risks. These lapses not only endanger laboratory personnel but can also compromise research integrity through contamination and experimental disruption. The section equips learners with practical knowledge to identify hazards, implement appropriate safety measures, properly manage laboratory waste, and understand the vital role of biosafety professionals in maintaining safe laboratory environments. These skills are essential for protecting individuals, communities, and the environment while ensuring scientific work proceeds effectively and ethically.

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 2

1. Risk assessment (4 marks) (1 mark for each category of risk assessment)

a. Identification of hazards (Each potential risk for 1 mark): Must list 2 potential risks, such as chemical burns, inhalation of toxic fumes, fire hazards, and biological contamination. (Accept any other relevant answer).

b. Risk severity and probability: Clear evaluation of how likely and severe each risk is. (1 mark)

c. Risk mitigation strategies (1 mark): Specific control measures such as fume hoods, restricted access, and controlled temperatures.

2. Personal protective equipment (PPE) (6 marks)

a. Selection of PPE (3 marks): Must specify 3 required gears, such as gloves, goggles, lab coats, respirators, and reinforced footwear for 3 marks. (Accept any 3 or any other relevant answer for 1 mark each).

b. Justification (3 marks): Explanation of how each PPE item protects against identified hazards. (Accept any 3 PPEs with correct justification or any other relevant answer for 1 mark each). Refer to Table 2.3 for examples.

Table 2.3

PPE	Justification
Gloves	1. protect hands from direct contact with hazardous substances, 2. prevent chemical burns and absorption of toxic substances and 3. Prevent contamination.
Goggles	4. Protect against chemical splashes that could cause burns and eye injuries. 5. Essential when handling volatile substances such as acids, or pressurized liquids that might spray unexpectedly. 6. Prevent exposure to airborne particles or fumes that can irritate or damage the eyes.
Lab coats	• Reduce contamination risks by ensuring chemical exposure is limited to the coat rather than personal clothing. • Provide a physical barrier against spills, splashes, and accidental contact with hazardous chemicals.
Respirators	b. Protect against inhalation of toxic vapors, aerosols, or biohazards present in the experimental environment. c. Essential when handling volatile organic compounds (VOCs), corrosive fumes, or airborne contaminants. d. Help prevent respiratory issues by filtering harmful particles that standard ventilation may not fully eliminate.
Reinforced footwears	1. Shield feet from chemical spills, falling objects, and broken glassware that could cause injuries. 2. Chemical-resistant boots prevent absorption of hazardous liquids, reducing skin exposure risks. 3. Slip-resistant soles provide stability in environments with liquid spills, minimizing fall hazards.

3. Safe handling (3 marks)

Step-by-step protocol (1 mark): Must provide a logical sequence for handling, storage, and disposal of hazardous materials.

Best practices (1 mark): Include methods such as proper labelling, chemical segregation, working in ventilated areas, and controlled environmental usage. Regulatory adherence (1 mark):

Reference and adherence to applicable standards (e.g., Food and Drugs Authority (FDA), Ghana Standards Authority (GSA), and World Health Organisation (WHO) guidelines) for real-world relevance.

4. Emergency procedures (2 marks) (1 mark for each correct procedure duly justified)

Emergency response steps (1 mark): Must cover specific actions in case of spills, fires, exposure, or contamination. For example, sodium bicarbonate to neutralize acid spills, and immediate flushing for chemical exposure.

Use of emergency equipment (1 mark): Detailed explanation of eyewash stations, fire extinguishers, spill kits, and chemical neutralizers.

WEEK 3

1. Sample Answer for 3 Marks (with other valid responses):

a. Sharps (e.g., needles, scalpel blades): Risk of cuts or puncture wounds; may transmit bloodborne infections like HIV or Hepatitis B.

b. Infectious waste (e.g., blood-soaked gloves, tissues): Risk of spreading infections to humans and contaminating surfaces or waste handlers.

c. Chemical waste (e.g., acids, alcohols, staining reagents): Risk of burns, toxic fumes, or environmental pollution if poured down drains.

Other acceptable waste types and risks may include:

a. Broken glassware: Risk of injury or contamination.

b. Expired reagents: May react dangerously or produce toxic by-products.

c. Contaminated cultures or media: May release pathogens if improperly disposed of.

Marking Criteria

a. 3 marks: Identifies three types of lab waste with accurate, specific risks.

b. 2 marks: Three wastes are mentioned, but one risk is unclear, or only two risks are explained clearly.

c. 1 mark: Fewer than three wastes or mostly general, vague risks.

2. Sample Answer for 9 Marks (with alternatives):

a. Sharps: Category – Sharps waste. Bin – Yellow puncture-resistant container.

Rationale: **Prevents puncture injuries and infection during handling and transport.**

b. Infectious waste (e.g., blood-contaminated gauze): Category – Infectious waste. Bin – Yellow bin or bag.

Rationale: **Needs incineration or secure handling due to potential for disease transmission.**

c. Chemical waste (e.g., expired stain): Category – Chemical waste; Bin – Brown bin or bag.

Rationale: **Prevents toxic release and environmental contamination.**

Other accepted examples and rationale

a. Contaminated glass: May go in yellow bins (if infectious) or black bins (if non-hazardous).

b. Expired drugs: May be classified under pharmaceutical waste with red or brown disposal.

c. Non-hazardous waste (e.g., packaging): Black bin – general waste.

Marking Criteria

a. 8–9 marks: All waste items correctly categorised and matched to the appropriate bin colour with a strong rationale.

b. 6–7 marks: Most responses correct with reasonable justification; one mismatch or partial rationale.

c. 4–5 marks: Some correct answers, but explanation lacks detail or contains some colour code confusion.

d. 1–3 marks: Limited understanding with only one or two correct answers; rationale may be weak.

3. Sample Answer for 3 Marks (with alternatives)

a. Prevents spread of infections and protects human health: Proper disposal of infectious waste reduces exposure to harmful pathogens.

b. Ensures environmental safety: Prevents contamination of water sources, soil, or air by hazardous waste.

Other valid reasons include

a. Legal compliance: Avoids penalties and meets national or hospital regulations.

b. Protects waste handlers and cleaners: Prevents accidental injuries or illness.

c. Improves public trust in health institutions: Maintains a clean and safe environment.

Marking Criteria

a. 3 marks: Two relevant, well-explained points.

b. 2 marks: Two points given, but one lacks clarity or is underdeveloped.

c. 1 mark: One relevant reason or two weakly explained ideas.

WEEK 4

Marking Scheme

1. Sample Answers (with other valid responses):

a. Overfilled sharps containers:

Risk of needle-stick injuries or cuts to workers and waste handlers, which can transmit bloodborne infections such as HIV, Hepatitis B, or C. Overfilled containers may also cause accidental spills affecting the public and environment.

b. Unlabelled chemical waste bottles:

Risk of accidental exposure to hazardous chemicals due to improper identification. This can lead to chemical burns, inhalation of toxic fumes, or environmental contamination if disposed of incorrectly.

c. Biohazardous waste bags not properly sealed:

Risk of leakage or spillage, which can expose workers, waste handlers, and the public to infectious agents. Surface contamination of the environment can occur.

d. PPE discarded in general waste:

Risk of spreading contamination since PPE may carry infectious material; improper disposal increases the risk of infection to waste workers and the community.

Marking criteria

a. 6 marks: Three specific risks clearly stated, each linked to one waste management practice, with explanations covering workers, public, and environmental risks.

b. 4–5 marks: Three risks stated with explanations, but some details or connections to all affected groups (workers, public, environment) are missing or unclear.

c. 2–3 marks: Two or three risks mentioned with partial or vague explanations.

d. 1 mark: Only one risk was clearly identified with limited explanation.

2. Sample Answers

a. Developing and enforcing proper waste disposal protocols to ensure sharps containers are not overfilled, and waste is segregated correctly.

b. Training laboratory staff on correct labelling and handling of chemical and biohazardous waste to prevent accidents.

c. Monitoring and auditing waste management practices to ensure compliance and improve safety.

d. Advising on the correct use and disposal of PPE to prevent contamination spread.

Marking criteria

a. 4 marks: Two clear responsibilities identified with explanations directly linked to the waste issues described.

b. 3 marks: Two responsibilities identified, but explanations are partially clear or not fully connected.

c. 2 marks: One responsibility explained well or two responsibilities mentioned with a weak explanation.

d. 1 mark: One responsibility vaguely identified.

3. Sample Answers

a. Proper planning involves identifying potential waste streams before experiments start, allowing for the correct preparation of disposal containers and PPE.

b. Risk assessments conducted during planning highlight hazards in waste production, enabling preventive measures to be put in place.

c. Planning ensures waste segregation, labelling, and storage procedures are established to reduce exposure and environmental contamination.

d. It promotes continuity of safety practices, ensuring protective measures during both experiments and waste handling.

e. Incorporates emergency preparedness, such as spill response plans, covering both experimental materials and waste.

Marking criteria

a. 5 marks: Comprehensive explanation showing a clear connection between planning and waste management with multiple relevant points.

b. 3–4 marks: Explanation includes main points but lacks some detail or examples.

c. 2 marks: Basic or partial explanation with limited connection between planning and waste management.

d. 1 mark: Vague or minimal understanding demonstrated.

Additional Reading

QR Code 5 Lab safety

QR Code 6 Safe Lab equipment use

QR Code 7 Ghana's first medical waste

QR Code 8 Waste categories and treatment

QR Code 9 The Biosafety Officer

QR Code 10 Development of lab Safety Programme

Sample Laboratory Risk Assessment Form

Basic Information
Date: _____
Assessor Name: _____
Laboratory/Room: _____
Procedure/Experiment: _____

1. Hazard identification

Hazard category	Present? (Y/N)	Description	Potential consequences
Chemical			
Biological			
Physical			
Electrical			
Mechanical			
Other			

2. Risk evaluation

Likelihood Scale: 1= Never 2= Sometimes 3= Always

Severity Scale: 1= Low, 2= Moderate, 3=High

Identified hazard	Likelihood (1-3)	Severity (1-3)	Risk rating (L×S)	Risk level (Low/Moderate/High)

Risk Level:
1. Low Risk (1-3): Acceptable
2. Medium Risk (4-6): Needs attention
3. High Risk (7-9): Immediate action required

3. Control measures

Hazard	Existing controls	Additional controls needed	Person responsible	Completion date

Required PPE

- Laboratory coat
- Safety glasses/goggles
- Gloves
- Respiratory protection (Type: _____)
- Other: _____

Waste disposal method(s):

- Yellow bins/bags (infectious waste)
- Yellow puncture-resistant bins (contaminated sharps/needles)
- Red bins/bags (pathological/ highly infectious waste)
- Brown bins/bags (chemical waste, expired reagents)
- Black bins/bags (general non-hazardous waste)

APPROVAL

Is it safe to proceed after implementing controls? □ Yes □ No

Assessor's signature: _____ Date: _____

Supervisor's signature: _____ Date: _____

SECTION 3: DIGESTION, ENERGY PRODUCTION & USE

Strand: Human Body System

Sub-Strand 1: Anatomy and Physiology

Learning Outcome: *Enzymes are the driving force behind digestion, breaking down complex food molecules into simpler forms the body can absorb, while the cardiovascular and respiratory systems work in tandem to deliver essential nutrients, water, and oxygen to every cell in the body.*

Content Standard: *Demonstrate an understanding of the interconnectedness of the body systems in energy generation and use (digestive, circulatory, and musculoskeletal systems).*

INTRODUCTION AND SECTION SUMMARY

The human body functions as a connected system where different parts work together to make, move, and use energy to keep us alive and healthy. Biomedical science students need to understand how enzymes help break down food, and how the heart, blood vessels, and lungs move nutrients and oxygen to body tissues. This section helps students learn how the digestive, circulatory, and muscular systems work together to produce energy. The main goal is for students to explain how enzymes support digestion and how nutrients and oxygen are transported to where they are needed for energy. Students will also learn what happens when these systems do not work properly and how this can lead to health problems that need medical care.

The weeks covered by the section are:

***Week 5**: Explain what enzymes are and their role in the digestive system.*

***Week 6**: Explain the transport of oxygen, food, and water to all cells in the body through the connection between the respiratory and cardiovascular systems.*

***Week 7**: Describe how the interconnectedness of the body systems aids in energy generation.*

***Week 8**: Demonstrate an understanding of how joints and muscles use energy to contribute to the movement of the human body.*

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teachers use inclusive strategies that combine discussion, practical activities, collaborative learning, and digital resources to engage all learners. Instruction begins by activating learners' prior knowledge of digestion and chemical reactions and identifying common misconceptions about enzymes. Through demonstrations and guided discussions, learners explore enzymes as biological catalysts and distinguish them from inorganic catalysts. Practical activities are used to investigate factors affecting enzyme action and enzyme specificity through the lock-and-key model. Learners relate enzyme activity to familiar examples such as digestion, fruit ripening, and the use of pawpaw or pineapple to tenderise meat.

ASSESSMENT SUMMARY

To assess learners' understanding of complex biological systems and enzyme functions, DOK Level 4 assessment strategies are recommended. These assessments focus on learners' ability to critically analyse and synthesise detailed concepts across diverse contexts, including enzyme activity and dysfunction in various populations. Learners are expected to design and evaluate experiments using practical materials, and explore the integrated roles of the respiratory, circulatory, musculoskeletal, nervous, and energy systems during physical activity and health. They interpret real-world data on nutrition and physiology to propose optimised solutions, predict system responses to exercise and failure, and explain the biochemical and anatomical processes. Through case studies, data analysis, experiments, and presentations, learners are challenged to think deeply about the interconnectedness of body systems and apply their knowledge to authentic scenarios involving health and physical performance.

Summary of the assessment used against the indicators

Indicators	**DOK Level**	**Assessment strategy and/or mode**
Explain what enzymes are and their role in the digestive system.	4	*Scenario-based individual homework*
Explain the transport of oxygen, food, and water to all cells in the body through the connection between the respiratory and cardiovascular systems.	4	*Individual class work*
Describe how the interconnectedness of the body systems aid in energy generation.	4	*Group design project*
Demonstrate an understanding of how joints and muscles use energy to contribute to movement of the human body.	4	*Group research project*

WEEK 5

Learning Indicator: *Explain what enzymes are and their role in the digestive system*

Recap Weeks

Year 1	**Week 7**: Explore the structure, functions, and parts of the major human body systems involved in communication, power, movement, protection, and homeostasis. **Week 8**: Explain the interconnections between the human body systems and how these systems work together to maintain health and homeostasis.
Year 2	**Week 8**: Determine how communication works in the body and its effects.

FOCAL AREA 1: WHAT ARE ENZYMES?

Introduce enzymes as biological catalysts

Enzymes are specialised proteins that act as biological catalysts in living organisms; that is, they increase the rate of chemical reactions (breakdown of substances) without being consumed in the process. Without enzymes, most biochemical reactions would occur too slowly to support life. For example, the breakdown of food by the digestive system would take a long time, depriving the body of energy.

An enzyme (Shown in **Figure 9**) has a special region called the active site where specific molecules called substrates bind. This active site is specific to one type of substrate. As illustrated in Figure 9, "substrate A" provides a perfect fit to the active site while "substrates B" and "substrate C" do not.

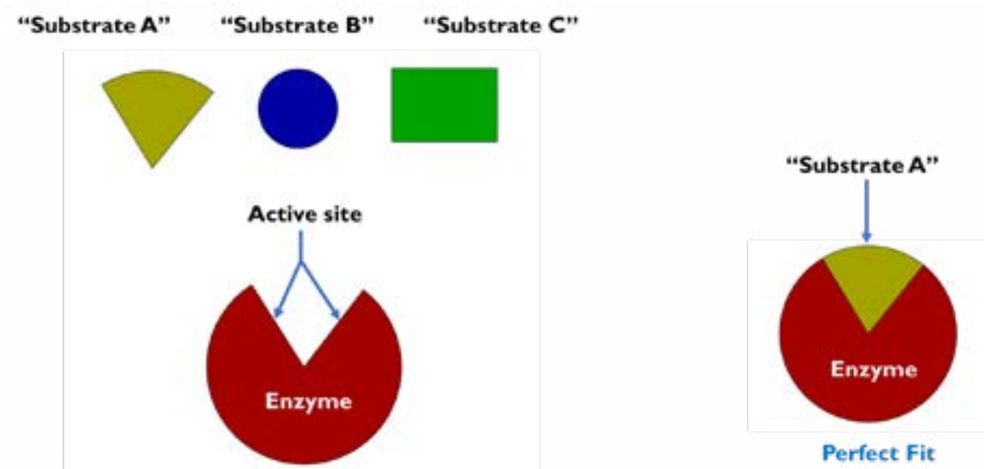


Figure 9: *Enzyme (showing active site) and substrate*

The actions of enzymes can be illustrated using the "lock and key" principle (See **Figure 10**). For an enzyme to facilitate the breakdown of substrates, the substrate must first fit perfectly into the enzyme's active site, like a key into its specific lock. This specific interaction ensures that substrate molecules are oriented, making it easier for bonds to break during the reaction to form the products.

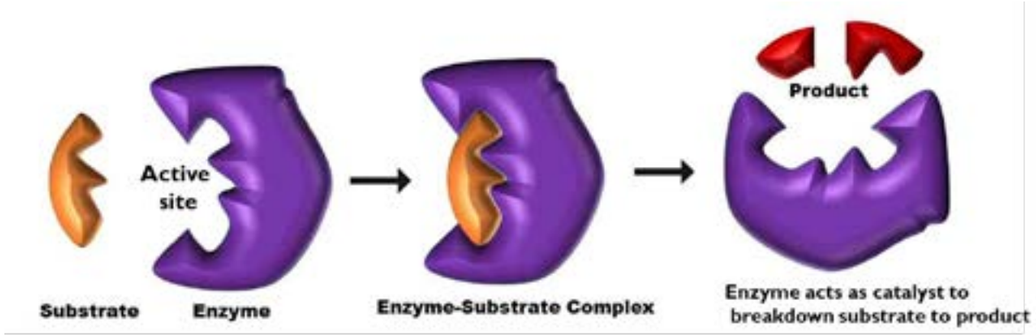


Figure 10: *The lock and key model of enzyme action*

Enzymes have the following characteristics:

1. Highly specific in their action, typically working on only one type of substrate.
2. Remain unchanged after the reaction and can be reused multiple times.
3. Work most effectively under optimal conditions of temperature and pH.
4. They can increase reaction rates by factors of millions or even billions.

Factors influencing enzyme activities

Several factors influence enzyme activity. These include the following:

Temperature: Enzymes perform optimally at a specific temperature; in the human body, this is approximately 37°C. At lower temperatures, molecular activity slows, reducing the frequency with which enzymes encounter their substrates and causing reaction rates to drop. On the other end of the spectrum, excessive heat poses a more serious threat: it destabilizes the enzyme's three-dimensional structure, a process known as denaturation. Once an enzyme loses its precise shape, it can no longer bind effectively to its substrate and becomes non-functional. This is precisely why severely high fevers are medically dangerous; a significant rise in body temperature risks denaturing critical enzymes, which can cascade into the breakdown of vital biochemical processes and ultimately endanger life.

1. **pH**: Each enzyme works best within a specific pH range. For example, pepsin, a digestive enzyme in the stomach, functions most effectively in a highly acidic environment with a pH around 1.5 to 2.0. In contrast, pancreatic enzymes like trypsin and lipase work best in the alkaline conditions of the small intestine, typically between pH 7.5 and 8.5. If the pH moves outside an enzyme's optimal range, its activity can drop sharply. For instance, antacids, which reduce stomach acidity, can interfere with protein digestion by making the stomach less acidic. This shift in pH reduces pepsin's effectiveness, since it needs a strongly acidic environment to function properly.
2. **Substrate concentration**: As the concentration of substrate increases, the rate of the enzymatic reaction also increases, up to a certain point. Beyond this saturation point, all active sites on the enzyme molecules are occupied, and the reaction rate plateaus, regardless of further increases in substrate concentration.
3. **Enzyme concentration**: Increasing the concentration of enzymes generally enhances the reaction rate, as more enzyme molecules are available to interact with the substrate simultaneously, if the substrate is not limiting.

4. **Inhibitors**: Certain substances, known as enzyme inhibitors, can reduce enzyme activity by binding to the enzyme and either blocking the active site or altering its shape. This interference can be temporary or permanent, depending on the type of inhibitor, and can significantly affect the reaction rate.

Explain how digestion involves breaking down large food molecules into smaller, absorbable units

Digestion is the process of breaking down complex food molecules into simpler, absorbable units that the body can use for energy, growth, and repair. This process includes both mechanical and chemical digestion. Mechanical digestion refers to the physical breakdown of food into smaller pieces, such as chewing in the mouth and churning in the stomach. Chemical digestion relies on enzymes to break down large, complex food molecules into smaller, soluble components that the body can absorb and utilize.

Digestion begins in the mouth, where food is mechanically broken down by chewing. At the same time, salivary amylase starts the chemical digestion of carbohydrates. The chewed food then travels down the oesophagus to the stomach, where it is further mixed and broken down. In the stomach, gastric juices and enzymes such as pepsin continue the digestion, especially of proteins.

From the stomach, partially digested food moves into the small intestine, where chemical digestion takes place. Here, enzymes from the pancreas and intestinal lining work together to complete the breakdown of carbohydrates, proteins, and fats. This is also where nutrients are absorbed through the intestinal wall into the bloodstream for use by the body.

Any material that cannot be digested continues into the large intestine, where water is absorbed, and the remaining waste is formed into faeces, which is eventually eliminated.

Figure 11 shows the main organs of the digestive system and the specific parts where each enzyme is active. This visual guide explains the process of digestion as a continuous, organised process that ensures the body receives the nutrients it needs while removing waste.

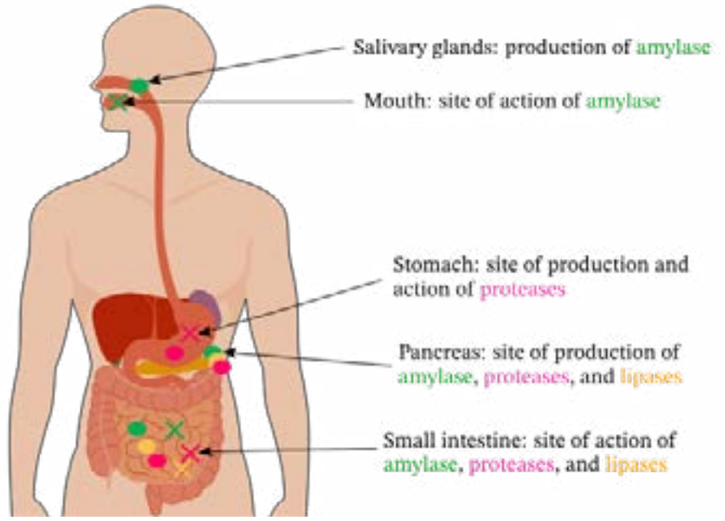


Figure 11: *A labelled diagram of the human digestive system showing the organs and locations where enzymes act.*

FOCAL AREA 2: ENZYMES IN ACTION

Examples of digestive enzymes and the food molecules they break down

Figure 12 presents a detailed infographic that matches different types of food with the specific enzymes responsible for breaking them down, along with the end products produced during digestion. It clearly illustrates the principle of enzyme–substrate specificity, showing that each enzyme is specially adapted to act on a particular nutrient such as a carbohydrate, protein, or fat.

For example, the diagram shows that:

1. Carbohydrates such as starch are broken down by enzymes such as amylase, which convert them into simple sugars like glucose.
2. Proteins are acted on by enzymes, including pepsin and trypsin, which break them down into smaller peptides and eventually into amino acids.
3. Fats (lipids) are digested by lipase, producing fatty acids and glycerol.

These final products of digestion (that is, sugars, amino acids, and fatty acids) are small enough to pass through the walls of the small intestine and enter the bloodstream. In contrast, the larger, complex molecules found in undigested food cannot be absorbed. This is why enzymatic breakdown is essential: It transforms large, insoluble food molecules into small, soluble forms that the body can absorb and use for energy, growth, and repair.

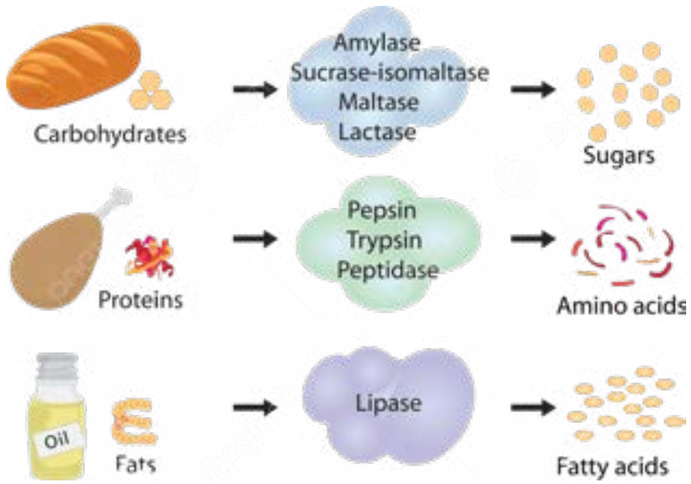


Figure 12: *Infographic showing different food types, the enzymes that act on them, and their resulting end products.*

Discuss how different enzymes target specific food components like carbohydrates, proteins, and fats

One of the most important features of enzymes in digestion is specificity, which refers to their ability to act only on a particular type of nutrient, such as carbohydrates, proteins, or fats. This depends on the unique shape of the active site and optimal conditions of temperature and pH. For example, the enzyme amylase is specific to carbohydrates like starch. Protein and fat

molecules have different structures that do not fit the active site of amylase, so they cannot be broken down by this enzyme into amino acids or fatty acids (See **Figure 13**). This precise matching ensures that enzymes act only on their intended targets and do not interfere with other substances or processes in the body. Such specificity makes digestion both efficient and well-controlled.

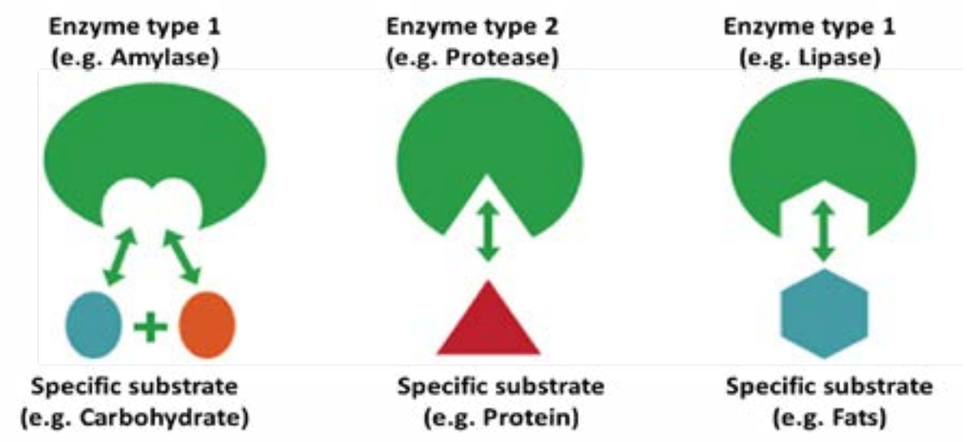


Figure 13: *Illustration of enzyme specificity based on active site fit.*

Here is how different enzymes target specific nutrients, focusing on how the active site determines specificity:

1. **Amylase**: This is an enzyme that specifically acts on carbohydrates. The active site of amylase is shaped in such a way that it fits exactly into the bonds between these carbohydrate units. This precise structural fit allows the enzyme to bind to the carbohydrate molecule and catalyse its breakdown into smaller units. The process begins in the mouth, where the pH level creates ideal conditions for salivary amylase to be secreted and begin its work. It continues in the small intestine, where pancreatic amylase is also secreted and active. The final product is glucose, a simple sugar that can be absorbed into the bloodstream and used for energy.
2. **Protease**: Proteases are enzymes that catalyse the breakdown of proteins into smaller peptides and amino acids. The active site of a protease is specifically shaped to recognise and bind particular peptide bonds within protein molecules. When a protein substrate enters the active site, the enzyme forms an enzyme–substrate complex and catalyses the cleavage of these bonds. Pepsin, a protease secreted in the stomach, begins protein digestion under highly acidic conditions and functions most effectively at a pH of approximately 1.5–2.5. Trypsin, produced by the pancreas and released into the small intestine, continues protein digestion under slightly alkaline conditions and functions optimally at a pH of approximately 7.0–8.5. These examples demonstrate that enzyme activity depends on specific environmental conditions, particularly pH and temperature, which influence the shape and function of the enzyme's active site.
3. **Lipase**: This is secreted by the pancreas and functions in the small intestine, where it plays a vital role in fat digestion. The active site of lipase is shaped to fit the bonds of fat molecules, allowing their breakdown into fatty acids and glycerol. However, because fats are not water-soluble, they are broken into smaller droplets (emulsified). This emulsification is

carried out by bile, a substance produced by the liver and stored in the gallbladder. Once the fat is emulsified, lipase can bind to the molecules at its active site for digestion.

Effects of enzyme deficiency in the body

When specific digestive enzymes are deficient or absent, it can lead to various digestive disorders and nutritional problems. These deficiencies can be congenital (present from birth) or acquired in life. The effects of some enzyme deficiencies in the body are as follows.

1. **Lactase deficiency**: One of the most common enzyme deficiencies worldwide, affecting approximately 65% of the global population. Lactase breaks down lactose (milk sugar) into glucose and galactose. When lactase is deficient, undigested lactose passes into the large intestine, where bacteria ferment it, producing gases and acids. This leads to symptoms such as bloating, abdominal pain, flatulence, and diarrhoea after consuming dairy products, a condition known as lactose intolerance.
2. **Pancreatic enzyme deficiencies**: Conditions like cystic fibrosis, chronic pancreatitis, or pancreatic cancer can reduce the production of pancreatic enzymes (lipases, proteases, and amylases). This leads to poor digestion and absorption of nutrients despite adequate food intake, resulting in symptoms such as:
    a. Steatorrhea (fatty, foul-smelling stools) due to lipase deficiency
    b. Weight loss despite normal food intake
    c. Deficiencies in fat-soluble vitamins (such as vitamins A, D, E, and K)
    d. Abdominal discomfort and bloating
3. **Sucrase-isomaltase deficiency**: This is a less common condition that involves a deficiency in the enzymes that break down sucrose and maltose. Affected individuals experience symptoms like lactose intolerance when consuming foods containing sucrose and maltose.

Learning Tasks

1. Explain how enzymes act as biological catalysts that speed up the breakdown of food during digestion.
2. Describe how enzymes help turn large food molecules like starch, proteins, and fats into smaller nutrients the body can absorb.
3. Identify at least four major digestive enzymes, including food or macromolecule they break down, where they work, and their function.
4. Show how the digestive system works with other body systems to keep the body balanced and healthy (homeostasis).

Pedagogical Exemplar

Initiating talk/ sign for learning: Learners discuss what enzymes are and the role of digestive enzymes in breaking down food for absorption. This introductory talk allows learners to activate prior knowledge and use their own words to describe the process of digestion. Prompt learners with guiding questions such as, “Why does food need to be broken down?” or “What happens if enzymes are missing?” These discussions help set a clear conceptual baseline and prepare learners for deeper inquiry into how enzymes function in the human body.

Experiential learning: Working in mixed-ability groups, use a set of lock and key or spanner and bolt analogies to explain why only certain keys or spanners can unlock a given lock or bolt. Learners handle the tools, test combinations, and observe that only the correct match works. This mirrors how enzymes act on specific substrates. The class then brainstorms how this analogy models enzyme-substrate specificity, with learners drawing direct comparisons to biological examples such as protease acting only on proteins. This engaging, hands-on activity fosters collaborative learning, accommodates a range of learning styles, and transforms an otherwise abstract biochemical concept into a tangible, memorable experience.

Managing talk/ sign for learning: This engaging, hands-on activity fosters collaborative learning, accommodates a range of learning styles, and transforms an otherwise abstract biochemical concept into a tangible, memorable experience. This guided discussion helps bridge biological content with everyday applications. Encourage learners to compare natural digestive processes with industrial uses of enzymes, fostering scientific thinking beyond the classroom. By examining how biological concepts are used in real-world products, learners develop a stronger understanding of enzyme function and engage in meaningful communication that supports both conceptual and applied science literacy.

Key Assessment: Scenario-based Individual Homework

Level 4 (Extended thinking): You are helping to create a learning guide for senior high school students about enzymes and how they help in digestion. Your job is to clearly explain what enzymes do, how they work in different parts of the body, what happens if they are missing, and how their activity can be tested through an experiment.

1. How do enzymes help break down food in the body, and why do they only work well in certain parts of the digestive system? (5 marks)
2. What happens when the body does not make enough of a digestive enzyme, and how can this be managed? (5 marks)
3. Design a simple experiment to test how a selected factor (temperature or pH) affects enzyme activity. (10 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 ***scenario-based individual 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 6

Learning Indicator: *Explain the transport of oxygen, food, and water to all cells in the body through the connection between the respiratory and cardiovascular systems*

Recap Weeks

Year 1	**Week 7**: Explore the structure, functions, and parts of the major human body systems. **Week 8**: Describe the interconnections between the human body systems and how these systems work together to maintain health and homeostasis. **Week 9**: Evaluate how the interconnections and interactions of multiple body systems are necessary for life.

FOCAL AREA(S) 1: THE RESPIRATORY SYSTEM – DELIVERING OXYGEN

Discuss the role the respiratory system plays in taking in oxygen and releasing carbon dioxide.

The respiratory system is a coordinated network of specialised organs and tissues responsible for gaseous exchange. Its main role is to deliver oxygen from the environment into the body and remove carbon dioxide from the cells. The respiratory system (see **Figure 14**) includes key anatomical structures (such as the nasal cavity, sinuses, pharynx, larynx, trachea, bronchi, bronchioles, and alveoli) that guide the movement of air into and out of the lungs.

Air first enters the body through the nasal cavity, which serves as the primary entry point. It also contains the paranasal sinuses, which are air-filled spaces in the skull that help warm, moisten, and filter incoming air. From the nasal cavity, air flows into the pharynx (throat), a passage shared with the digestive system. It then moves into the larynx (voice box), which contains the vocal cords. The air continues down the trachea (windpipe), the main airway. This then branches into two bronchi (singular: bronchus), each leading into a lung. The bronchi further break into tiny tubules called bronchioles which end up in the airways known as alveoli. The alveoli are modified for gaseous exchange.

Within the lungs, the bronchi divide into narrower bronchioles, which eventually terminate in alveoli (tiny, balloon-like air sacs). Gaseous exchange, that is, absorption of oxygen into the bloodstream and release of carbon dioxide, occurs in the alveoli.

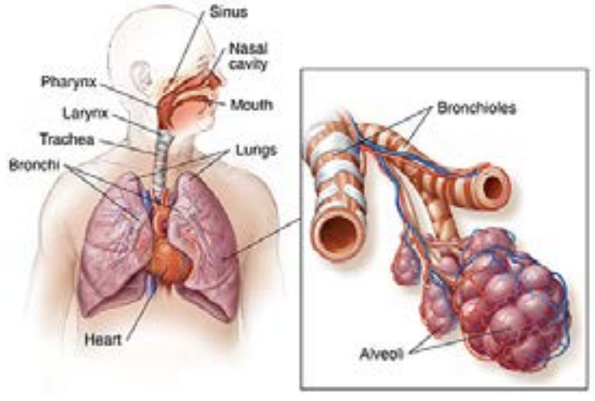


Figure. 14: *The respiratory system*

Gaseous exchange in the lungs depends on the continuous movement of air in and out of the body, a process known as breathing. Breathing consists of two key phases (see **Figure 15**): inhalation (inspiration) and exhalation (expiration). Each phase involves specific muscular actions that change the volume of the thoracic (chest) cavity. This creates a pressure difference that drives airflow.

Inhalation (Inspiration): This is an active process that draws air into the lungs. It is primarily driven by muscle contraction and involves the following steps:

1. The diaphragm contracts and moves downward, flattening from its relaxed dome shape.
2. The thoracic cavity expands, causing an increase in its internal volume.
3. The pressure inside the lungs (intrapulmonary pressure) falls below atmospheric pressure, due to the increased volume.
4. As a result of the pressure difference between the lungs and the external environment, air is drawn into the lungs.

Exhalation (Expiration): This is usually a passive process. It involves the following steps:

1. The diaphragm relaxes, returning to its original dome shape.
2. The thoracic cavity contracts, causing a decrease in its internal volume.
3. The pressure inside the lungs increases above the atmospheric pressure, due to the decreased volume.
4. As a result of the pressure difference between the lungs and the external environment, air (carbon dioxide) is expelled from the lungs.

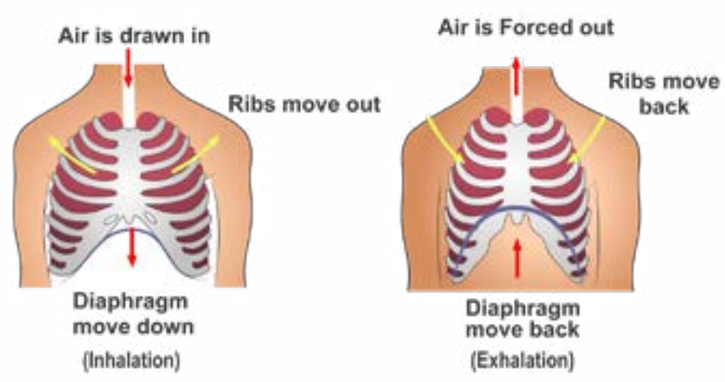


Figure 15: *Comparison of Inhalation and Exhalation*

Explanation of how oxygen enters the bloodstream through the lungs.

Gaseous exchange between the air in the lungs and the blood takes place across the thin walls of the alveoli and the surrounding capillaries. Several specialised structural features ensure that this process is both rapid and efficient. The following are some examples of these features.

1. The alveolar walls are extremely thin, composed of a single layer of flat cells. This single layer allows for rapid gaseous exchange. The cells are flat to increase the surface area for efficient gaseous exchange.

2. The inner surface of each alveolus is moist, enabling oxygen to dissolve before it enters the bloodstream.
3. Surrounding the alveoli is a dense network of capillaries, which brings blood low in oxygen and rich in carbon dioxide (deoxygenated blood) close to the alveolar surface for gaseous exchange.
4. The alveoli have a large surface area for optimum gaseous exchange. The surface area of the alveoli is about 70 to 80 square metres (about half the size of a tennis court) in an adult (see **Figure 16**).

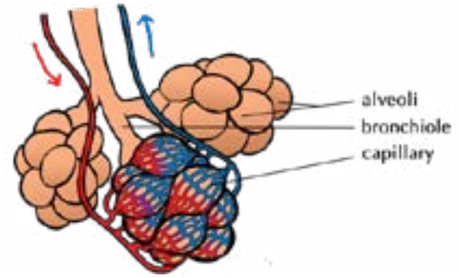


Figure 16: *Structure of an alveolus and surrounding capillaries*

The gaseous exchange occurs by diffusion, the movement of gases from regions of higher concentration to regions of lower concentration. The oxygen concentration in the alveoli is significantly higher than in the blood. Consequently, oxygen diffuses from the alveoli into the blood. At the same time, carbon dioxide concentration is higher in the blood than in the alveoli. Hence, it diffuses out of the blood to be exhaled (as illustrated in **Figure 17**). Once oxygen enters the bloodstream, it binds to a specialised protein called haemoglobin within red blood cells. Each haemoglobin molecule can carry up to four oxygen molecules. This method of transport is highly efficient: without haemoglobin, only about 1.5% of oxygen would dissolve directly in the blood, which would be insufficient to meet the body's energy demands. Haemoglobin is therefore essential for the transport of oxygen for respiration and physical activities (see **Figure 17**).

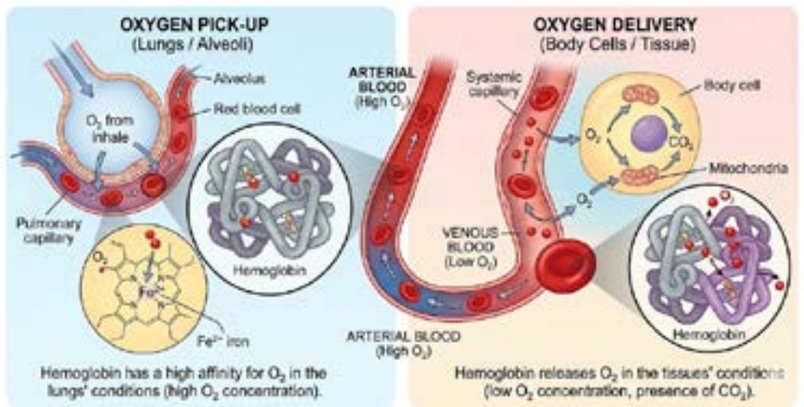


Figure 17: *Haemoglobin as a means of oxygen transport*

Teachers can use real-life examples, such as feeling tired or shortness of breath during exercise, to explain the critical role of oxygen transport in maintaining health and energy levels.

FOCAL AREA(S) 2: THE CIRCULATORY NETWORK – DISTRIBUTING ESSENTIALS

Introduction to the cardiovascular system

The cardiovascular system, also called the circulatory system, acts as the body's transport network. It transports important substances such as oxygen, nutrients, hormones, and water to cells throughout the body. It also helps remove waste products like carbon dioxide and urea from the body. The system is made up of three main components: the heart, the blood vessels, and the blood itself. The heart is a strong muscular organ that pumps, keeping the blood moving around the body. The heart has four chambers. The upper chambers are called atria, and the lower chambers are called ventricles. The right atrium receives blood from the body and sends it to the right ventricle, which pumps it to the lungs through the pulmonary artery for gaseous exchange. Oxygen-rich blood returns to the left atrium and flows into the left ventricle, which pumps it through the aorta and to the rest of the body. The flow of blood is divided into two: pulmonary and systemic circulations (See **Figure 18**), which illustrates the interconnectedness between the respiratory and circulatory systems. The pulmonary circulation carries blood between the heart and lungs. The systemic circulation carries blood between the heart and the rest of the body.

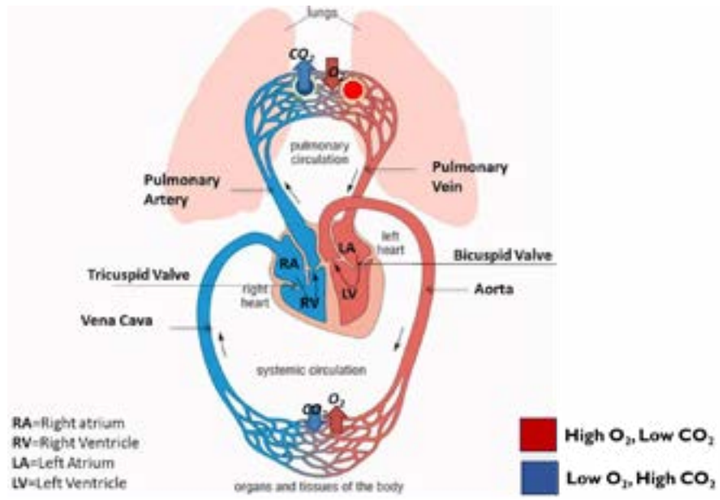


Figure 18: *Pulmonary and systemic circulation*

Blood vessels as highways

Blood vessels (arteries, veins, and capillaries) are the tubes that carry blood in different directions.

1. **Arteries**: Carry oxygen-rich blood away from the heart to the body's tissues. All arteries carry oxygenated blood away from the heart except the pulmonary artery, which carries deoxygenated blood away from the heart. They have thick walls to transport blood at high pressure.
2. **Veins**: Return deoxygenated blood to the heart. All veins carry deoxygenated blood to the heart except the pulmonary vein, which carries oxygenated blood to the heart.Veins contain

valves that act as one-way gates, ensuring blood flows in the correct direction and preventing it from flowing backward.

3. **Capillaries**: These are the smallest blood vessels that connect arteries and veins. Capillaries are the site for gaseous exchange of oxygen, nutrients, and waste between the blood and body tissues. They have very thin walls made of a single layer of cells, which allows substances to pass easily in and out of the blood. In the capillaries, oxygen and nutrients diffuse from the blood into nearby cells, while carbon dioxide and waste products move from the cells into the blood for excretion. See Figure 19 for illustration.

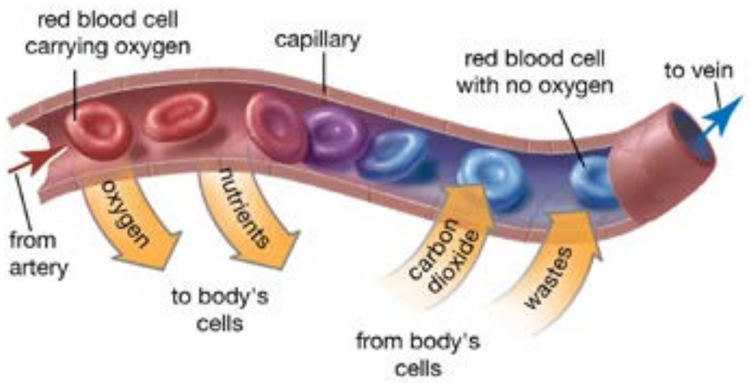


Figure 19: *Capillary exchange showing movement of substances*

The cardiovascular system is a means of transport in the body

The cardiovascular system acts as the body's transportation network, delivering essential supplies and removing waste. This system ensures every cell gets what it needs to function, much like a delivery service keeping a city supplied.

1. **Transportation of gases**: Oxygen is transported by the circulatory system through its binding to haemoglobin in red blood cells. The oxygenated blood travels from the lungs through the pulmonary vein to the heart, after which it is pumped throughout the body. As cells consume oxygen during cellular respiration, they generate carbon dioxide as a by-product, which is then carried back to the lungs via the pulmonary artery for exhalation.
2. **Transportation of nutrients**: Nutrients such as glucose, amino acids, and fatty acids are absorbed from the small intestine. Water-soluble nutrients such as glucose, amino acids, and minerals enter the hepatic portal vein to the liver for processing. Processed water-soluble nutrients leave the liver through the hepatic veins and drain directly into the inferior vena cava and into the heart. Fat-soluble nutrients (fatty acids, glycerol, and vitamins A, D, E, and K) are absorbed into specialised lymphatic vessels, which eventually drain into the bloodstream near the heart, bypassing initial processing by the liver.
3. **Transportation of water**: When you drink water, it passes through your mouth, oesophagus, and into the stomach. Water absorption primarily occurs in the small intestine, with some additional absorption occurring in the large intestine. It is absorbed across the intestinal lining and enters the bloodstream through the capillaries. Once absorbed into the bloodstream, water becomes a major component of blood plasma, which is transported throughout the entire body via arteries, arterioles, and to the vast network of capillaries.

Learning Tasks

1. Describe how the respiratory system brings oxygen into the body and removes carbon dioxide through breathing.
2. Explain how oxygen moves from the lungs into the blood, and how carbon dioxide moves from the blood into the lungs.
3. Describe how the circulatory system transports oxygen, nutrients, water, and removes waste products throughout the body.

Pedagogical Exemplars

Initiating talk/ sign for learning: Begin by activating learners' prior knowledge through a think-pair-share activity. Ask learners why humans cannot survive without oxygen, food, and water, and what happens to these substances after they enter the body. Learners discuss their ideas with a partner and then share with the class. Use their responses to introduce the concept that body systems work together to transport essential substances to all cells.

Guide learners to identify the roles of the respiratory system in obtaining oxygen and the cardiovascular system in transporting oxygen, nutrients, and water throughout the body. Address misconceptions and encourage learners to explain their reasoning using examples from everyday life.

Digital Learning: Learners watch a short animation on the circulatory system and the transport of oxygen and nutrients through the body (e.g., an Amoeba Sisters circulatory system animation or a similar educational resource). While watching, learners complete a guided observation sheet that prompts them to identify:

- How oxygen enters the blood in the lungs.
- How nutrients and water enter the bloodstream.
- The role of the heart in circulation.
- How body cells receive essential substances.

Following the video, learners discuss their observations in small groups and compare their explanations.

To deepen understanding, learners use an interactive simulation (e.g., PhET or a similar browser-based simulation) to investigate how changes in heart rate, blood pressure, or blood vessel diameter influence blood flow. Learners record observations and discuss how these changes affect the transport of oxygen, food, and water throughout the body.

Activity-Based Learning: Learners work in mixed-ability groups to construct a flow diagram, concept map, or labelled illustration showing the pathway of oxygen from the lungs to body cells and the pathway of nutrients and water from the digestive system into the bloodstream. Groups explain how the respiratory and cardiovascular systems work together to ensure the delivery of these substances.

Provide each group with a three-dimensional heart model, chart, or digital model. Learners identify the chambers of the heart, major blood vessels, and valves, and trace the pathway of blood through the heart and body. Encourage learners to explain how the structure of the heart supports its function as a pump.

Learners then measure and compare their pulse rates before and after light physical activity. Using the data collected, groups discuss why heart rate changes during exercise and how the cardiovascular and respiratory systems respond to increased demand for oxygen and nutrients.

Collaborative Learning and Reflection: Each group presents its model, diagram, or findings to the class. Learners ask questions, provide feedback, and compare different explanations. Encourage shy learners to contribute by assigning specific roles such as presenter, recorder, timekeeper, or discussion leader.

Conclude the lesson with a whole-class reflection in which learners explain how oxygen, food, and water are transported throughout the body and why the respiratory and cardiovascular systems must function together to maintain life.

Differentiation and Support: Provide visual aids, simplified diagrams, vocabulary cards, and guided questions for learners who require additional support. Challenge higher-achieving learners to predict how diseases or injuries affecting the heart, lungs, or blood vessels might disrupt the transport of oxygen, nutrients, and water. Ensure that all learners participate actively through structured group roles and scaffolded questioning techniques.

Key Assessment: Mid-Semester Examination

Case Study

Level 4 (Extended thinking): You are a student researcher investigating how the body responds to physical activity. Your task is to explain in detail how the respiratory and circulatory systems work together to supply oxygen, remove carbon dioxide, and deliver nutrients and water to body cells. You will also describe how the body adapts during exercise and what might happen if either system fails.

Your report should answer these four questions:

1. Explain the pathway of air and blood through the respiratory and circulatory systems, describing the roles of key structures in oxygen delivery and carbon dioxide removal.
2. Describe how oxygen and nutrients are transported to body cells and how waste products are removed.
3. Analyse how the respiratory and circulatory systems respond and adapt during physical activity.
4. Evaluate the potential consequences if either the respiratory or circulatory system fails during physical activity.



Hint

*Conduct **a mid-semester examination**. It should cover the contents taught from Week 1 to 5. Refer to the **Table of Specifications and Structure of the Paper**. Learners' papers should be marked immediately, and scores should be entered into the SAP.*

Structure

Section A: 25 Multiple-choice questions

Section B: 2 Essay Questions

Table of specifications for item construction for sections A and B

Week	Learning Indicator	Types of questions	DoK Levels				Total
			1	2	3	4	
1	Explain common practices that could result in malpractice, liability, and/or negligence in the field of biomedical science Describe the purpose of informed consent from the patient and healthcare provider perspectives Identify and explain personal and long-term consequences of unethical or illegal behaviour in the workplace	MCQs	2	2	-		4
		ESSAY	-	-	-		-
2	Undertake proper planning of experiments to avoid accidents	MCQs	2	2	2		6
		ESSAY	-	-	1		1
3	Identify the correct waste stream and demonstrate proper disposal of hazardous waste in the laboratory	MCQs	-	2	1		3
		ESSAY	-	-	-		
4	Identify and describe the role of biosafety professionals in biomedical research laboratories	MCQs	3	2	1		6
		ESSAY					
5	Explain what enzymes are and their role in the digestive 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

- 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 7

Learning Indicator: *Describe how the interconnectedness of the body systems aids in energy generation*

Recap Weeks

Year 1	**Week 7**: Explore the structure, functions, and parts of the major human body systems. **Week 8**: Describe the interconnections between the human body systems and how these systems work together to maintain health and homeostasis. **Week 9**: Evaluate how the interconnections and interactions of multiple body systems are necessary for life.

FOCAL AREA 1: DIGESTION AS THE FUEL SOURCE

Discuss the products of digestion as a source of fuel for the body

Once digestion is complete, the body absorbs small, usable molecules such as glucose, amino acids, fatty acids, and glycerol. These molecules act as essential sources of energy (fuel) to power cellular processes, support physical activity, and maintain internal balance.

1. **Glucose**: The most important immediate source of energy. It circulates in the blood and is delivered to cells throughout the body. Inside each cell, glucose is used in a process called cellular respiration to produce ATP (an energy source). ATP fuels muscle contraction, active transport, nerve impulses, and other essential body functions. Glucose is the preferred energy source because it is quick and efficient. When glucose levels are high, the excess is stored in the liver and muscles as glycogen, a reserve fuel that can quickly be converted back into glucose when energy is needed. Once glycogen stores are full, additional glucose is converted into fat.
2. **Fatty Acids and Glycerol**: These act as important energy sources, particularly when the body's energy demand increases or when glucose becomes limited. Fatty acids can be broken down slowly to produce a large amount of ATP, making them ideal for long-duration activities like walking or sleeping. Glycerol can be converted into glucose in the liver if needed. When not immediately used, fats are stored in adipose tissue, where they form the body's main long-term energy reserves. Fats are especially valuable during periods of fasting, prolonged exercise, or in between meals.
3. **Amino Acids**: These are primarily used for growth, repair, and maintenance of body tissues. However, when carbohydrate and fat supplies are low, such as during intense exercise or starvation, amino acids can be converted into glucose or used directly in cellular respiration to produce ATP. Although amino acids are not the body's first choice for energy, they provide an alternative fuel source during emergencies. Their use as fuel is carefully controlled, since relying on amino acids for energy can reduce the body's ability to build and maintain tissues.

FOCAL AREA 2: THE POWERHOUSE WITHIN – CELLULAR RESPIRATION

Introduction to the concept of cellular respiration

Cellular respiration is the biological mechanism by which the body extracts energy from food, powering everything from muscle movement and organ function to the maintenance of body temperature. This process occurs primarily within specialized structures inside cells called mitochondria, often referred to as the cell's "powerhouses." Within the mitochondria, chemical energy derived from food is converted into a usable form called adenosine triphosphate, or ATP, which serves as the primary fuel that cells rely on to carry out their various functions. Cellular respiration itself takes two distinct forms: aerobic and anaerobic respiration.

1. **Aerobic respiration**: A chemical process in which glucose (a sugar) reacts with oxygen to release energy, carbon dioxide, and water. Aerobic respiration uses oxygen to break down glucose, producing ATP. It requires both glucose and oxygen. The equation for aerobic respiration is given as:

   C6H12O6 + 6O2 6CO2 + 6H2O + Energy (ATP).

   Glucose + oxygen → Carbon dioxide + water + Energy (ATP)

   Inside the mitochondria, glucose reacts with oxygen to produce ATP. This process also creates byproducts, such as carbon dioxide and water. These are transported away from the cells by the bloodstream. The carbon dioxide is expelled during exhalation.

2. **Anaerobic respiration**: The process by which cells produce energy without using oxygen. It occurs in the cytoplasm and breaks down glucose to generate ATP. During intense physical activities, such as running or lifting weights, when muscles do not receive enough oxygen for aerobic respiration, the body switches to anaerobic respiration. Although anaerobic respiration produces much less ATP than aerobic respiration, it provides quick energy production when oxygen is limited. This process also creates lactic acid as a by-product. A build-up of lactic acid in the muscles can cause tiredness or a burning sensation. The equation for anaerobic respiration in humans is:

   $C6H12O6 \rightarrow 2C_3H_6O_3 +$ Energy (ATP)

   Glucose → Lactic acid + Small amount of energy (ATP)

   Figure 21 shows aerobic and anaerobic respiration in the body. In aerobic respiration, glucose and oxygen cross the cell membrane and enter the mitochondrion, where they are used to produce ATP, carbon dioxide, and water. In anaerobic respiration, which occurs when oxygen is limited, only glucose enters the cytoplasm and is converted into a smaller amount of ATP and lactic acid. **Table 3.1** summarises the sources and destinations of the key inputs and outputs for both types of respiration.

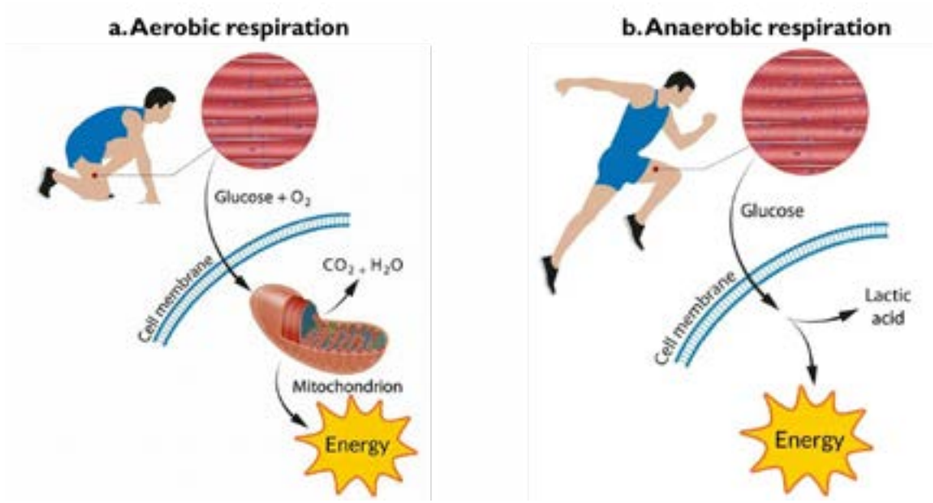


Figure 21: *aerobic and anaerobic respiration*

Table 3.1: Inputs and Outputs of Cellular Respiration

Input / Output	Source / Product	Aerobic respiration	Anaerobic respiration
Glucose	Carbohydrates in food	Absorbed in the small intestine and transported to cells	Same as aerobic: absorbed and transported to cells
Oxygen	Air (via lungs)	Taken in during breathing and delivered to cells	Not required
Energy (ATP)	Produced during respiration	A large amount is produced in mitochondria	A small amount is produced in the cytoplasm
Carbon Dioxide	Waste product	Produced and exhaled via the lungs	Not produced
Water	Waste product	Produced and used or excreted by the body	Not produced
Lactic Acid	Waste product	Not produced	Produced in muscles and can cause fatigue

FOCAL AREA 3: ENERGY ON DEMAND

Discuss briefly how the body uses ATP for various functions like muscle movement, organ function, and maintaining body temperature.

ATP is the energy that cells use to perform all their activities. It powers almost everything inside the body. Here are the main ways ATP is used in the body:

1. **Muscle contraction**: ATP provides the energy required for muscles to contract and relax. Every movement, whether walking, running, lifting a hand, or blinking, depends on muscles using ATP. It also powers involuntary muscles, such as the heart beating and the diaphragm, aiding breathing. These actions happen continuously and need a constant supply of ATP to continue.
2. **Organ function**: All organs need ATP to perform their specialised tasks. The brain uses ATP to send and receive nerve signals that enable thinking, feeling, and reacting. The kidneys rely on ATP to filter waste and regulate water and salt levels in the body. The liver uses energy to process nutrients, break down toxins, and produce essential chemicals. Without sufficient ATP, these organs cannot function properly.
3. **Temperature regulation**: ATP helps maintain body temperature. As ATP is produced during cellular respiration, a portion of the energy is released as heat, which plays a key role in maintaining the body's warmth, particularly in colder environments. For example, shivering causes muscles to contract rapidly, producing heat through ATP. Without this heat, internal body temperature could fall to dangerous levels.
4. **Movement of substances across cell membranes**: ATP is necessary for moving substances into and out of cells through active transport. Cells must absorb nutrients such as glucose, amino acids, and minerals, and eliminate waste products. This movement requires energy supplied by ATP. ATP is also vital for nerve signal transmission, for communication between the brain and other body parts. Without enough ATP, cells would struggle to take in necessary substances or remove waste.

Learning Tasks

1. Explain how the digestive, respiratory, and circulatory systems work together to provide energy for the body.
2. Describe how the digestive system breaks down food into nutrients the body can absorb.
3. Explain how cells use oxygen and glucose to make ATP through cellular respiration.
4. Identify three ways the body uses energy from ATP, such as muscle movement, organ function, and temperature control.

Pedagogical Exemplars

Activity-Based Learning: In mixed-ability groups, learners are given stethoscopes or shown how to locate a pulse using palpation techniques, such as pressing two fingers gently against the wrist or neck. Each group member takes turns measuring and recording their peers' resting heart rates, after which the group compares results and identifies any patterns or variations. This practical experience helps learners grasp that heart rate is not a fixed value, but it differs from person to person based on a range of internal and external influences**.**

Discussion-Based Learning: Learners then participate in a guided group discussion or teacher-facilitated brainstorming session, where they share their observations and begin investigating why heart function varies among individuals. The conversation encourages learners to consider contributing factors such as physical fitness, stress, age, emotional state, and recent activity levels. Broader biological concepts, including homeostasis, cardiovascular health, and the body's responses to environmental demands, may also be woven into the discussion. Through this collaborative exchange, learners strengthen their conceptual understanding of the heart's role in the body while developing their reasoning and communication abilities.

Key Assessment: Group Design Project

1. **Level 4 (Extended thinking)**: Maya, a 16-year-old student, is studying how her diet affects her energy levels for a school project. She kept track of her meals, physical activity, and energy levels for two weeks. She also measured her blood glucose levels before and after exercise and meals.

Table: Maya's Diet and Energy Levels

Day	Breakfast	Lunch	Dinner	Activity	Energy Level (1–10)
Mon	Skipped	White rice and stew	Fried plantain & beans	30 min walking	5
Wed	Oatmeal with fruit	Jollof rice & chicken	Vegetable soup & fish	45 min football	8
Fri	Sugary cereal	Meat pie & soda	Banku with okra soup	None	4 (afternoon crash)

Maya's glucose readings (mmol/L):

- After Monday diet: 3.8 before exercise
- After Wednesday diet: 4.7 before exercise
- After sugary drink: Spiked to 7.2, dropped to 3.5 within 2 hours

Use Maya's food diary and glucose data to answer the following:

1. Describe how simple and complex carbohydrates affect her energy levels.
   (3 marks)
2. Explain how the glucose from her meals is used in her body to release energy.
   (3 marks)
3. Suggest one reason why she felt a drop in energy after the sugary drink.
   (2 marks)
4. Based on her diary, which day shows the best balance for energy? Explain your answer. (2 marks)

2. **Level 4 (Extended thinking)**: A sports physiologist is studying how a young athlete's body turns food into energy during exercise. The focus is on how the digestive, circulatory, and respiratory systems work together to power the muscles.

1. Explain how the digestive, respiratory, and circulatory systems work together to get glucose and oxygen to the muscle cells where energy is made.
2. Create a flowchart or diagram showing how a slice of bread is turned into energy for muscle movement.
3. After 10 minutes of intense cycling, the athlete's oxygen levels drop, and lactic acid builds up.
   a. What process happens in the muscle cells when there is not enough oxygen?
   b. How is this process different from aerobic respiration?
   c. How does it affect the athlete's body and performance?

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 ***group design 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.

WEEK 8

Learning Indicator: *Demonstrate an understanding of how joints and muscles use energy to contribute to the movement of the human body*

Recap Weeks

Year 1	**Week 7**: Explore the structure, functions, and parts of the major human body systems. **Week 8**: Describe the interconnections between the human body systems and how these systems work together to maintain health and homeostasis. **Week 9**: Evaluate how the interconnections and interactions of multiple body systems are necessary for life.
Year 2	**Week 8:** Determine how communication works in the body and its effects.

FOCAL AREA 1: ROLE OF THE MUSCULOSKELETAL SYSTEM IN ENERGY GENERATION AND USE

Introduction of the musculoskeletal system

The musculoskeletal system (**Figure 22**) shows one of the complex systems in the human body, serving as the framework for physical movement and providing essential protection for vital organs. This integrated network consists of bones, muscles, tendons, ligaments, and joints that work in precise coordination to enable the diverse range of movements that characterise human activity.

1. **Skeletal component**: The adult human skeleton comprises 206 bones that vary considerably in size and shape, from the ossicles of the middle ear to the femur (thigh bone). Beyond merely providing structural support, the skeletal system serves several critical functions:

a. **Structural support**: The skeleton forms the rigid framework that maintains body shape and posture.

b. **Protection**: bones shield vital organs from external trauma (e.g., the cranium protects the brain, the ribcage safeguards the heart and lungs).

c. **Movement facilitation**: bones act as levers that, when acted upon by muscles, generate movement.

d. **Mineral storage**: Bones serve as the primary reservoir for essential minerals, particularly calcium and phosphorus.

e. **Blood cell production**: Red blood cells, white blood cells, and platelets are produced in the bone marrow of selected bones through the process of haematopoiesis.

2. **Muscular component**: The human body contains around 600 skeletal muscles, which together account for roughly 40 to 45 percent of total body weight. These specialised contractile tissues convert chemical energy into mechanical force, enabling movement. Key characteristics of skeletal muscles include:

a. **Contractility**: The ability to shorten and generate force

b. **Excitability**: The capacity to respond to stimulation, particularly from nerve impulses

c. **Extensibility**: The ability to stretch without damage
d. **Elasticity**: The ability to return to original length after stretching

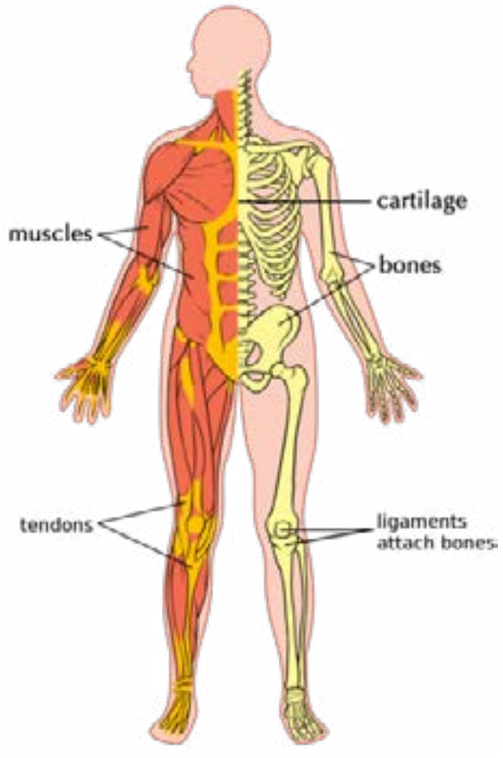


Figure 22: *The musculoskeletal system*

When explaining Figure 22, point out that bones and muscles are a team: bones provide the necessary structure but cannot move on their own, while muscles provide the power but need the skeleton to turn that power into actual movement.

The musculoskeletal system's functional capabilities extend far beyond simple movement. It enables precise manipulations (such as writing or playing musical instruments), powerful exertions (lifting heavy objects), sustained postural maintenance, and the complex, coordinated movements required for activities like walking, running, and dancing. This versatility stems from the system's remarkable architectural design, which combines rigid and flexible components in an optimally balanced arrangement.

Explain how muscles contract and relax using energy (ATP) to generate force and movement

Skeletal muscle tissue (**Figure 23**) has a highly organised, layered structure that is essential for generating movement. Each whole muscle is made up of bundles called muscle fascicles, which contain groups of muscle fibres (the individual muscle cells). Within each muscle fibre are long, threadlike structures known as myofibrils, which are organised into repeating units called sarcomeres. Sarcomeres are the basic functional units of muscle contraction. They are composed of two main types of protein filaments: thick filaments, made mostly of the protein myosin, and

thin filaments, made mostly of actin. The specific arrangement of these filaments within the sarcomeres enables muscles to contract and produce force efficiently.

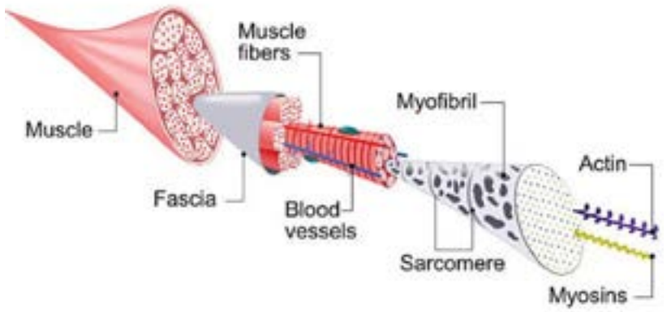


Figure 23: *Hierarchical Structure of Skeletal Muscle Tissue*

Muscle contraction is one of the best examples of how the body changes energy from one form to another. It transforms chemical energy stored in a molecule called ATP into movement and force.

Muscle contraction begins when the brain sends a signal through a nerve. This nerve impulse reaches a point called the neuromuscular junction, where the nerve connects with a muscle fibre. When the signal arrives, it causes the nerve ending to release a chemical messenger called acetylcholine. This chemical binds to receptors on the muscle fibre's surface and starts an electrical signal that spreads across the muscle.

The signal then reaches the sarcoplasmic reticulum, an organelle. It is a specialised form of the endoplasmic reticulum found within muscle fibres. It releases these calcium ions into the muscle. The calcium binds to a protein called troponin, which is attached to thin filaments made of actin. This causes another protein, tropomyosin, to move out of the way and uncover binding sites on the actin filaments.

Once the actin binding sites are exposed, thick filaments made of a protein called myosin attach to them. This forms a cross-bridge. At this point, ATP is needed to power the contraction through a series of steps called the cross-bridge cycle:

1. **Energising the myosin head**: ATP attaches to the myosin head and is broken down into ADP and phosphate. This gives the myosin energy and puts it into a high-energy position.
2. **Power stroke**: The myosin head binds to actin and releases the phosphate, causing it to pivot and pull the actin filament inward.
3. **Detachment**: A new ATP molecule binds to the myosin head, which makes it release the actin.
4. **Resetting**: The ATP is broken down again, and the myosin head returns to the high-energy position, ready to start another cycle.

This cycle repeats if there is enough calcium and ATP in the muscle. When the nerve signal stops, calcium is pumped back into the sarcoplasmic reticulum, the binding sites on actin are covered again, and the muscle relaxes.

Figure 24 shows how antagonistic muscles work together to control movement. Emphasise that when one muscle contracts, its opposing muscle (the antagonist) must relax to allow motion to occur. This coordination is essential for controlled movement. Both contraction and relaxation

use energy from ATP. During contraction, ATP powers the cross-bridge cycling of actin and myosin. During relaxation, ATP is used to pump calcium ions back into the sarcoplasmic reticulum, which resets the muscle fibre for the next contraction.

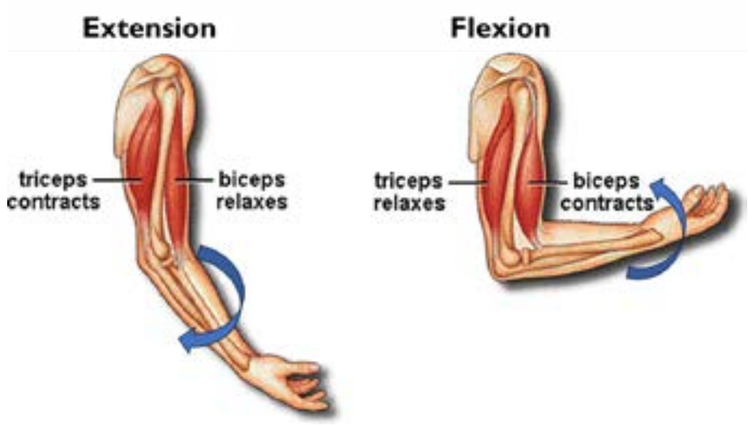


Figure 24: *Antagonistic muscle pair in both contracted and relaxed states*

Briefly discuss the role of the nervous system in sending signals to muscles for movement.

The nervous system controls muscle activity by sending fast electrical signals from the brain to the muscles, directing them to contract or relax. This coordination enables smooth movement and quick responses during actions such as walking, writing, or playing sports. **Figure 25** illustrates the connection between the brain and muscles, highlighting the motor cortex, spinal cord, motor neurons, and the neuromuscular junction.

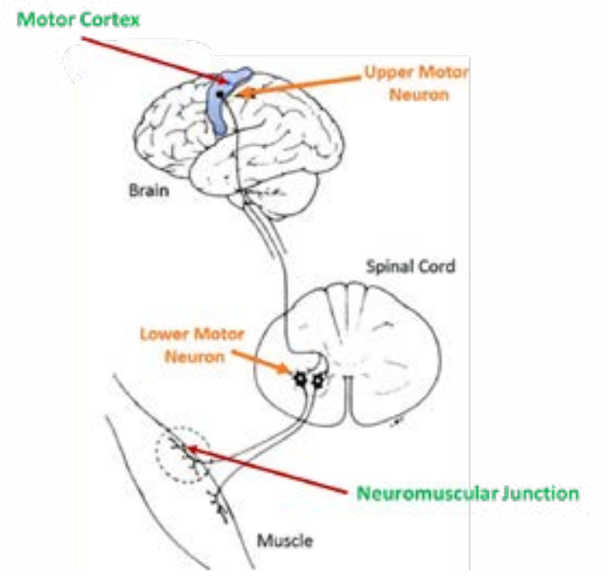


Figure 25: *Nerve pathway from brain to muscle*

The nervous system controls voluntary movement through a series of steps described as follows:

1. **Starting point (the brain)**: Movement begins in the motor cortex, which is the part of the brain that decides which part of the body needs to move.
2. **Sending the signal (upper motor neurons)**: The brain sends an electrical signal down the spinal cord through upper motor neurons. These neurons carry the message toward the correct part of the body.
3. **Passing the message (lower motor neurons)**: In the spinal cord, the upper motor neurons pass the signal to lower motor neurons, which are responsible for delivering the message directly to the muscles.
4. **Reaching the muscle through nerves and the neuromuscular junction**: The lower motor neurons carry the signal through nerves that extend out of the spinal cord and reach the muscles. When the signal arrives at the neuromuscular junction (the point where a nerve meets a muscle), it triggers the release of acetylcholine. **Muscle contraction begins**: Acetylcholine crosses the small gap between the nerve and the muscle, attaches to the muscle fibre, and causes an electrical signal. This signal starts the process that makes the muscle contract.

The nervous system does not just tell muscles when to move. It also controls how much force they produce. This is important whether you are writing with a pencil or lifting a heavy object. The body adjusts muscle force in three main ways:

1. **Motor unit recruitment**: Muscles are made up of many motor units. Each motor unit is a group of muscle fibres controlled by a single motor neuron. When you need a small amount of force, your body activates only a few small motor units. As the need for strength increases, more motor units, including larger ones, are gradually recruited. This order of activation, starting with the smallest units and ending with the largest, is called the size principle. For example, picking up a pencil requires fewer and smaller motor units than lifting a backpack.
2. **Rate coding (frequency of nerve signals)**: Another way to increase muscle force is by changing how quickly nerve signals are sent to the muscles. These signals, called action potentials, cause the muscle fibres to contract. If the signals are sent more frequently, the muscle does not have time to relax fully between contractions. As a result, the individual twitches combine to produce a stronger, more sustained contraction. This process is called summation. The faster the nerve signals, the greater the force.
3. **Synchronisation of motor units**: The nervous system can also make muscles stronger by coordinating the timing of when different motor units fire. When multiple motor units are activated simultaneously, their combined effort produces more powerful and efficient movements. This is especially useful in activities that require quick bursts of strength, such as jumping or throwing. Training and practice can improve this synchronisation, which is why skilled athletes often move more smoothly and powerfully than beginners.

In addition to controlling voluntary movement, the nervous system helps protect the body through reflexes. Reflexes are quick, automatic responses that occur without conscious thought. They act as built-in safety mechanisms to help the body react rapidly to sudden changes or dangers.

Inside every skeletal muscle are special sensory receptors called muscle spindles. These spindles constantly monitor the muscle length. If the muscle is suddenly stretched, such as when you unexpectedly step into a hole, or someone taps just below your kneecap, the muscle spindles

quickly detect the change. The receptors then send a signal to the spinal cord, where the information is processed immediately without the need to travel all the way to the brain. The spinal cord responds by sending a message straight back to the same muscle, telling it to contract. This contraction helps resist the stretch and protects the muscle and joint from injury.

A classic example of this is the knee-jerk reflex. When the area just below the kneecap (patellar tendon) is gently tapped, the thigh muscle (quadriceps) stretches slightly. The muscle spindle detects this and causes the muscle to contract, resulting in a sudden kick of the lower leg. This whole process takes only a fraction of a second and shows how the nervous system can act quickly to protect the body, even before you realise something is happening.

FOCAL AREA 2: JOINTS – THE MOVERS AND SHAKERS

Introduce joints as the connection points between bones that allow for movement

Joints are highly specialised structures that serve as the connection points between two or more bones in the human body. They play a central role in enabling movement and flexibility while maintaining the integrity and stability of the skeletal framework. Without joints, the body would be a stiff, immobile structure made up of solidly connected bones. Joints transform this rigid framework into a dynamic, responsive system that performs a vast range of movements essential for everyday life and physical activity.

These connection points allow the bones to move relative to one another in controlled ways. Whether it is bending an elbow to bring food to the mouth, twisting the torso to look behind, or flexing the fingers to grip a pencil, joints make these actions possible. They act as mechanical levers or hinges, guiding and limiting motion in specific directions depending on their design and location in the body. At the same time, joints provide the necessary support to bear the body's weight and resist forces that could otherwise cause dislocation or injury.

Beyond movement, joints also contribute to shock absorption and energy transfer during dynamic activities like running, jumping, or lifting. They help distribute mechanical stress across the skeletal system and soft tissues, reducing the impact on individual bones and protecting internal organs. To achieve this balance of mobility and stability, joints are supported by various tissues, including ligaments (which connect bones and prevent excessive movement), cartilage (which cushions the ends of bones), and synovial fluid (which lubricates the joint to reduce friction).

Briefly discuss different types of joints and their role in various body movements.

Based on the structure and function of joints, they can be divided into three main types: fibrous joints, cartilaginous joints, and synovial joints. Each type plays a unique role in body movement and protection.

1. **Fibrous joints**: These joints are the least movable joints in the body. In these joints, the bones are tightly held together by strong fibrous connective tissue, with no joint cavity and almost no space between the bones. This makes them very stable and strong. The main function of fibrous joints is protection. A common example is the sutures found in the skull (**Figure 26**). These joints fuse the bones of the skull and do not allow movement after early childhood. By locking the bones firmly in place, they form a solid structure that protects the brain from impact and injury.

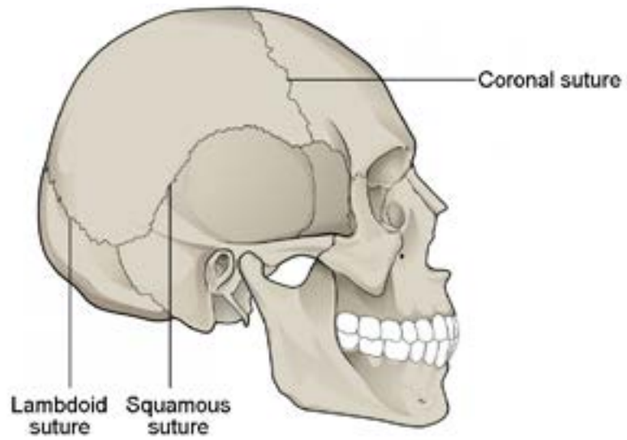


Figure 26: *Fibrous joint of the Skull*

2. **Cartilaginous joints**: These joints allow limited movement and provide both support and flexibility. In these joints, the bones are connected by cartilage, a tough but flexible tissue that helps absorb shock during daily activities. These joints have no joint cavity but allow slight movement that helps protect the body from stress caused by motion. A good example is the joints between the vertebrae in the spine (**Figure 27**). The cartilage discs between the vertebrae allow the spine to bend and twist slightly while keeping it strong and stable. Cartilaginous joints are important for reducing impact from actions like walking, running, and jumping, especially in areas where full movement is not necessary.

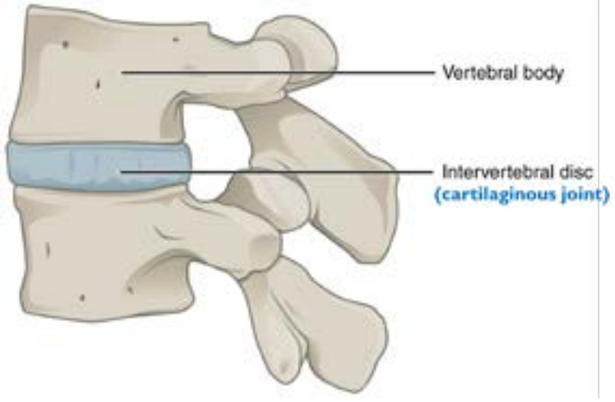


Figure 27: *Cartilaginous joint between vertebrae*

3. **Synovial Joints**: These are the most common and flexible joints in the body. They allow movements like bending, straightening, and rotating, which are important for activities such as walking, running, and throwing. These joints have a fluid-filled space called the joint cavity that helps bones move smoothly. Key parts (**Figure 28**) include articular cartilage (to reduce friction), the joint capsule (to protect the joint), synovial fluid (for lubrication), and ligaments (to keep bones stable). Some joints also have menisci for shock absorption and bursae to reduce rubbing between bones and soft tissues. Types of synovial joints are:

a. Hinge joint: This type of joint allows movement in only one direction, much like the motion of a door hinge. It enables bending and straightening actions, known as flexion and extension. Hinge joints are found in places such as the elbow (between the humerus and ulna), the knee (between the femur and tibia), and in the fingers and toes, where they help with gripping and balance during movement.

b. Ball-and-socket joint: This joint offers the greatest range of motion in all directions, including rotation. It is formed when the round head of one bone fits into the cup-shaped socket of another. The shoulder joint (where the humerus meets the scapula) and the hip joint (where the femur fits into the pelvis) are classic examples. These joints allow the arm and leg to move in a full circle and rotate freely, making them essential for actions like throwing, kicking, dancing, or climbing.

c. Pivot joint: A pivot joint allows rotational movement around a single axis. One bone rotates within a ring formed by another bone and surrounding ligaments. An important example is the joint between the first and second cervical vertebrae in the neck (the atlas and axis), which allows you to turn your head from side to side. Another example is the elbow, where the radius rotates around the ulna to turn the palm upward or downward.

d. Gliding joint: Also known as a plane joint, this type allows flat or slightly curved bones to slide past one another in any direction within a small range. These joints are found in the wrists (between the carpal bones), ankles (between the tarsal bones), and between the small joints in the spine (called facet joints). They provide flexibility, help with balance, and allow small but important adjustments during movements like walking, stretching, or twisting the back.

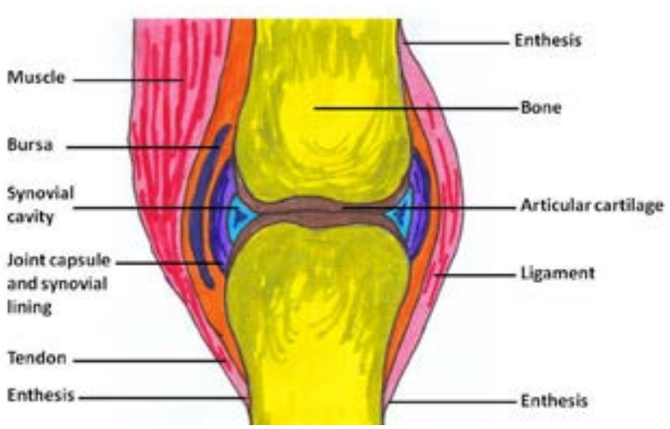


Figure 28: *A Synovial Joint*

Learning Tasks

1. Describe how the muscular and skeletal systems work together to move, including how muscles use ATP to contract and relax.
2. Explain how the nervous system sends signals that lead to muscle contraction and physical movement.
3. Identify the role of joints in movement and give examples of different joint types and the movements they allow.

4. Apply knowledge of the body systems to explain how they work together to make movement possible, and how problems in one system can affect the whole process.

Pedagogical Exemplars

Collaborative learning: Learners work in small groups to explore the movements of different joints in their own bodies. They are asked to move their fingers, wrists, elbows, shoulders, knees, ankles, and necks and observe the kinds of movement each joint allows. Based on their observations, learners identify and classify at least five different joints in the human body, such as hinge, pivot, and ball-and-socket joints. They discuss the function of each joint and explain how its structure determines the type of movement it permits. Where available, a white PVC skeleton model is used to help learners locate the joints and relate their observations to the skeletal system. Groups present their findings to the class and compare similarities and differences among the various joint types.

Project-Based learning: Learners work in groups to design and build a simple model of a joint and the surrounding skeletal muscle using local or recycled materials. The model should demonstrate how movement occurs at the joint, such as bending, rotating, or extending. After completing the model, learners will use library resources or the internet to explore how muscles use ATP, the body's energy molecule, to move. They will present both their model and their findings to the class, helping others understand how energy is used during movement.

Key Assessment: Group Research Project

Level 4 (Extended thinking): You are preparing a training guide to help junior athletes understand how their bodies produce and use energy during physical activity. Write an informative explanation that clearly describes how the musculoskeletal system, nervous system, and energy systems work together to support movement and performance.

Your guide must include:

1. How muscles and bones work together to create movement, including the role of tendons, joints, and antagonistic muscle pairs. (4 marks)
2. How ATP is involved in muscle contraction, including the role of myosin and actin in the cross-bridge cycle. (4 marks)
3. The two main energy systems used to produce ATP, and the kinds of physical activities each supports. (4 marks)
4. How the nervous system controls voluntary movement, starting from the brain and ending at the muscle fibre. (4 marks)
5. How do all these systems work together during real-life activities such as sprinting, jumping, or playing football? (4 marks)

What You Should Include

1. At least one clearly labelled diagram to support your explanation.
2. At least one example of a real physical activity where each system is used.
3. Use simple scientific terms and structure your ideas in clear paragraphs.

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 ***group research 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 Review

This section reviews all the lessons taught over the past four weeks. It summarises the core concepts students should understand about how body systems work together to digest food, transport nutrients, produce energy, and enable movement. If differentiation has been effectively implemented, each learner should now be able to answer the following key questions:

1. What are enzymes, and how do they function as biological catalysts in the digestive system?

2. How does digestion break down food into smaller molecules like glucose, amino acids, and fatty acids for absorption and energy production?
3. How do the respiratory and cardiovascular systems work together to deliver oxygen to cells and remove carbon dioxide?
4. How are food, oxygen, and water transported to body cells through blood circulation?
5. What is the role of mitochondria in converting glucose and oxygen into energy (ATP) through cellular respiration?
6. How do joints and muscles use energy to move, and what role do tendons and antagonistic muscle pairs play?
7. How does the nervous system control muscle activity and coordinate movement through motor signals?

This section prepares learners to apply biomedical knowledge in real-world contexts by exploring how digestion, energy generation, and movement are interconnected. Learners will discover how disruptions in these systems, such as poor enzyme function or reduced oxygen delivery, can impact health and physical performance. These concepts are foundational for understanding health science, physiology, and disease prevention. Student understanding of these integrated systems should be assessed using DOK Level 4 extended thinking tasks. Learners will be expected to analyse the coordination of the digestive, circulatory, respiratory, muscular, and nervous systems, and explain how these systems communicate to maintain energy supply and body function. This assessment builds on Year 1 and 2 learning indicators related to the structure and function of body systems and how systems work together. Students demonstrate not only factual knowledge but applied understanding, such as how enzyme failure affects energy production or how oxygen delivery supports muscle function, through realistic and health-relevant scenarios.

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 5

Question 1

1 mark: Mentions that enzymes help break down food.

2–3 marks: Explains that enzymes speed up digestion by breaking large molecules into smaller ones, and states that they work best in specific parts of the body due to factors like pH or temperature.

4–5 marks: Provides a clear explanation of enzyme function, includes mention of active site or "lock and key" model, and accurately explains how conditions like pH and temperature affect different enzymes in different parts of the digestive system.

Question 2

1 mark: States that enzyme deficiency affects digestion.

2–3 marks: Identifies one specific enzyme deficiency and gives at least one symptom or consequence.

4–5 marks: Identifies two enzyme deficiencies with appropriate examples, describes symptoms or effects on digestion and health, and suggests effective ways to manage the conditions (such as dietary changes or enzyme supplements).

Question 3

1–3 marks: Basic outline or idea provided, limited clarity or detail

- 1 mark: A general idea is given (e.g., "Test how heat affects enzymes") but lacks clarity or structure.
- 2 marks: A testable factor is named (e.g., temperature or pH), and there's a simple plan, but with missing steps or a vague procedure.
- 3 marks: Mentions variables or measurement, but with unclear hypotheses, missing controlled factors, or no mention of how results would be observed.

4–6 marks: Satisfactory experimental plan with some scientific accuracy

- 4 marks: Includes a testable hypothesis, basic procedure, and some materials; may list some variables.
- 5 marks: Procedure is clear, includes materials, mentions independent/dependent variables, and explains briefly how enzyme activity will be observed (e.g., change in colour or foam).
- 6 marks: Accurate structure with logical steps, clear hypothesis, materials, and variable control. Brief mention of repeat trials or improvement suggestions.

7–8 marks: Strong experimental design with clear structure and scientific detail

- 7 marks: Hypothesis is focused and testable. Steps are well-organised and safe. Variables are clearly identified and controlled. Data collection described (e.g., time to digest, bubble count, colour change).
- 8 marks: Accurate method and measurement plan. Mentions controls, repeat trials, and limitations. Reflects a good understanding of how to assess enzyme activity.

9–10 marks: Excellent and well-thought-out design with critical thinking

- 9 marks: Full plan with detailed steps, testable hypothesis, clear data collection method, thorough variable control, repeated trials, and understanding of scientific method.
- 10 marks: Also includes thoughtful consideration of potential errors (e.g., inconsistent temperature), with suggestions for improvement (e.g., using a water bath, same enzyme batch). Demonstrates a strong grasp of experimental reliability and validity.

WEEK 6 (20 marks total)

Question1

a. 5 marks: Clear, complete sequence of airflow (nostrils → pharynx → larynx → trachea → bronchi → bronchioles → alveoli) and blood flow (lungs → left atrium → left ventricle → body → right atrium → right ventricle → lungs) with detailed description of the role of key structures in gas exchange and transport.

b. 3–4 marks: Mostly correct sequence with some minor omissions or less detailed explanation of roles.

c. 1–2 marks: Partial or incomplete description of either respiratory or circulatory pathways; limited role explanation.

Question 2

a. 5 marks: Full explanation of oxygen transport via haemoglobin, nutrient and water absorption from the digestive system into blood, and the removal of carbon dioxide and metabolic wastes; includes capillary structure and function in exchange.

b. 3–4 marks: Mostly correct explanation, but lacking some detail or missing parts of nutrient or waste transport.

c. 1–2 marks: Basic understanding shown; some concepts missing or unclear (e.g., only oxygen transport explained).

Question 3

a. 5 marks: Detailed analysis of increased breathing rate, heart rate, blood flow redistribution, and how these adaptations meet the higher oxygen and nutrient demands; explains physiological mechanisms clearly.

b. 3–4 marks: Good understanding with most adaptations explained, but some detail or clarity is missing.

c. 1–2 marks: Basic description of changes (e.g., faster breathing and heart rate) without detailed analysis or explanation.

Question 4

a. 5 marks: Comprehensive evaluation of how failure in one system affects oxygen delivery, carbon dioxide removal, nutrient supply, and overall body function during exercise; includes potential health risks and outcomes.

b. 3–4 marks: Good explanation with some gaps or less detail on consequences or health risks.

c. 1–2 marks: Basic mention of problems caused by system failure, but lacking depth or clear link to exercise demands.

WEEK 7

Question 1

a. 3 marks: Explains that simple carbohydrates (like sugary cereal and soda) are broken down quickly, leading to a rapid spike in blood glucose followed by a sudden drop, often causing fatigue or low energy. Also explains that complex carbohydrates (oatmeal and rice) are digested more slowly, providing a gradual and sustained release of energy. Uses Maya's meals to illustrate the contrast, e.g., Friday's sugary cereal caused a crash; Wednesday's oatmeal supported energy for football.

2 marks: Identifies the difference in digestion speed and energy release, but the explanation may lack depth or clarity. Some connection to Maya's meals is present, but might not be connected to physiological effects.

1 mark: Gives a basic statement like "sugar gives quick energy" or "some carbs last longer," without explaining how or giving relevant examples.

b. 3 marks: Describes the process where glucose is absorbed in the small intestine, enters the bloodstream, travels to body cells, and is used in the mitochondria during cellular respiration to make ATP. You may also reference insulin's role in facilitating the movement of glucose into cells, while drawing a clear and explicit connection between glucose availability and the body's overall energy levels.

2 marks: Describes most of the pathway but omits some details (e.g., may not mention mitochondria or insulin). Reasonable connection between glucose and energy.

1 mark: Vague idea that glucose gives energy, but no clear pathway is described.

c. 2 marks: Explains that simple sugars are absorbed quickly, causing a sharp blood glucose rise, which triggers the release of insulin. This leads to rapid glucose uptake into cells, sometimes causing levels to fall too low (reactive hypoglycemia), resulting in tiredness or weakness.

1 mark: States that sugar leads to a crash or tiredness, but does not clearly explain the mechanism.

d. 2 marks: Identifies Wednesday as the best-balanced day, supporting it with the following evidence: all meals included (no skipping), a mixture of protein, complex carbs, and fibre, moderate physical activity (football), stable energy rating of 8, blood glucose was 4.7 mmol/L before exercise, showing good balance.

1 mark: Choose Wednesday or another day with limited explanation (e.g., "She felt good").

Question 2

a. 6 marks: Clearly explains how all three systems help get glucose and oxygen to muscles. Names body parts and enzymes. Diagram is clear and correctly labelled.

4–5 marks: Good explanation with small errors or missing details. Diagram mostly correct.

2–3 marks: Gives basic facts but missing links between systems. Diagram unclear or incomplete.

1 mark: Very short or confused answer. Poor or no diagram.

b. 6 marks: All steps shown clearly: digestion, absorption, transport, ATP production, and muscle use: correct terms and good layout.

4–5 marks: Most steps are correct. A few are missing or unclear.

2–3 marks: Some correct ideas. May miss key steps or mix up the order.

1 mark: Poor or unclear chart. Few correct stages.

c. 6 marks: Correctly explains what anaerobic respiration is. Compares ATP from both processes. Describes effects like tiredness or cramping.

4–5 marks: Good explanation. Some minor errors or missing effects.

2–3 marks: Gives some correct info but lacks detail.

1 mark: Minimal or incorrect explanation.

WEEK 8

Question 1

4 marks: Accurately explains how muscles, bones, tendons, and joints function together. Includes a correct example of antagonistic muscle pairs and explains how joint movement is produced.

2 marks: Gives a basic explanation with some key terms or examples missing or unclear.

1 mark: Mentions muscles and bones, but shows limited understanding of how movement occurs.

Question 2

4 marks: Clearly explains how ATP powers contraction through the cross-bridge cycle. Includes the role of myosin, actin, power stroke, detachment, and ATP reuse.

2 marks: Gives a general explanation of ATP's role in contraction but lacks detail about the cross-bridge process.

1 mark: Mentions ATP or energy use but does not show understanding of its role in muscle contraction.

Question 3

4 marks: Accurately describes all three energy systems, identifies aerobic vs anaerobic, and connects each to a specific type of activity.

2 marks: Describes at least two systems with general or unclear activity examples.

1 mark: Mentions energy or ATP, but does not correctly explain the systems.

Question 4

4 marks: Clearly describes the pathway from the brain to the muscle (motor cortex, spinal cord, motor neuron, neuromuscular junction, acetylcholine). Explains how signals lead to contraction.

2 marks: Gives a basic description of nerve control but leaves out key parts of the pathway.

1 mark: Mentions nerves or the brain, but does not explain how signals control muscles.

Question 5

4 marks: Provides a clear, accurate example of how all systems (muscular, skeletal, nervous, energy) interact during a real activity (e.g., sprinting, football). Demonstrates understanding of how systems coordinate.

2 marks: Example is given but lacks a clear explanation of how the systems interact.

1 mark: Includes an activity example, but without showing how body systems work together.

Additional Reading

QR Code 11 Enzymes as biological catalysts

QR Code 12 Digestive Enzymes

QR Code 13 Digestive System Process

QR Code 14 Cellular respiration

QR Code 15 Types of joints and movement

QR Code 16 Nervous System and Movement

SECTION 4: DISEASES AND DISORDERS

Strand: Human Body System

Sub-Strand: *Diseases and Disorders*

Learning Outcome: *Describe the different types of lipids in the body, explain how cholesterol – lipoprotein complexes affect the risk of heart diseases, and how risk diseases may be assessed.*

Content Standard: *Demonstrate an understanding of the function of cholesterol in the body and its role in heart disease.*

INTRODUCTION AND SECTION SUMMARY

In this section, learners will examine the different types of lipids and how imbalances in lipids and cholesterol can influence cardiovascular health and overall body function. The section explores the biochemical nature and functions of different lipid types, and how cholesterol is transported in the blood by HDL and LDL. Learners will analyse how variations in these lipoproteins affect the risk of heart disease and explore diagnostic tools such as angiograms. The section also introduces strategies for assessing and managing cardiovascular risk. These topics provide learners with a comprehensive look at the role of cholesterol-lipoprotein complexes in both healthy physiological function and the pathogenesis of cardiovascular disease.

The weeks covered by the section are:

Week 9: *Describe the different types of lipid molecules and their different physical properties and functions.*

Week 10: *Explain how cholesterol is transported in the blood by high-density lipoprotein (HDL) and low-density lipoprotein (LDL), and the role each of them plays in the body.*

Week 11: *Describe how the concentrations of these complexes (HDL and LDL) affect a person's risk of heart disease.*

Week 12: *Describe the function of an angiogram in diagnosing blocked vessels and discuss the risk factors for heart disease.*

SUMMARY OF PEDAGOGICAL EXEMPLARS

To achieve the content standard for this section, the following pedagogical exemplars are recommended. Through structuring talk for learning, learners engage in whole-class discussions to explore lipids as a diverse group of hydrophobic molecules, using diagrams or physical models to identify structural differences and key terms like "amphiphilic" and "glycerol backbone." With activity-based learning, learners model and match lipid types to their biological functions, then present their findings, linking structure to function. In talk-for-learning, cholesterol and triglycerides are discussed in terms of their necessity and transport, prompting deeper inquiry into lipoproteins (LDL, HDL, VLDL) and their health impacts. Collaborative

learning fosters peer engagement as mixed-ability groups analyse the roles of HDL and LDL, followed by class presentations. Initiating talk for learning involves a guest speaker or a chart summary on lipoprotein measurement, leading to discussions on cardiovascular risks. Finally, using structured talk, learners examine angiogram images in pairs and reflect on heart disease risk factors through informed discussion.

ASSESSMENT SUMMARY

To assess learners' understanding of lipid structures, cholesterol transport, and cardiovascular diagnostics using angiograms, DOK Levels 3 and 4 assessment strategies are recommended. These assessments target learners' ability to critically analyse, synthesise, and apply their knowledge of lipids and heart disease risk across varied contexts. Learners are expected to compare lipid types by physical properties and biological roles, and to explain cholesterol transport via HDL and LDL, including their contrasting effects on cardiovascular disease. They analyse case-based scenarios to evaluate how imbalanced lipoprotein levels contribute to atherosclerosis, interpret angiogram data to identify blocked vessels, and assess individual cardiovascular risk. Learners also examine how factors such as diet, genetics, and lifestyle influence lipoprotein levels and disease progression. Using case studies, they evaluate how varying HDL and LDL levels influence the risk of heart disease and explore the biological basis of atherosclerosis. Learners also interpret angiogram results to identify blocked vessels and assess the impact of lifestyle, diet, and genetics on cardiovascular risk.

Indicators	**DOK Level**	***Assessment Strategy and/or Mode***
Describe the different types of lipid molecules and their different physical properties and functions.	4	*Short answer individual class exercise*
Explain how cholesterol is transported in the blood by high-density lipoprotein (HDL) and low-density lipoprotein (LDL) and the role each of them plays in the body.	3	*Short answer Individual class exercise*
Describe how the concentrations of these complexes (HDL and LDL) affect a person's risk of heart disease.	4	*Group Project (out of class) and Individual Case Study Analysis*
Describe the function of an angiogram in diagnosing blocked vessels and discuss the risk factors for heart disease.	3	*Individual Class Assessment (Multiple Choice Questions)*

WEEK 9

Learning Indicator: *Describe the different types of lipid molecules and their different physical properties and functions*

FOCAL AREA 1: LIPIDS AS A DIVERSE GROUP OF MOLECULES

Discussion on the different types of lipids and their properties

Lipids are a diverse group of hydrophobic or nonpolar molecules, primarily composed of hydrocarbons, that serve various essential functions in living organisms. They are insoluble in water (hydrophobic) but soluble in organic solvents. Lipids play crucial roles in the body, such as energy storage, cell membrane structure, and hormone signalling. The main types of lipids are triglycerides, phospholipids, and steroids (See **Figure 29**).

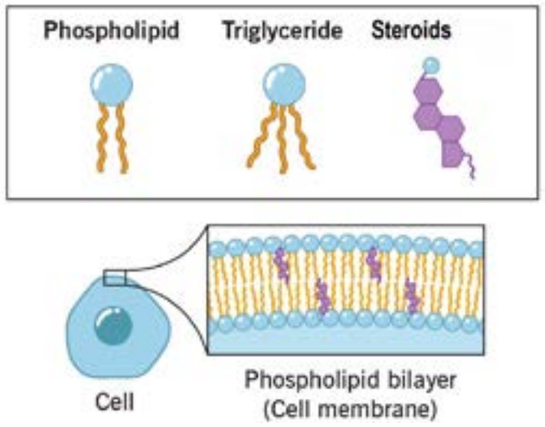


Figure 29: *Types of lipids (Cleveland, 2022)*

Structure of lipids

Lipids are made of carbon, hydrogen, and oxygen, but have a much lower proportion of water than other molecules, such as carbohydrates. Unlike polysaccharides (e.g., starch) and proteins, lipids are not polymers because they lack a repeating monomeric unit. Lipids are made from two molecules: glycerol and fatty acids. A glycerol molecule is made up of three carbon atoms with a hydroxyl (OH) group attached to it and hydrogen atoms occupying the remaining positions (See Figure 30). For instance, structurally, a triglyceride molecule consists of one glycerol backbone attached to three fatty acid chains.

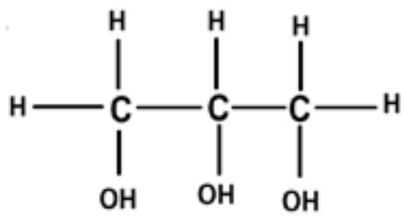


Figure 30: *Structure of glycerol*

Fatty acids consist of an acid group at one end of the molecule and a hydrocarbon chain, which is usually denoted by the letter 'R'. They may be saturated or unsaturated. A fatty acid is saturated if every possible bond is made with a hydrogen atom, such that there exist no carbon-carbon (C=C) bonds. Unsaturated fatty acids, on the other hand, do contain C=C bonds. Monounsaturated fatty acids (e.g., avocados, olive oil, etc) have one C=C bond, and polyunsaturated fatty acids (e.g., omega-3 in fish such as salmon, mackerel, herring, tuna; avocado, olive oil) have more than one C=C bond. Unsaturated fats, which are liquid at room temperature, are considered beneficial fats because they can improve blood cholesterol levels.

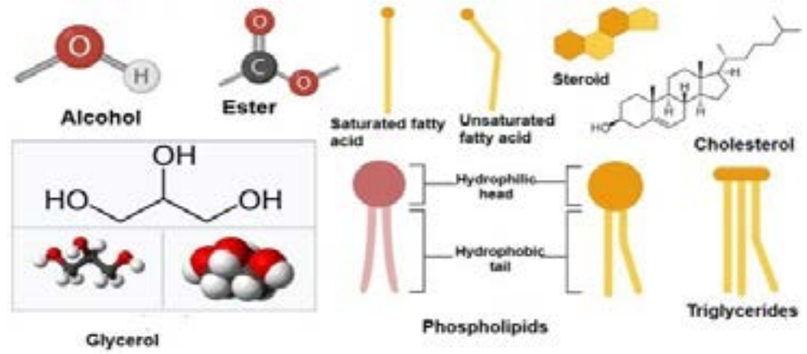


Figure 31: *Structure of lipids*

Classification of lipids

Lipids are classified based on their structure (Bloor's classification) or function. They are categorised as simple (e.g., triglycerides), compound/complex (e.g., phospholipids and lipoproteins), and derived (e.g., hormones and cholesterol). Understanding the main categories is crucial for grasping their roles in cell membranes, energy balance, and human health and disease.

Simple lipids: These are esters of fatty acids. Fatty acids are long chains of carbon atoms with a carboxylic acid group (-COOH) at one end. They are the building blocks of many lipids, especially triglycerides. Depending upon the constituent alcohols, they are further divided into fats or oils and waxes. Fats, also known as triglycerides, are esters of glycerol with fatty acids.

a. Triglycerides: These are the main form of lipids in the body and in foods. More than 95% of lipids in the diet are in the form of triglycerides. Concentrated fats, such as those in butter, vegetable oil, and meat, are easy to see. However, some fats are also hidden in foods such as pastries, milk, cheese, and fried foods. There are also naturally occurring triglycerides, such as those found in avocados, palm fruits, and nuts. Triglycerides in food are commonly called "fats and oils". At room temperature, fats are solid, whereas oils are liquid. The structure of a triglyceride is made up of glycerol and three fatty acids. Glycerol is the three-carbon backbone of triglycerides, while fatty acids are longer chains of carbon molecules attached to the glycerol backbone. The "glyceride" in the word "triglyceride" refers to this glycerol backbone, while the "tri" refers to the fact that there are three fatty acids attached. Fatty acids are acidic because they have an acid group (−COOH) on one end of a carbon chain. See **Figure 31.**

Complex/compound lipids: These are esters containing chemical groups in addition to alcohol and fatty acids, such as phosphate (in phospholipids), sugars (in glycolipids), or nitrogen-containing groups like amino or choline (in sphingolipids).

a. **Phospholipids**: These are special types of lipids made up of two fatty acid chains, a glycerol backbone, and a phosphate group. They play many important roles in the body, even though they make up only about 2% of dietary lipids. The human body can synthesise phospholipids, so they do not have to be consumed in a diet. Every cell in the body is encased in a membrane composed primarily of a double layer of phospholipids (also known as the phospholipid bilayer). The phospholipid bilayer is made up of two layers of phospholipid molecules arranged tail-to-tail. Each phospholipid has a hydrophilic (water-attracting) head that contains a phosphate group and glycerol, and two hydrophobic (water-repelling) fatty acid tails (See Figure. 29). In the bilayer, the hydrophilic heads face outward, toward the watery environments inside and outside the cell. In contrast, the hydrophobic tails point inward, away from water, forming a flexible barrier. Phospholipids are similar in structure to triglycerides. But unlike triglycerides, they only have two fatty acid molecules attached to the glycerol backbone, while the third carbon of the glycerol backbone is bonded to a phosphate group. This arrangement makes the membrane semipermeable, allowing it to control which substances can enter or leave the cell. Small, non-polar molecules like oxygen and carbon dioxide can pass through easily, while larger or charged molecules require special protein channels. The bilayer also contains embedded proteins, cholesterol, and carbohydrates that support cell communication, transport, and structure. This unique structure of phospholipids makes them amphiphilic (that is, both fat- and water-soluble). The fatty acids are hydrophobic, and the phosphate group and glycerol are hydrophilic (attracted to water). The amphiphilic nature of phospholipids makes them very useful for several functions in the body. For example, they protect the inside of the cell from the outside environment and allow for the transport of fat and water through the cell membrane.

b. **Lipoproteins**: These are lipids bound to proteins. They are spherical complexes composed of lipids (core) and proteins (shell), designed to transport water-insoluble lipids, like triglycerides and cholesterol, through the aqueous bloodstream. Examples include high-density lipoprotein (HDL) and low-density lipoprotein (LDL).

Derived lipids: These are molecules derived from simple or compound lipids during digestion or metabolism, which still possess the general characteristics of lipids. They are derived from simple and compound lipids by hydrolysis of alcohols and fatty acids. They are utilised in biochemical reactions to produce substances, such as steroids and bile acids.

Steroids have a very different structure from triglycerides and phospholipids. Most steroids do not contain fatty acids but rather contain multi-ring carbon structures. They contain interlinking rings of carbon atoms (See Figure 31), with side chains of carbon, hydrogen, and oxygen attached. Cholesterol is the most common steroid because of its role in heart diseases. It forms a large part of the fatty plaques that narrow arteries and obstruct blood flow (atherosclerosis). However, cholesterol also has many essential functions in the body. Like phospholipids, cholesterol is present in all body cells as it helps maintain the structure and fluidity of cell membranes. Cholesterol fits between the phospholipids in the membrane, preventing it from becoming too rigid or too fluid, and thereby reducing permeability to certain small molecules.

Properties of lipids

Lipids are a family of organic compounds, composed of fats and oils. These molecules yield high energy and are responsible for different functions within the human body. Some important properties of lipids are as follows.

1. Lipids may be either liquids or non-crystalline solids at room temperature.
2. Pure fats and oils are colourless, odourless, and tasteless.
3. They are energy-rich organic molecules.
4. They are insoluble in water but soluble in organic solvents such as alcohol, chloroform, acetone, and benzene.
5. They have no ionic charge.
6. Fats have high proportions of saturated fatty acids (have no double bonds between the carbon atoms). Some sources of saturated fats include beef, cheese, ice cream, and fats found in some plants, such as palm fruit, coconut, and palm kernel.
7. Oils have high proportions of unsaturated fatty acids (contain one or more double bonds between carbon atoms in their hydrocarbon chain). Unsaturated fats are found predominantly in foods such as avocado, vegetable oils (e.g., soybean, sunflower), nuts, fish, and seeds.

Functions of lipids

Lipids are multifunctional molecules that go far beyond energy storage. They are integral to the structure, protection, communication, and regulation of nearly all biological processes in the human body.

1. **Energy storage and supply**: Lipids, especially triglycerides, are stored in adipose (fat) tissues. When the body needs energy, hormones like glucagon signal fat cells to break down triglycerides into glycerol and free fatty acids, which are released into the blood and used by cells to generate ATP via cellular respiration. Lipids provide more than twice as much energy per gram as carbohydrates or proteins, making them an efficient energy reserve. This sustains the body during fasting or periods of high energy demand.
2. **Structural framework of cells**: Phospholipids and cholesterol form the core structural framework of cell membranes. Their amphipathic nature creates a selective barrier that controls the passage of substances and maintains cell integrity. Cholesterol fits between phospholipids in cell membranes, maintaining membrane fluidity and stability, especially at varying temperatures. This structure allows cells to maintain internal conditions, communicate, and control what substances move in and out.
3. **Insulation and protection**: Fat stored under the skin acts as thermal insulation, reducing heat loss. They also surround and cushion internal organs such as the kidneys and heart, protecting them from mechanical damage.
4. **Hormone and vitamin production**: Cholesterol is the precursor for the synthesis of steroid hormones, including oestrogen and testosterone (reproductive hormones), Cortisol (stress hormone), and aldosterone, which regulates salt and water balance. Lipids also help in the synthesis and transport of fat-soluble vitamins (A, D, E, and K), which are essential for vision, bone health, antioxidant function, and blood clotting.
5. **Cell signalling and communication**: Some lipids act as second messengers or signalling molecules. For example, prostaglandins, derived from fatty acids, mediate inflammation,

pain, and fever. Lipid signalling helps the body respond to internal and external changes (e.g., injury, infection, and stress).

6. **Immune system support**: Lipids such as omega-3 and omega-6 fatty acids are involved in the production of eicosanoids (e.g., prostaglandins) that act as local messengers in inflammation, blood clotting, and immunity. They help balance immune reactions and prevent chronic inflammation.

Learning Tasks

1. Recap the definition and biological significance of lipids, focusing on their structural features, solubility, and major functions in the human body.
2. Classify the different types of lipids as simple, compound, and derived.
3. Compare their structures, physical properties, and relate them to their functions.
4. Explain why phospholipids are described as "amphiphilic" and how this property is critical for their role in forming cell membranes.

Pedagogical Exemplars

Structuring Talk/Sign for Learning: Engage learners in a whole-class discussion to explore lipids as a diverse group of hydrophobic molecules, their classification, and their significance in the human body. Using videos (Scan **QR code 17** for a sample video), diagrams (See Figure 31), or physical models, guide learners to identify and describe the structural differences between lipids. Encourage them to use key terms such as "hydrophobic," "amphiphilic," "fatty acids," and "glycerol backbone" during the discussion.

Activity-Based Learning: Facilitate small group activities where learners sketch or model the structure of different types of lipids using stick and ball models or sketches. Classify the different types of lipids based on their structures and match them with their functions (e.g., energy storage, membrane structure, and hormone synthesis). Students present their sketch or model to the class and explain how the lipid structures relate to function.

Key Assessment

1. **Level 4 (Extended critical thinking and reasoning)**: A nutritionist is analysing a patient's diet that is high in saturated fats and low in unsaturated fats.
   a. Based on your understanding of lipid structure and function, propose an explanation of how high saturated fat content could affect the patient's health. (5 marks)
   b. What will be the effect of this low unsaturated fat diet on cardiovascular health? (2 marks) Recommend two (2) foods that can help increase the patient's unsaturated fats. (2 marks)
2. **Level 4 (Extended critical thinking and reasoning):** A biotechnology company wants to create a synthetic cell membrane. Using your understanding of lipid structure, predict how replacing phospholipids with triglycerides would impact the structure and function of the membrane. (6 marks)
3. **Level 4 (Extended critical thinking and reasoning):** A patient's diet is high in triglycerides and low in phospholipids and cholesterol. Integrate your understanding of lipid types, structures, and functions to analyse how this imbalance could affect the patient's energy storage, hormone regulation, and cellular integrity. (6 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 ***short answers***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the assessment (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 10

Learning Indicator: *Explain how cholesterol is transported in the blood by high-density lipoprotein (HDL) and low-density lipoprotein (LDL), and the role each of them plays in the body*

FOCAL AREA: DISCUSS CHOLESTEROL, ITS ROLES, AND TRANSPORT

Discussion on cholesterol and its roles in the body should focus on the following

Cholesterol is a derived lipid molecule that plays several vital roles in the body. It is used in the body as a precursor in the synthesis of a few important substances, such as vitamin D, bile, and sex hormones (e.g., progesterone, testosterone, and oestrogen). Cholesterol can be manufactured in the liver and hence does not necessarily need to be absorbed from the food we eat.

Roles of cholesterol in the body

1. **Regulation of membrane fluidity**: It acts as a "buffer" to membrane fluidity. That is, at high temperatures, cholesterol reduces membrane fluidity, preventing it from becoming too liquid. Again, at low temperatures, it prevents the membrane from becoming too rigid or solidifying by preventing phospholipids from packing too tightly. This ensures the membrane remains flexible and functional across a range of temperatures.
2. **Integrity and stability**: They contribute to the overall stability, strength, and integrity of the cell membrane, enabling it to act as a selective barrier to the movement of substances across the cell.
3. **Precursor for bile acids**: Cholesterol is used by the liver to synthesize bile acids and salts. They are crucial for the digestion and absorption of dietary fats and fat-soluble vitamins (A, D, E, K) in the small intestine. Bile acids act as detergents, emulsifying fats into smaller molecules, making them accessible to digestive enzymes.
4. **Precursor for vitamin D absorption**: Cholesterol acts as a starting molecule (precursor) in the absorption of vitamin D. When the skin is exposed to ultraviolet (UV) light from the sun, cholesterol is converted to a precursor molecule (provitamin D3). This molecule is thermally unstable and quickly transforms into vitamin D3 (cholecalciferol), which is necessary for vitamin D absorption. Vitamin D is essential for calcium absorption, bone health, and immune function.
5. **Precursor for steroid hormones**: Cholesterol serves as the fundamental precursor molecule for the synthesis of steroid hormones, which are critical signalling molecules involved in regulating a few physiological processes. These include sex and adrenocortical hormones.

a. **Sex hormones**: Such as oestrogen, testosterone, and progesterone, which are vital for reproduction and secondary sexual characteristics.

b. **Adrenocortical hormones**: Such as cortisol, which is vital for regulating metabolism, stress response, and inflammation, as well as aldosterone, a hormone for regulating blood pressure and electrolyte balance.

Transportation of cholesterol

Cholesterol needs carriers to be transported in the blood because cholesterol is a lipid, and like all lipids, it is hydrophobic, meaning it does not dissolve in water. Blood is mostly made of water, and since cholesterol is insoluble in water, it would not be able to travel freely without help. Cholesterol needs lipoproteins for transportation in the body, as it cannot dissolve in the watery environment of blood. The body, therefore, packages cholesterol into lipoproteins. Lipoproteins are specialised protein-lipid complexes that act as sophisticated transport vehicles and carry cholesterol and other fats (e.g., triglycerides). Without lipoproteins, cholesterol would float on top of the blood. Lipoproteins are spherical particles with a unique structure.

- **A hydrophobic core**: This inner region is filled with the water-insoluble lipids, primarily cholesterol (in its esterified form) and triglycerides.
- **A hydrophilic outer shell**: This outer layer is composed of water-soluble components, including phospholipids (with their polar heads facing outwards towards the water), free cholesterol, and crucial proteins (apolipoproteins). These apolipoproteins not only stabilise the structure but also serve as recognition signals for cells and activate enzymes involved in lipid metabolism.

This structure allows lipoproteins to effectively "package" and transport cholesterol and other lipids throughout the aqueous bloodstream, delivering them to cells and tissues where they are needed for energy, structural components, hormone production, etc. Different types of lipoproteins, such as LDL and HDL, vary in composition and density and play specific roles in cholesterol transport (Scan **QR code 18** to watch a video on cholesterol transport).

The types of lipoproteins

Lipids (cholesterol and triglycerides) are insoluble in the blood, and so they must be bound to lipoproteins to be transported. The types of lipoproteins involved in this function are LDL, HDL, and VLDL.

1. **Low-density lipoproteins**: Transport cholesterol from its site of synthesis in the liver to the cells, where the cholesterol is separated from the LDL. It is often called "bad cholesterol" because high levels are associated with an increased risk of cardiovascular disease. LDL - bound cholesterol is primarily responsible for the plaque build-up of fatty deposits on the blood vessel walls. About 70% of all cholesterol in the blood is carried by LDL.
2. **High-density lipoproteins**: Transport excess or unused cholesterol from the body's tissues back to the liver, where the cholesterol is broken down to bile acids and excreted. HDL transports about 30% of cholesterol. It reduces plaque build-up, hence it is beneficial to health. HDL is often called "good cholesterol", as higher levels are generally associated with a lower risk of cardiovascular disease. It is synthesised in the liver and intestines and circulates in the bloodstream, acting as "scavengers".
3. **Very Low-density lipoprotein**: Is a type of lipoprotein made by the liver that transports triglycerides through the bloodstream to tissues for energy or storage. VLDL is also considered a "bad" cholesterol because high levels can contribute to plaque build-up in arteries, increasing the risk of heart disease and stroke.

The role and transportation of triglycerides in the body

Triglycerides are energy-dense fats transported via lipoproteins to fuel tissues. They are unable to travel freely in the bloodstream and are therefore transported by lipoproteins. One of the

main lipoproteins involved in this process is very low-density lipoprotein (VLDL), which carries triglycerides from the liver to tissues throughout the body. Triglycerides serve as the body's most efficient form of energy storage. They are stored in adipose (fat) tissue and can be broken down when the body needs energy. During fasting, physical activity, or periods of low food intake, hormones signal fat cells to release fatty acids from triglycerides. These fatty acids are then used by cells to generate ATP. Triglycerides provide more than twice as much energy per gram as carbohydrates or proteins, making them a vital energy reserve. In addition to energy storage, triglycerides help maintain body temperature and protect vital organs. Fat stored under the skin provides insulation, reducing heat loss, while fat around internal organs cushions them from mechanical shocks. Therefore, the transport of triglycerides by lipoproteins is essential not only for energy distribution but also for physical protection and thermoregulation in the human body.

Learning Tasks

1. Learners recap what cholesterol and triglycerides are, paying attention to their structure and why they need lipoproteins for their transport in the bloodstream.
2. Learners explore the roles of cholesterol in the body.
3. Learners analyse case scenarios that illustrate how LDL, HDL, and VLDL function and the effect(s) of their malfunction.

Pedagogical Exemplars

Talk/sign for Learning: Engage learners in a whole-class discussion on cholesterol and triglycerides and why they are necessary in the body. Discuss also their roles in the body and how they are transported in the body. Accept diverse opinions and guide the discussion with probing or clarifying questions to deepen understanding of lipoproteins (LDL, HDL, VLDL) and their functions.

Collaborative Learning: Learners work in mixed-ability groups to prepare a write-up on HDL and LDL, focusing on their differences and functions. Learners present their write-ups in class for comments.

Key Assessment: Short Answers

1. **Level 3 (Strategic reasoning):** Mutation causes an individual's body to produce defective lipoproteins. Predict and explain two systemic consequences a mutation would have on lipid transport and health outcomes (4 marks).
2. **Level 3 (Strategic reasoning):** Kojo, a 17-year-old student, feels unusually tired and sluggish after eating fatty foods. His doctor notices that his blood tests show very high levels of triglycerides and low-density lipoproteins (LDL).
   - **a.** Explain what triglycerides, cholesterol, and LDLs are, and their roles in the body. (6 marks)
   - **b.** Discuss why triglycerides and cholesterol require lipoproteins for transport in the bloodstream. (2 marks)
   - **c.** Explain the implications of this observation to Kojo and propose one lifestyle recommendation that might help him regulate his lipid levels. (2 marks)

3. **Level 3 (Strategic reasoning):** Adizatu has been on an extremely low-fat diet to lose weight. Although she has lost some weight, she now feels constantly tired. Her blood test shows very low VLDL and triglyceride levels.

   a. Explain the roles of VLDL and triglyceride in the body, especially in energy metabolism (4 marks).

   b. Analyse how a reduction in VLDL production due to dietary changes could contribute to Adizatu's fatigue (4 marks).

   c. Discuss two potential long-term risks of such a diet (2 marks).

PLC Session 10

45 minutes	Planning & Reviewing the Learning Plan

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10 minutes	Content Exploration

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   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).

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

5 minutes	Reflection

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

WEEK 11

Learning Indicator: *Describe how the concentrations of these complexes (HDL and LDL) affect a person's risk of heart disease*

FOCAL AREA: HDL, LDL, AND HEART DISEASE RISK – THE CONNECTION BETWEEN LIPOPROTEIN LEVELS AND HEART DISEASE RISK

The role of LDL in heart disease risk

LDL is primarily responsible for transporting cholesterol from the liver to peripheral tissues throughout the body. It carries cholesterol that accumulates as plaque inside blood vessels. This plaque increases the risk of coronary artery disease, heart attacks, and stroke. Once inside the cell, LDL particles are broken down by lysosomes, releasing cholesterol for use. The LDL receptors are then returned to the cell surface to pick up more cholesterol. When LDL levels are high or when LDL receptors are deficient or dysfunctional (e.g., due to genetics or lifestyle), excess LDL particles may accumulate. This excess LDL can become oxidised and contribute to the formation of fatty plaques within arterial walls, leading to narrowed arteries, reduced blood flow, and an increased risk of heart attack and stroke. Plaque build-up can narrow blood vessels, making it harder for blood to flow freely. This condition is referred to as atherosclerosis. Scan **QR Code 19** for an illustration.

Role of HDL in heart disease

HDL plays a crucial role in reverse cholesterol transport (RCT). RCT is the process of collecting excess cholesterol from peripheral tissues and arteries and transporting it back to the liver for excretion or re-use. Once cholesterol is picked up, an enzyme associated with HDL converts the free cholesterol into more hydrophobic esters. These esters move into the core of the HDL particle, causing it to mature and become spherical. Mature HDL particles then return the cholesterol to the liver (Scan **QR Code 20** for video illustration). Once in the liver, the cholesterol can be converted into bile acids and excreted into the bile, eventually leaving the body via faeces, completing the reverse cholesterol transport pathway. High levels of HDL are beneficial because they indicate an efficient removal of excess cholesterol from tissues, including arterial plaques, thereby preventing its accumulation and reducing the risk of atherosclerosis.

Explanation of how LDL and HDL levels can contribute to atherosclerosis

The concentrations of HDL and LDL in the blood play a crucial role in determining a person's risk of developing heart disease. These lipoprotein complexes are responsible for transporting cholesterol throughout the body, but they have opposite effects on cardiovascular health. When there is an imbalance, specifically, when LDL level is high and HDL level is low, cholesterol accumulates in the arteries with little being removed. This imbalance not only accelerates plaque formation but also increases inflammation in the arterial walls, further increasing the risk of cardiovascular disease. Even in individuals who appear healthy, such as young people with no obvious risk factors, this silent build-up can progress unnoticed for years before causing serious or even life-threatening events. Imagine the arteries as a busy highway, where the

smooth flow of traffic is essential for keeping your heart healthy. LDL in the body is like a flood of heavy, slow-moving trucks loaded with cholesterol that enter this highway. When there are too many of these LDL trucks, they clog the lanes, piling up excess cholesterol along the arterial walls (See Figure 32).

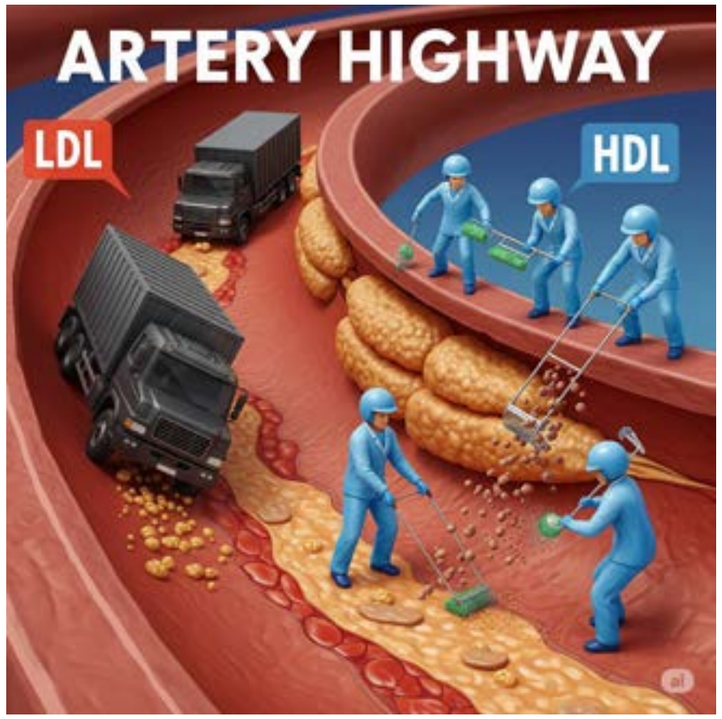


Figure 32: *Illustration of plaque build-up in the arteries*

Over time, this build-up forms sticky plaques, like roadblocks or debris, that narrow the highway and make it harder for blood to flow freely. This congestion increases the risk of heart disease, as the heart struggles to get the oxygen and nutrients it needs through the restricted arteries. When LDL levels are high, too many of these trucks flood the roads. These LDL trucks tend to break down or spill their cholesterol cargo onto the delicate highway surface (the artery lining), creating sticky debris.

HDL, in contrast, functions as the highway's dedicated maintenance and clean-up crew, with specialised tow trucks and sweepers constantly patrolling. Their primary function is to identify and pick excess cholesterol deposits, removing them from the artery walls and carrying them back to the liver, where they can be processed and eliminated. When HDL levels are low, there are far too few clean-up vehicles to handle the debris dumped by excessive LDL traffic.

The dangerous combination of too many LDL trucks spilling cargo and too few HDL crews cleaning up leads to disaster. The uncleared debris triggers inflammation. Like debris forcing lane closures on a real highway, plaque physically narrows the arterial passage, restricting blood flow. Worse, if the plaque ruptures, it can cause a catastrophic traffic jam (a blood clot), completely blocking the artery. This blockage in heart arteries causes a heart attack; in brain arteries, it causes a stroke. Thus, high LDL clogs the highway with damaging spills, while low HDL fails to clear them, creating the conditions for life-threatening plaque build-up.

Learning tasks

1. Learners describe the roles of LDL and HDL in cholesterol transport and explain how their levels affect the risk of developing atherosclerosis.
2. Analyse the biological processes by which LDL contributes to plaque formation and evaluate how HDL participates in reverse cholesterol transport.
3. Use analogies and case scenarios to demonstrate how imbalances in LDL and HDL levels lead to narrowed arteries, reduced blood flow, and increased risk of heart attack or stroke.

Pedagogical Exemplar

Initiating Talk/ Sign for Learning: Lead a class discussion on how levels of LDL and HDL affect the risk of heart disease, blocked blood vessels, and stroke. Invite a resource person to give a talk or show a video on how HDL and LDL are measured and the normal concentrations of these complexes (Scan **QR Code 21** for a sample video).

Key Assessment: Case Study Analysis

1. **Level 4 (Extended Critical Thinking and Reasoning):** A 45-year-old has a genetic predisposition to high cholesterol, is obese, and consumes diets high in saturated fats and sugars. The lipid profile shows HDL 35 mg/dL and LDL 180 mg/dL.

   a. Analyse the significance of the patient's lipid profile. (6 marks)

   b. Why is the combination of high LDL and low HDL particularly dangerous for his health? Explain one specific effect associated with each lipoprotein imbalance. (4 marks)

2. **Level 4 (Extended Critical Thinking and Reasoning):** A 50-year-old male patient receives the following lipid profile from his recent blood test:

Lipid component	Patient value (mg/dL)	Reference range (mg/dL)
Total Cholesterol	240	<200
LDL Low-density lipoprotein)	165	<100
HDL (High-density lipoprotein)	35	>60
Triglycerides	190	<150

Evaluate how the concentrations of the patient's LDL and HDL in this result interact to influence his overall risk of heart disease. Justify your evaluation with reference to the data and explain how each lipoprotein contributes differently to atherosclerosis. (6 marks)

3. **Level 4 (Extended Critical Thinking and Reasoning):** Working in groups, use your knowledge of lipoproteins and cardiovascular health to develop a detailed public health advisory poster that explains how the concentrations of HDL and LDL affect an individual's risk of heart disease. Each group's advisory must:

   i. Describe the biological roles of HDL and LDL in cholesterol transport.

   ii. Analyse how imbalances in their concentrations contribute to atherosclerosis and other cardiovascular conditions.

   iii. Critically evaluate existing lifestyle or medical interventions aimed at improving HDL: LDL ratios, referencing scientific evidence.

   iv. Propose a realistic and culturally relevant strategy for promoting heart health in your community, using your findings. (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 ***case study analysis***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the analysis (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 12

Learning Indicator: *Describe the function of an angiogram in diagnosing blocked vessels and discuss the risk factors for heart disease*

FOCAL AREA: ANGIOGRAMS AND HEART DISEASE RISK FACTORS

Introduction to angiograms as a diagnostic tool for visualising blood vessels

An angiogram is a medical imaging technique used to visualise the inside of blood vessels, especially arteries and veins. It is a key diagnostic tool in detecting and assessing blockages or narrowing in blood vessels, particularly those supplying the heart, brain, or limbs. During an angiogram, a contrast dye is injected into the bloodstream through a catheter (See Figure 33). This dye makes the blood vessels visible on X-ray images, allowing doctors to see any areas where blood flow may be restricted or obstructed due to plaque build-up or blood clots. Angiograms are often used to diagnose conditions like coronary artery disease, stroke, or peripheral artery disease. The information obtained from an angiogram helps healthcare professionals plan appropriate treatments, such as lifestyle changes, medication, or surgical interventions such as angioplasty or bypass surgery. Angiograms are the most accurate method for visualising the lumen (inside) of arteries, especially the coronary arteries, for diagnosing heart disease.

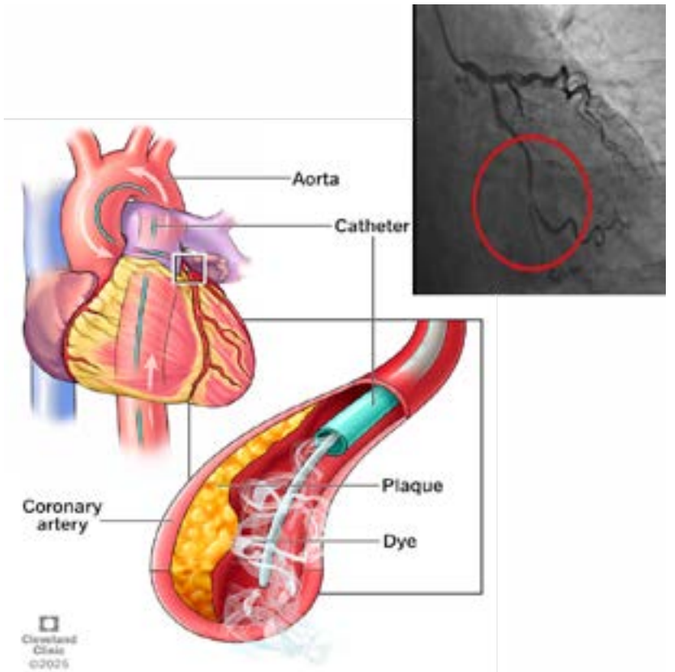


Figure 33: *Angiography (Cleveland, 2025), inset: angiogram showing plaque in an artery*

Briefly explain the procedure and its role in diagnosing heart disease

A patient will be admitted to the hospital the day before the angiogram procedure and asked not to eat or drink for 6 hours before the procedure. The angiography procedure is as follows.

1. A thin catheter is inserted into an artery around the region of interest (usually in the groin/ femoral artery or wrist/radial artery).
2. The catheter is carefully threaded under real-time x-ray (fluoroscopy) guidance up the aorta to the openings of the coronary arteries.
3. A special iodine-based contrast dye is injected through the catheter directly into the region of interest.
4. X-ray images (angiograms) are taken to capture the dye flowing through the blood vessels and highlight their internal shape and path, as well as any obstructions or irregularities.
5. Blockage (plaque), narrowing (stenosis), bulge (aneurysm), or any other abnormalities become clearly visible as areas where dye flow is reduced, absent, or the vessel wall is irregular.
6. Cardiologists measure the percentage of narrowing in any blocked artery segments.

The role of angiograms in diagnosing heart diseases includes the following

1. Angiograms serve as the gold standard, being the definitive test for diagnosing coronary artery disease (CAD) – the build-up of plaque in heart arteries.
2. Directly visualises the location, severity (percentage narrowing), number, and nature of blockages causing reduced blood flow to the heart muscle.
3. Used to confirm suspected CAD based on symptoms (chest pain/angina, shortness of breath), abnormal stress tests, or ECG findings.
4. They map the entire coronary artery system, showing the exact location and severity of the disease.
5. Angiograms are critical for deciding the best treatment strategy, such as;
    a. Medication: If blockages are mild/moderate.
    b. Angioplasty & stenting: If suitable severe blockages are found (often done during the same procedure).
    c. Coronary artery bypass grafting: If multiple severe blockages are present.
6. Angiograms can help diagnose causes of heart attack, congenital heart artery anomalies, or complications after prior interventions.

Discussion on various risk factors for heart diseases

Heart disease, such as CAD, heart attack, and stroke, is a significant health concern globally. While often associated with older age, its development is influenced by a combination of factors, many of which may impact health much earlier in life. Understanding these risk factors is crucial for prevention and management.

Some risk factors associated with heart disease

1. **High blood pressure (hypertension):** This is often called the "silent killer" because it typically has no symptoms, but it causes serious damage over time. When blood pressure is consistently too high, it puts excessive force on the arterial walls. This constant high pressure can directly damage the inner lining of the arteries, making them more susceptible to the accumulation of fatty plaque (atherosclerosis). The arteries become stiff and less elastic, narrowing the passageways and making it harder for blood to flow freely to the heart and other organs. Over time, this sustained strain can weaken the heart muscle, leading to heart failure, or contribute to blockages that result in heart attacks or strokes.
2. **Family history:** A strong family history of heart disease significantly increases an individual's risk. This means if close relatives such as parents, siblings, and grandparents experienced heart attacks, strokes, or other heart-related issues at a relatively young age (e.g., before age 55 for males or 65 for females), there is a higher chance of experiencing the same. Family history suggests a genetic predisposition to certain risk factors like high cholesterol, high blood pressure, diabetes, or even a direct inherited tendency towards cardiovascular disease. While genetics cannot be changed, being aware of a family history is a powerful motivator to manage modifiable risk factors.
3. **Unhealthy diet**: The food we consume has a profound impact on heart health. An unhealthy diet, typically characterised by high intake of saturated fats, cholesterol, sodium (salt), and added sugars, contributes significantly to heart disease.
    a. **Saturated fats**: These raise "bad" LDL cholesterol levels, promoting plaque formation in arteries.
    b. **High sodium (salt)**: Excessive sodium intake contributes to high blood pressure. When you consume too much sodium, the body retains more water to dilute the sodium concentration in the blood. The excess water retained in the bloodstream raises the blood volume. A higher blood volume means more pressure is exerted on the walls of the arteries.
    c. **Added sugars:** High sugar consumption can lead to weight gain, inflammation, high triglycerides, and insulin resistance, all of which elevate heart disease risk.

Conversely, a diet low in fruits, vegetables, whole grains, and healthy fats (like omega-3s found in fish or monounsaturated fats in olive oil) deprives the body of protective antioxidants, fibre, and beneficial compounds that support cardiovascular health.

4. **Lack of physical activity (sedentary lifestyle):** Sedentary lifestyle, marked by insufficient physical activity, is a major risk factor for heart disease. Regular physical activity helps to:
    a. Prevent obesity, a significant contributor to heart disease.
    b. Lower blood pressure by strengthening the heart, allowing it to pump more blood with less effort.
    c. Improve cholesterol levels by raising HDL cholesterol and lowering LDL cholesterol and triglycerides.
    d. Manage blood sugar by improving insulin sensitivity, reducing the risk of Type 2 diabetes.

e. Reduce stress, as chronic stress can negatively impact cardiovascular health. Without regular movement, the body's systems become less efficient, increasing vulnerability to cardiovascular problems.

5. **Smoking (tobacco use):** Smoking is one of the most significant and preventable risk factors for heart disease. The harmful chemicals in tobacco smoke damage the entire cardiovascular system.

   a. Damages blood vessels: Toxins in smoke directly injure the cells lining the arteries, making them more prone to plaque build-up and hardening.

   b. Increases cholesterol levels: Smoking can lower HDL cholesterol and raise LDL cholesterol.

   c. Increases blood clotting, making the blood stickier and more likely to clot, which can block arteries leading to a heart attack or stroke.

   d. Raises blood pressure and heart rate, putting extra strain on the heart. Even passive exposure to tobacco smoke significantly increases the risk of heart disease.

Understanding these interconnected risk factors empowers individuals to make informed lifestyle choices and work with healthcare providers to mitigate their risk of developing heart disease.

Learning tasks

1. Explain the procedure of an angiogram and its role in diagnosing coronary artery disease.
2. Evaluate major risk factors for heart disease and analyse how each factor contributes to the development of cardiovascular disease.
3. Interpret case studies involving angiogram results and heart disease risk factors and propose evidence-based recommendations for clinical intervention or lifestyle changes to reduce cardiovascular risk.

Pedagogical Exemplar

Structuring Talk for Learning: Engage learners in a paired or small-group activity using sample angiogram images to identify blocked blood vessels. Facilitate a whole-class discussion where learners list and explore the risk factors for heart disease. Encourage them to share and justify their opinions on why these factors increase cardiovascular risk. Use probing and clarifying questions to deepen their understanding of how lifestyle, genetics, and lipid imbalances contribute to heart disease.

Key Assessment: Practice Paper 1

Level 3 (Strategic reasoning) - Multiple Choice Questions

1. Which lipoprotein is primarily responsible for transporting cholesterol away from tissues to the liver?

   a. VLDL

   b. LDL

   c. HDL

   d. IDL

2. A patient undergoes an angiogram, and the image shows restricted dye flow in the left coronary artery. What is the most likely interpretation of this finding?

   a. Blood should have been used instead of dye

   b. Reduced blood flow due to a blockage

   c. The dye was not injected correctly

   d. The heart muscle is inflamed

3. Which of the following patients is at the highest risk of heart disease?

   a. A 25-year-old athlete with elevated cholesterol after a high-protein meal.

   b. A 38-year-old with high LDL and borderline HDL levels.

   c. 57-year-old who exercises regularly and follows a strict diet plan.

   d. 30-year-old obese smoker with high blood pressure

4. A patient's angiogram shows a narrowing that blocks 40% of a coronary artery. The patient is asymptomatic. What is the most likely course of action?

   a. Schedule immediate bypass surgery.

   b. Lifestyle changes and regular monitoring.

   c. Prescribe medication to dissolve the blockage.

   d. Implant a coronary stent to widen the artery immediately.

5. A young adult has a strong family history of heart disease but normal cholesterol levels. Why should they still be monitored?

   a. Because family history is a risk factor.

   b. Because heart disease can occur at a young age.

   c. Because cholesterol is not a real factor in heart disease.

   d. Because monitoring is only needed if symptoms are present.

6. A community health program aims to lower heart disease rates by addressing lipid profiles. Which strategy would **most** effectively reduce LDL levels, and why?

   a. Encourage high-cholesterol foods to balance lipids.

   b. Increase saturated fat intake to boost HDL.

   c. Promote a diet rich in unsaturated fats.

   d. Reduce exercise to stabilise heart rates.

7. A patient's blood test shows low HDL and high LDL levels. Based on these concentrations, what is the **most likely** impact on their heart disease risk, and why?

   a. Increased risk, because low HDL impairs reverse transportation.

   b. Decreased risk, because the HDL and LDL levels balance out.

c. Increased risk, because LDL delivers cholesterol to the liver

d. Decreased risk, because high LDL reduces arterial plaque.

8. A patient's lipid profile shows:

HDL = 30 mg/dL (low)

LDL = 160 mg/dL (high)

Which of the following actions would **most likely** reduce the patient's risk of heart disease?

a. Avoid all dietary fats.

b. Increase intake of saturated fats.

c. Eat more carbohydrates for energy.

d. Increase intake of omega-3-rich foods.

9. A biology student claims that a certain lipid helps stabilize cell membranes and serves as a precursor for steroid hormones. Based on your understanding of lipid functions, which lipid **best fits** this description?

a. Triglyceride

b. Cholesterol

c. Phospholipid

d. Sphingolipid

10. A student argues that all fats are unhealthy. Based on what you know, how would you respond?

a. True, fats always increase disease risk.

b. False, only saturated fats are healthy.

c. True, avoiding fats improves cholesterol balance.

d. False, unsaturated fats are healthy.

Hint

*Conduct **Practice Paper 1**. It should cover the contents taught from Years 1 to 3. Refer to the **Table of Specifications and Structure of the Paper** at the end of this section. Learners' papers should be marked immediately, and scores entered into the SAP.*

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.

TABLE OF TEST SPECIFICATION – BIOMEDICAL SCIENCE

INTRODUCTION

Paper 1 will comprise of 50 multiple choice questions for a total of 50 marks. Paper 2 will consist of two parts, Sections A and B. Section A will consist of ten (10) compulsory structured questions for 2 marks each. There will be three (3) questions in total in Section B out of which candidates will be required to answer two (2) for 50 marks. There will be two (2) compulsory questions in Paper 3 for a total of 40 marks. Each of the two questions will have the same structure as indicated in the specification table. A record of all LIs/Levels used in each examination should be kept to ensure that all LIs are included over time.

NOTE: Sections coloured orange will be a replacement for the yellow-coloured sections during for the 1st semester Practice exams which will be taken around Week 10. This does not apply to the Mock examinations as this will span the whole of the curriculum.

PAPER 1

Strand 1: BIOMEDICAL SCIENCE IN SOCIETY

Sub-strand 1: Biomedical Science in Practice

Learning Outcomes	Content Standards	Learning Indicators	Levels of Assessment				Total
			1	2	3	4	
1.1.1.LO.1 Describe what biomedical science is and how scientific investigation is applied in biomedical science.	**1.1.1.CS.1** Demonstrate an understanding of Biomedical Science.	**1.1.1.LI.1** Explain what biomedical science is and what it is not.	1	0	0		1
		1.1.1.LI.2 Identify problems in the society that can be solved by applying biomedical science.	0	0	1		1
		1.1.1.LI.3 Explain how the scientific method can be applied to undertake investigations or address problems in biomedical science.	0	1	0		1
2.1.1.L.O.1 Describe various roles of biomedical scientists in society.	**2.1.1.CS.1** Explore the various roles of biomedical scientists in society.	**2.1.1.LI.1** Investigate and discuss a variety of biomedical science careers that relate to the prevention, diagnosis, and treatment of diseases.					
		2.1.1.LI.2 Discuss and describe the role of biomedical science professionals in forensics.	1	0	0		1
		2.1.1.LI.3 Explore any two/three biomedical career fields related to clinical or research studies and describe these career fields.	0	1	0		1

Learning Outcomes	Content Standards	Learning Indicators	Levels of Assessment				Total
3.1.1.L.O.1 Explain actions that can constitute malpractice, liability, and negligence and how the biomedical scientist can guard against them.	**3.1.1.CS.1** Demonstrate knowledge of good professional practice as a biomedical scientist.	**3.1.1.LI.1** Explain common practices that could result in malpractice, liability, and/or negligence in the field of biomedical science.	**0**	**0**	**1**		**1**
		3.1.1.LI.2 Describe the purpose of Informed Consent from the patient and healthcare provider perspective.	**0**	**1**	**0**		**1**
		3.1.1.LI.3 Identify and explain personal and long-term consequences of unethical or illegal behaviour in the workplace					
TOTAL			**2**	**3**	**2**		**7**

Strand 1: BIOMEDICAL SCIENCE IN SOCIETY

Sub-strand 2: Biosafety

Learning Outcomes	Content Standards	Learning Indicators	Levels of Assessment				Total
			1	**2**	**3**	**4**	
1.1.2.L.O.1 Describe various biohazards and critically analyse their routes of exposure.	**1.1.2.CS.1** Demonstrate an understanding of biohazards and analyse their routes of exposure.	**1.1.2.LI.1** Discuss the various biohazards as well as the risk groups.	**1**	**0**	**0**		**1**
		1.1.2.LI.2 Explain the routes of exposure of pathogens to humans.	**1**	**1**	**0**		**2**
		1.1.2.LI.3 Analyse Laboratory-acquired infections including some case studies	**0**	**1**	**1**		**2**

2.1.2.L.O.1 Explain the need for protection from biohazard exposure.	**2.1.2.CS.1** Demonstrate an understanding of the essence of protection from biohazard exposure.	**2.1.2.LI.1** Describe features of the biosafety levels and proper practice.	**0**	**1**	**0**		**1**
		2.1.2.LI.2 Demonstrate proper setup of biosafety cabinets and its environment.	**0**	**1**	**0**		**1**
		2.1.2.LI.3 Demonstrate proper methods for donning and removal of personal protective equipment (PPE) such as gloves, lab coats, eye protection and respiratory protection.	**0**	**1**	**0**		**1**
3.1.2.L.O.1 Apply the principles of biosafety to set up experiments.	**3.1.2.CS.1** Demonstrate knowledge and understanding of the principles of biosafety in setting up experiments.	**3.1.2.LI.1** Undertake proper planning of experiments to avoid accidents.	**1**	**0**	**0**		**1**
		3.1.2.LI.2 Identify the correct waste stream and demonstrate proper disposal of hazardous waste in the laboratory.	**0**	**1**	**0**		**1**
		3.1.2.LI.3 Identify and describe the role of biosafety professionals in biomedical research laboratories.					
TOTAL			**3**	**6**	**1**		**10**

Strand 2: HUMAN BODY SYSTEMS

Sub-strand 1: Human Anatomy and Physiology

Learning Outcomes	Content Standards	Learning Indicators	Levels of Assessment				Total
			1	2	3	4	
1.2.1.L.O.1 Identify the various human body systems and establish the interrelations between the systems for life.	**1.2.1.CS.1** Demonstrate an understanding of the human body systems and how they are interconnected.	**1.2.1.LI.1** Explore the structure, functions, and parts of the major human body systems involved in communication, power, movement, protection, and homeostasis.	1	0	1		2
		1.2.1.LI.2 Explain the interconnections between the human body systems and how these systems work together to maintain health and homeostasis	2	0	1		3
		1.2.1.LI.3 Evaluate how the interconnections and interactions of multiple body systems are necessary for life.					
2.2.1.L.O.1 Identify the various regions of the brain, and describe their functions and interconnectedness with some body systems for communication.	**2.2.1.CS.1** Demonstrate an understanding of the interconnectedness of some body systems for communication.	**2.2.1.LI.1** Explain the role of the brain and brain mapping play in the communication system of the human body.	0	1	1		2
		2.2.1.LI.2 Determine how communication works in the body and its effects.					
		2.2.1.LI.3 Describe the importance of technological tools in biomedical sciences to measure parameters associated with communication in the human body.	1	0	0		1

3.2.1.L.O.1 Describe the role of enzymes in digestion and explain how food, water, and oxygen are transported by the cardiovascular and respiratory systems.	**3.2.1.CS.1** Demonstrate an understanding of the interconnectedness of the body systems in energy generation and use (digestive, circulatory, and musculoskeletal systems).	**3.2.1.LI.1** Explain what enzymes are and their roles in the digestive system.	1	0	0		1
		3.2.1.LI.2 Explain the transport of oxygen, food, and water to all cells in the body through the connection between the respiratory and cardiovascular systems.	0	1	0		1
		3.2.1.LI.3 Describe how the interconnectedness of the body systems aids in energy generation.	0	0	1		1
		3.2.1.LI.4 Demonstrate an understanding of how joints and muscles use energy to contribute to the movement of the human body.					
TOTAL			5	2	4		11

Strand 2: HUMAN BODY SYSTEMS

Sub-strand 2: Diseases and Disorders

Learning Outcomes	Content Standards	Learning Indicators	Levels of Assessment				Total
			1	2	3	4	
1.2.2.L.O.1 Explain what a disease is with examples, identify the symptoms of common diseases, and illustrate how the symptoms of diseases lead to diagnosis.	**1.2.2.CS.1** Show an understanding of common diseases and conditions that can disrupt the functioning of cells, tissues, and organs within the body.	**1.2.2.LI.1** Explain what a disease is.	0	0	1		1
		1.2.2.LI.2 Explore how initial symptoms of an illness can be used for diagnosis and treatment.	0	0	1		1
		1.2.2.LI.3 Explore the symptoms and factors contributing to sickle cell disease and its impact on humans.	0	1	1		2

2.2.2.L.O.1 Describe how malfunctions in the nervous and endocrine systems affect other body systems and lifestyle.	**2.2.2.CS.1** Apply knowledge of human body systems to indicate how damage to one system can impact function in another system.	**2.2.2.LI.1** Explain how serious nervous system disorders impact the quality of life.	**0**	**1**	**0**		**1**
		2.2.2.LI.2 Interpret the symptoms and physical characteristics of a given patient to determine an endocrine system malfunction (e.g., hyperthyroidism).					
		2.2.2.LI.3 Identify and discuss the causes, symptoms, treatments, effects, and impact of diabetes on the human body and human lifestyle.	**0**	**1**	**0**		**1**
2.2.2.L.O.2 Understand how the structure of bacteria and virus dictates treatment protocols, concept of immune response and the impact of infections in the society.	**2.2.2.CS.2** Demonstrate knowledge of bacteria and viruses as causative agents of infectious diseases.	**2.2.2.LI.1** Identify the structural differences between bacteria and viruses.					
		2.2.2.LI.2 Explore the symptoms, prevalence, and treatment of bacterial and viral infections considering infections of the reproductive system.	**0**	**0**	**1**		**1**
		2.2.2.LI.3 Explore the immune response in relation to the introduction of antigens.	**0**	**1**	**0**		**1**
		2.2.2.LI.4 Analyse how antibiotics are used to treat infections and explain how the effectiveness depends on the causative bacteria.	**0**	**1**	**0 or 1**		**1 or 2**
		2.2.2.LI.5 Discuss the global and social impact of an infectious disease that is caused by bacteria or viruses.	**1**	**0**	**0**		**1**

3.2.2.L.O.1 Describe the different types of lipids in the body, and explain how cholesterol-lipoprotein complexes affect the risk of heart diseases and how the risk of heart diseases may be assessed.	**3.2.2.CS.1** Demonstrate an understanding of the function of cholesterol in the body and its role in heart disease.	**3.2.2.LI.1** Describe the different types of lipid molecules and their different physical properties and functions.	**0**	**0**	**1**		**1**
		3.2.2.LI.2 Explain how cholesterol is transported in the blood by high-density lipoprotein (HDL) and low-density lipoprotein (LDL) and the role each of them plays in the body.					
		3.2.2.LI.3 Describe how the concentrations of these complexes (HDL and LDL) affect a person's risk of heart disease.					
		3.2.2.LI.4 Describe the function of an angiogram in diagnosing blocked vessels and discuss the risk factors for heart disease.					
TOTAL			**1**	**5**	**5**		**11**

Strand 3: BIOMEDICAL INTERVENTION

Sub-strand 1: Diagnostic Devices

Learning Outcomes	Content Standards	Learning Indicators	Levels of Assessment				Total
			1	2	3	4	
1.3.1.L.O.1 Explain medical intervention. Identify and describe various diagnostic medical interventions.	**1.3.1.CS.1** Explore medical interventions and their relevance to diagnosis.	**1.3.1.LI.1** Explain medical intervention in relation to diagnosis, therapy, and prevention.	**0**	**0**	**0**		**0**
		1.3.1.LI.2 Compare and contrast primitive diagnostic medical interventions and modern diagnostic devices.	**0**	**1**	**0**		**1**
		1.3.1.LI.3 Explore the significance of the various diagnostic devices used for medical intervention.	**1**	**0**	**0**		**1**

2.3.1.L.O.1 Describe the importance of technology in clinical diagnosis, the composition of diagnostic medical devices and explain basic principles relating to diagnostic medical device design.	**2.3.1.CS.1** Demonstrate an understanding of the concepts applied to build diagnostic devices.	**2.3.1.LI.1** Investigate the application of technology in the provision of healthcare.	**0**	**1**	**0**		**1**
		2.3.1.LI.2 Identify the components of a typical diagnostic device and its functions.	**1**	**0**	**0**		**1**
		2.3.1.LI.3 Discuss the bioinstrumentation principles used in the construction of a diagnostic device.			**0 or 1**		
3.3.1.LO.1 Design and construct some basic medical devices and pitch them to potential investors.	**3.3.1.CS.1** Demonstrate understanding of the knowledge and skills required to design and construct some basic medical devices.	**3.3.1.LI.1** Evaluate the role of biomedical engineers in the production, acquisition and maintenance of medical devices.	**0**	**0**	**1**		**1**
		3.3.1.LI.2 Design and construct a simple diagnostic device and assemble the units of a medical device.					
		3.3.1.LI.3 Develop a marketing plan to pitch the designed device to potential investors.					
TOTAL			**2**	**2**	**1**		**5**

Strand 3: BIOMEDICAL INTERVENTION

Sub-strand 2: Therapeutic Devices

Learning Outcomes	Content Standards	Learning Indicators	Levels of Assessment				Total
			1	2	3	4	
1.3.2.L.O.1 Identify the forms of therapy and describe the roles of various therapists and the tools they use in healthcare delivery.	**1.3.2.CS.1** Demonstrate an understanding of the use of therapeutic devices for medical intervention.	**1.3.2.LI.1** Identify the various forms of therapy.	**0**	**1**	**0**		**1**
		1.3.2.LI.2 Investigate who a therapist is and enumerate the various specialties					
		1.3.2.LI.3 Identify the various therapeutic devices used by the therapist.					
2.3.2.L.O.1 Describe some treatment and management strategies for cancer, disabilities, damaged tissues and organs.	**2.3.2.CS.1** Explore how therapies are used in health facilities to address health problems.	**2.3.2.LI.1** Explain the use of prostheses and orthoses to manage, correct and treat disabilities.	**0**	**1**	**0**		**1**
		2.3.2.LI.2 Investigate the treatments and therapies available to treat cancer and their physical, mental and emotional effects.	**0**	**0**	**1**		**1**
		2.3.2.LI.3 Explore the future application of regenerative medicine for patients with disabilities.					
3.3.2.L.O.1 Identify constituent components of a therapeutic device, develop an operating manual for a medical device and describe the regulatory processes for medical devices.	**3.3.2.CS.1** Demonstrate an understanding of the interconnections among components of therapeutic devices and explain the medical device regulation process.	**3.3.2.LI.1** Disassemble and assemble components of a therapeutic device.					
		3.3.2.LI.2 Develop an operating manual for a therapeutic device.					
		3.3.2.LI.3 Discuss the role of regulatory agencies in the production and marketing of medical devices.					
TOTAL			**0**	**2**	**1**		**3**

Strand 4: BIOMEDICAL INNOVATIONS

Sub-strand 1: Research and Design in Biomedical Science

Learning Outcomes	Content Standards	Learning Indicators	Levels of Assessment				Total
			1	2	3	4	
1.4.1.LO.1 Use credible online resources to research and propose solutions to healthcare problems	**1.4.1.CS.1** Demonstrate knowledge of how to access and use information from credible sources	**1.4.1.LI.1** Analyse website content and assess overall credibility of the information.	1	0	0		1
		1.4.1.LI.2 Use online search engines and journal databases to locate reliable scientific articles.					
		1.4.1.LI.3 Use different approaches to propose solutions to healthcare problems in the country					
		1.4.1.LI.4 Make an effective presentation of scientific information on a healthcare issue.					
2.4.1.LO.1 Use scientific literature and statistics to design experiment and analyse results.	**2.4.1.CS.1** Demonstrate understanding and application of a variety of biomedical experimental designs.	**2.4.1.LI.1** Critique and compare science and data presented in popular media and data presented in scientific journals.	1	0	0		1
		2.4.1.LI.2 Apply knowledge of specified statistical analysis methods to analyse the results of experimental studies.	0	0	1		1
3.4.1.LO.1 Use scientific literature and statistics to design experiments and analyse results.	**3.4.1.CS.1** Demonstrate understanding and application of a variety of biomedical experimental designs.	**3.4.1.LI.1** Apply knowledge of specified statistical analysis methods to analyse the results of experimental studies.					
		3.4.1.LI.2 Design, conduct and analyse an experimental study to answer a question relating to human health					
TOTAL			2	0	1		3
OVERALL TOTAL			15	20	15		50

TABLE OF TEST SPECIFICATION FOR PAPER 2

SECTION A

Strand 1: BIOMEDICAL SCIENCE IN SOCIETY

Sub-strand 1: Biomedical Science in Practice

Learning Outcomes	Content Standards	Learning Indicators	Levels of Assessment				Total
			1	2	3	4	
1.1.1.LO.1 Describe what biomedical science is and how scientific investigation is applied in biomedical science.	**1.1.1.CS.1** Demonstrate an understanding of Biomedical Science.	**1.1.1.LI.1** Explain what biomedical science is and what it is not.		1			1
		1.1.1.LI.2 Identify problems in the society that can be solved by applying biomedical science.					
		1.1.1.LI.3 Explain how the scientific method can be applied to undertake investigations or address problems in biomedical science.					

Learning Outcomes	Content Standards	Learning Indicators	**Levels of Assessment**				**Total**
2.1.1.L.O.1 Describe various roles of biomedical scientists in society.	**2.1.1.CS.1** Explore the various roles of biomedical scientists in society.	**2.1.1.LI.1** Investigate and discuss a variety of biomedical science careers that relate to the prevention, diagnosis, and treatment of diseases.					
		2.1.1.LI.2 Discuss and describe the role of biomedical science professionals in forensics.					
		2.1.1.LI.3 Explore any two/three biomedical career fields related to clinical or research studies and describe these career fields.					
3.1.1.L.O.1 Explain actions that can constitute malpractice, liability, and negligence and how the biomedical scientist can guard against them.	**3.1.1.CS.1** Demonstrate knowledge of good professional practice as a biomedical scientist.	**3.1.1.LI.1** Explain common practices that could result in malpractice, liability, and/or negligence in the field of biomedical science.					
		3.1.1.LI.2 Describe the purpose of Informed Consent from the patient and healthcare provider perspective.					
		3.1.1.LI.3 Identify and explain personal and long-term consequences of unethical or illegal behaviour in the workplace					
TOTAL			**0**	**1**			**1**

Strand 1: BIOMEDICAL SCIENCE IN SOCIETY

Sub-strand 2: Biosafety

Learning Outcomes	Content Standards	Learning Indicators	**Levels of Assessment**				**Total**
			1	**2**	**3**	**4**	
1.1.2.L.O.1 Describe various biohazards and critically analyse their routes of exposure.	**1.1.2.CS.1** Demonstrate an understanding of biohazards and analyse their routes of exposure.	**1.1.2.LI.1** Discuss the various biohazards as well as the risk groups.		**1**	**1**		**2**
		1.1.2.LI.2 Explain the routes of exposure of pathogens to humans.					
		1.1.2.LI.3 Analyse Laboratory-acquired infections including some case studies					
2.1.2.L.O.1 Explain the need for protection from biohazard exposure.	**2.1.2.CS.1** Demonstrate an understanding of the essence of protection from biohazard exposure.	**2.1.2.LI.1** Describe features of the biosafety levels and proper practice.					
		2.1.2.LI.2 Demonstrate proper setup of biosafety cabinets and its environment.					
		2.1.2.LI.3 Demonstrate proper methods for donning and removal of personal protective equipment (PPE) such as gloves, lab coats, eye protection and respiratory protection.					

3.1.2.L.O.1 Apply the principles of biosafety to set up experiments.	**3.1.2.CS.1** Demonstrate knowledge and understanding of the principles of biosafety in setting up experiments.	**3.1.2.LI.1** Undertake proper planning of experiments to avoid accidents.					
		3.1.2.LI.2 Identify the correct waste stream and demonstrate proper disposal of hazardous waste in the laboratory.					
		3.1.2.LI.3 Identify and describe the role of biosafety professionals in biomedical research laboratories.					
TOTAL			**0**	**1**	**1**		**2**

Strand 2: HUMAN BODY SYSTEMS

Sub-strand 1: Human Anatomy and Physiology

Learning Outcomes	Content Standards	Learning Indicators	Levels of Assessment				Total
			1	**2**	**3**	**4**	
1.2.1.L.O.1 Identify the various human body systems and establish the interrelations between the systems for life.	**1.2.1.CS.1** Demonstrate an understanding of the human body systems and how they are interconnected.	**1.2.1.LI.1** Explore the structure, functions, and parts of the major human body systems involved in communication, power, movement, protection, and homeostasis.		**1**	**1**		**2**
		1.2.1.LI.2 Explain the interconnections between the human body systems and how these systems work together to maintain health and homeostasis					

		1.2.1.LI.3 Evaluate how the interconnections and interactions of multiple body systems are necessary for life.					
2.2.1.L.O.1 Identify the various regions of the brain, and describe their functions and interconnectedness with some body systems for communication.	**2.2.1.CS.1** Demonstrate an understanding of the interconnectedness of some body systems for communication.	**2.2.1.LI.1** Explain the role of the brain and brain mapping play in the communication system of the human body.					
		2.2.1.LI.2 Determine how communication works in the body and its effects.					
		2.2.1.LI.3 Describe the importance of technological tools in biomedical sciences to measure parameters associated with communication in the human body.					
3.2.1.L.O.1 Describe the role of enzymes in digestion and explain how food, water, and oxygen are transported by the cardiovascular and respiratory systems.	**3.2.1.CS.1** Demonstrate an understanding of the interconnectedness of the body systems in energy generation and use (digestive, circulatory, and musculoskeletal systems).	**3.2.1.LI.1** Explain what enzymes are and their roles in the digestive system.					
		3.2.1.LI.2 Explain the transport of oxygen, food, and water to all cells in the body through the connection between the respiratory and cardiovascular systems.					

		3.2.1.LI.3 Describe how the interconnectedness of the body systems aids in energy generation.					
		3.2.1.LI.4 Demonstrate an understanding of how joints and muscles use energy to contribute to the movement of the human body.					
TOTAL			**0**	**1**	**1**	**0**	**2**

Strand 2: HUMAN BODY SYSTEMS

Sub-strand 2: Diseases and Disorders

Learning Outcomes	**Content Standards**	**Learning Indicators**	**Levels of Assessment**				**Total**
			1	**2**	**3**	**4**	
1.2.2.L.O.1 Explain what a disease is with examples, identify the symptoms of common diseases, and illustrate how the symptoms of diseases lead to diagnosis.	**1.2.2.CS.1** Show an understanding of common diseases and conditions that can disrupt the functioning of cells, tissues, and organs within the body.	**1.2.2.LI.1** Explain what a disease is.		**1**	**1**		**2**
		1.2.2.LI.2 Explore how initial symptoms of an illness can be used for diagnosis and treatment.					
		1.2.2.LI.3 Explore the symptoms and factors contributing to sickle cell disease and its impact on humans.					

2.2.2.L.O.1 Describe how malfunctions in the nervous and endocrine systems affect other body systems and lifestyle.	**2.2.2.CS.1** Apply knowledge of human body systems to indicate how damage to one system can impact function in another system.	**2.2.2.LI.1** Explain how serious nervous system disorders impact the quality of life.					
		2.2.2.LI.2 Interpret the symptoms and physical characteristics of a given patient to determine an endocrine system malfunction (e.g., hyperthyroidism).					
		2.2.2.LI.3 Identify and discuss the causes, symptoms, treatments, effects, and impact of diabetes on the human body and human lifestyle.					
2.2.3.L.O.2 Understand how the structure of bacteria and virus dictates treatment protocols, concept of immune response and the impact of infections in the society.	**2.2.3.CS.2** Demonstrate knowledge of bacteria and viruses as causative agents of infectious diseases.	**2.2.3.LI.1** Identify the structural differences between bacteria and viruses.					
		2.2.3.LI.2 Explore the symptoms, prevalence, and treatment of bacterial and viral infections considering infections of the reproductive system.					
		2.2.3.LI.3 Explore the immune response in relation to the introduction of antigens.					

		2.2.2.LI.4 Analyse how antibiotics are used to treat infections and explain how the effectiveness depends on the causative bacteria.					
		2.2.2.LI.5 Discuss the global and social impact of an infectious disease that is caused by bacteria or viruses.					
3.2.2.L.O.1 Describe the different types of lipids in the body, and explain how cholesterol-lipoprotein complexes affect the risk of heart diseases and how the risk of heart diseases may be assessed.	**3.2.2.CS.1** Demonstrate an understanding of the function of cholesterol in the body and its role in heart disease.	**3.2.2.LI.1** Describe the different types of lipid molecules and their different physical properties and functions.					
		3.2.2.LI.2 Explain how cholesterol is transported in the blood by high-density lipoprotein (HDL) and low-density lipoprotein (LDL) and the role each of them plays in the body.					
		3.2.2.LI.3 Describe how the concentrations of these complexes (HDL and LDL) affect a person's risk of heart disease.					

		3.2.2.LI.4 Describe the function of an angiogram in diagnosing blocked vessels and discuss the risk factors for heart disease.					
TOTAL			**0**	**1**	**1**	**0**	**2**

Strand 3: BIOMEDICAL INTERVENTION

Sub-strand 1: Diagnostic Devices

Learning Outcomes	**Content Standards**	**Learning Indicators**	**Levels of Assessment**				**Total**
			1	**2**	**3**	**4**	
1.3.1.L.O.1 Explain medical intervention. Identify and describe various diagnostic medical interventions.	**1.3.1.CS.1** Explore medical interventions and their relevance to diagnosis.	**1.3.1.LI.1** Explain medical intervention in relation to diagnosis, therapy, and prevention.		**1**			**1**
		1.3.1.LI.2 Compare and contrast primitive diagnostic medical interventions and modern diagnostic devices.					
		1.3.1.LI.3 Explore the significance of the various diagnostic devices used for medical intervention.					

2.3.1.L.O.1 Describe the importance of technology in clinical diagnosis, the composition of diagnostic medical devices and explain basic principles relating to diagnostic medical device design.	**2.3.1.CS.1** Demonstrate an understanding of the concepts applied to build diagnostic devices.	**2.3.1.LI.1** Investigate the application of technology in the provision of healthcare.					
		2.3.1.LI.2 Identify the components of a typical diagnostic device and its functions.					
		2.3.1.LI.3 Discuss the bio-instrumentation principles used in the construction of a diagnostic device.					
3.3.1.LO.1 Design and construct some basic medical devices and pitch them to potential investors.	**3.3.1.CS.1** Demonstrate understanding of the knowledge and skills required to design and construct some basic medical devices.	**3.3.1.LI.1** Evaluate the role of biomedical engineers in the production, acquisition and maintenance of medical devices.					
		3.3.1.LI.2 Design and construct a simple diagnostic device and assemble the units of a medical device.					
		3.3.1.LI.3 Develop a marketing plan to pitch the designed device to potential investors.					
TOTAL			**0**	**1**	**0**	**0**	**1**

Strand 3: BIOMEDICAL INTERVENTION

Sub-strand 2: Therapeutic Devices

Learning Outcomes	Content Standards	Learning Indicators	Levels of Assessment				Total
			1	2	3	4	
1.3.2.L.O.1 Identify the forms of therapy and describe the roles of various therapists and the tools they use in healthcare delivery.	**1.3.2.CS.1** Demonstrate an understanding of the use of therapeutic devices for medical intervention.	**1.3.2.LI.1** Identify the various forms of therapy.		**1**			**1**
		1.3.2.LI.2 Investigate who a therapist is and enumerate the various specialties					
		1.3.2.LI.3 Identify the various therapeutic devices used by the therapist.					
2.3.2.L.O.1 Describe some treatment and management strategies for cancer, disabilities, damaged tissues and organs.	**2.3.2.CS.1** Explore how therapies are used in health facilities to address health problems.	**2.3.2.LI.1** Explain the use of prostheses and orthoses to manage, correct and treat disabilities.					
		2.3.2.LI.2 Investigate the treatments and therapies available to treat cancer and their physical, mental and emotional effects.					
		2.3.2.LI.3 Explore the future application of regenerative medicine for patients with disabilities.					

3.3.2.L.O.1 Identify constituent components of a therapeutic device, develop an operating manual for a medical device and describe the regulatory processes for medical devices.	**3.3.2.CS.1** Demonstrate an understanding of the interconnections among components of therapeutic devices and explain the medical device regulation process.	**3.3.2.LI.1** Disassemble and assemble components of a therapeutic device.					
		3.3.2.LI.2 Develop an operating manual for a therapeutic device.					
		3.3.2.LI.3 Discuss the role of regulatory agencies in the production and marketing of medical devices.					
TOTAL			**0**	**1**	**0**	**0**	**1**

Strand 4: BIOMEDICAL INNOVATIONS

Sub-strand 1: Research and Design in Biomedical Science

Learning Outcomes	**Content Standards**	**Learning Indicators**	**Levels of Assessment**				**Total**
			1	**2**	**3**	**4**	
1.4.1.LO.1 Use credible online resources to research and propose solutions to healthcare problems	**1.4.1.CS.1** Demonstrate knowledge of how to access and use information from credible sources	**1.4.1.LI.1** Analyse website content and assess overall credibility of the information.			**1**		**1**
		1.4.1.LI.2 Use online search engines and journal databases to locate reliable scientific articles.					

		1.4.1.LI.3 Use different approaches to propose solutions to healthcare problems in the country					
		1.4.1.LI.4 Make an effective presentation of scientific information on a healthcare issue.					
2.4.1.LO.1 Use scientific literature and statistics to design experiments and analyse results.	**2.4.1.CS.1** Demonstrate understanding and application of a variety of biomedical experimental designs.	**2.4.1.LI.1** Critique and compare science and data presented in popular media and data presented in scientific journals.					
		2.4.1.LI.2 Apply knowledge of specified statistical analysis methods to analyse the results of experimental studies.					
3.4.1.LO.1 Use scientific literature and statistics to design experiments and analyse results.	**3.4.1.CS.1** Demonstrate understanding and application of a variety of biomedical experimental designs.	**3.4.1.LI.1** Apply knowledge of specified statistical analysis methods to analyse the results of experimental studies.					
		3.4.1.LI.2 Design, conduct and analyse an experimental study to answer a question relating to human health					
TOTAL			**0**	**6**	**4**	**0**	**10**

PAPER 2 – SECTION B

Each of the three questions will have the same structure as indicated in the specification table below.

Strand	Sub-strand	Learning Outcomes	Levels of Assessment				Total
			1	2	3	4	
BIOMEDICAL SCIENCE IN SOCIETY	**Biomedical Science in Practice**	**1.1.1.LO.1** Describe what biomedical science is and how scientific investigation is applied in biomedical science.	1		1		2
		2.1.1.L.O.1 Describe various roles of biomedical scientists in society.					
		3.1.1.L.O.1 Explain actions that can constitute malpractice, liability, and negligence and how the biomedical scientist can guard against them.					
	Biosafety	**1.1.2.L.O.1** Describe various biohazards and critically analyse their routes of exposure.					
		2.1.2.L.O.1 Explain the need for protection from biohazard exposure. **2.1.1.LI.2** Discuss and describe the role of biomedical science professionals in forensics. **2.1.1.LI.3** Explore any two/three biomedical career fields related to clinical or research studies and describe these career fields.					

Strand	Sub-strand	Learning Outcomes	Levels of Assessment				Total
		3.1.2.L.O.1 Apply the principles of biosafety to set up experiments. **3.1.1.LI.2** Describe the purpose of Informed Consent from the patient and healthcare provider perspective. **3.1.1.LI.3** Identify and explain personal and long-term consequences of unethical or illegal behaviour in the workplace					
TOTAL			**1**		**1**		**2**

Strand	Sub-strand	Learning Outcomes	Levels of Assessment				Total
			1	2	3	4	
HUMAN BODY SYSTEM	**Anatomy and Physiology**	**1.2.1.L.O.1** Identify the various human body systems and establish the interrelations between the systems for life.	**2**		**3**		**5**
		2.2.1.L.O.1 Identify the various regions of the brain, and describe their functions and interconnectedness with some body systems for communication.					
		3.2.1.L.O.1 Describe the role of enzymes in digestion and explain how food, water, and oxygen are transported by the cardiovascular and respiratory systems.					

	Diseases and Disorders	**1.2.2.L.O.1** Explain what a disease is with examples, identify the symptoms of common diseases, and illustrate how the symptoms of diseases lead to diagnosis.					
		2.2.2.L.O.1 Describe how malfunctions in the nervous and endocrine systems affect other body systems and lifestyle.					
		2.2.2.L.O.2 Understand how the structure of bacteria and virus dictates treatment protocols, concept of immune response and the impact of infections in the society.					
		3.2.2.L.O.1 Describe the different types of lipids in the body, and explain how cholesterol-lipoprotein complexes affect the risk of heart diseases and how the risk of heart diseases may be assessed.					
TOTAL			**2**		**3**		**5**

Strand	**Sub-strand**	**Learning Outcomes**	**Levels of Assessment**				**Total**
			1	**2**	**3**	**4**	
BIOMEDICAL INTERVENTION	**Diagnostic Devices**	**1.3.1.L.O.1** Explain medical intervention. Identify and describe various diagnostic medical interventions.	**1**		**1**		**2**

		2.3.1.L.O.1 Describe the importance of technology in clinical diagnosis, the composition of diagnostic medical devices and explain basic principles relating to diagnostic medical device design.					
		3.3.1.LO.1 Design and construct some basic medical devices and pitch them to potential investors.					
	Therapeutic Devices	**1.3.2.L.O.1** Identify the forms of therapy and describe the roles of various therapists and the tools they use in healthcare delivery.					
		2.3.2.L.O.1 Describe some treatment and management strategies for cancer, disabilities, damaged tissues and organs.					
		3.3.2.L.O.1 Identify constituent components of a therapeutic device, develop an operating manual for a medical device and describe the regulatory processes for medical devices.					
TOTAL			**1**		**1**		**2**

Strand	Sub-strand	Learning Outcomes	Levels of Assessment				Total
			1	2	3	4	
BIOMEDICAL INNOVATIONS	**Research and Design in Biomedical Science**	**1.4.1.LO.1** Use credible online resources to research and propose solutions to healthcare problems			1		1
		2.4.1.LO.1 Use scientific literature and statistics to design experiments and analyse results.					
		3.4.1.LO.1 Use scientific literature and statistics to design experiments and analyse results.					
TOTAL			4		6		10

TABLE OF TEST SPECIFICATION FOR PAPER 3 (PRACTICAL-BASED TEST)

Each of the two questions will have the same structure as indicated in the specification table below.

Strand	Sub-strand	Learning Outcomes	Levels of Assessment				Total
			1	2	3	4	
BIOMEDICAL SCIENCE IN SOCIETY	**Biomedical Science in Practice**	**1.1.1.LO.1** Describe what biomedical science is and how scientific investigation is applied in biomedical science.	1		1		2
		2.1.1.L.O.1 Describe various roles of biomedical scientists in society.					

Strand	Sub-strand	Learning Outcomes	Levels of Assessment				Total
		3.1.1.L.O.1 Explain actions that can constitute malpractice, liability, and negligence and how the biomedical scientist can guard against them.					
	Biosafety	**1.1.2.L.O.1** Describe various biohazards and critically analyse their routes of exposure.					
		2.1.2.L.O.1 Explain the need for protection from biohazard exposure. **2.1.1.LI.2** Discuss and describe the role of biomedical science professionals in forensics. **2.1.1.LI.3** Explore any two/three biomedical career fields related to clinical or research studies and describe these career fields.					
		3.1.2.L.O.1 Apply the principles of biosafety to set up experiments. **3.1.1.LI.2** Describe the purpose of Informed Consent from the patient and healthcare provider perspective. **3.1.1.LI.3** Identify and explain personal and long-term consequences of unethical or illegal behaviour in the workplace					

Strand	Sub-strand	Learning Outcomes	Levels of Assessment				Total
TOTAL			1		1		2

Strand	Sub-strand	Learning Outcomes	Levels of Assessment				Total
			1	2	3	4	
HUMAN BODY SYSTEM	Anatomy and Physiology	1.2.1.L.O.1 Identify the various human body systems and establish the interrelations between the systems for life.	2		3		5
		2.2.1.L.O.1 Identify the various regions of the brain, and describe their functions and interconnectedness with some body systems for communication.					
		3.2.1.L.O.1 Describe the role of enzymes in digestion and explain how food, water, and oxygen are transported by the cardiovascular and respiratory systems.					
	Diseases and Disorders	1.2.2.L.O.1 Explain what a disease is with examples, identify the symptoms of common diseases, and illustrate how the symptoms of diseases lead to diagnosis.					
		2.2.2.L.O.1 Describe how malfunctions in the nervous and endocrine systems affect other body systems and lifestyle.					

		2.2.2.L.O.2 Understand how the structure of bacteria and virus dictates treatment protocols, concept of immune response and the impact of infections in the society.					
		3.2.2.L.O.1 Describe the different types of lipids in the body, and explain how cholesterol-lipoprotein complexes affect the risk of heart diseases and how the risk of heart diseases may be assessed.					
TOTAL			2		3		5

Strand	Sub-strand	Learning Outcomes	Levels of Assessment				Total
			1	2	3	4	
BIOMEDICAL INTERVENTION	Diagnostic Devices Therapeutic Devices	1.3.1.L.O.1 Explain medical intervention. Identify and describe various diagnostic medical interventions.	1		1		2
		2.3.1.L.O.1 Describe the importance of technology in clinical diagnosis, the composition of diagnostic medical devices and explain basic principles relating to diagnostic medical device design.					
		3.3.1.LO.1 Design and construct some basic medical devices and pitch them to potential investors.					
		1.3.2.L.O.1 Identify the forms of therapy and describe the roles of various therapists and the tools they use in healthcare delivery.					

		2.3.2.L.O.1 Describe some treatment and management strategies for cancer, disabilities, damaged tissues and organs.					
		3.3.2.L.O.1 Identify constituent components of a therapeutic device, develop an operating manual for a medical device and describe the regulatory processes for medical devices.					
TOTAL			**1**		**1**		**2**

Strand	**Sub-strand**	**Learning Outcomes**	**Levels of Assessment**				**Total**
			1	**2**	**3**	**4**	
BIOMEDICAL INNOVATIONS	**Research and Design in Biomedical Science**	**1.4.1.LO.1** Use credible online resources to research and propose solutions to healthcare problems			**1**		**1**
		2.4.1.LO.1 Use scientific literature and statistics to design experiments and analyse results.					
		3.4.1.LO.1 Use scientific literature and statistics to design experiments and analyse results.					
TOTAL			**4**		**6**		**10**

Section Review

This section reviews all the lessons taught over the last four (4) weeks. A summary of what should have been taught and what each learner should have learnt if differentiation had been done.

1. What are the different types of lipid molecules found in the human body?
2. What are the physical properties and biological functions of lipids such as triglycerides, phospholipids, and cholesterol?
3. How is cholesterol transported in the blood?
4. What is the role of high-density lipoprotein (HDL) and low-density lipoprotein (LDL) in the body?
5. How do abnormal levels of HDL and LDL contribute to heart disease?
6. What is an angiogram, and how is it used in diagnosing blocked blood vessels?
7. How do risk factors such as lifestyle and genetic factors influence lipid levels and cardiovascular risk?

Lipids are a diverse group of biological molecules essential for energy storage, membrane structure, and hormone production. Cholesterol is a vital lipid transported in the blood by lipoproteins such as HDL and LDL. While HDL helps remove excess cholesterol from the bloodstream, LDL delivers cholesterol to tissues. An imbalance in these complexes, such as high LDL and low HDL, increases the risk of atherosclerosis and heart disease. Angiograms are medical imaging tools used to detect blood vessel blockages and help diagnose cardiovascular conditions. Understanding the types, functions, and transport mechanisms of lipids, as well as their impact on health and wellbeing, enables learners to interpret clinical data and recognise how lifestyle, genetic factors, and diet influence disease risk.

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 9

Question 1

Marking scheme and rubric

a. Award 1 mark for each point clearly explained and linked to high levels of saturated fats.

Clearly explains the following effects and links them to the high levels of saturated fat in a logical manner.

i. increase LDL levels

ii. promote cholesterol plaque formation or atherosclerosis,

iii. Narrows the arteries and

iv. Raises blood pressure

v. increases risk of cardiovascular disease.

b. Understanding of omega-3 Fatty acid role (2 marks)

i. Award 2 marks if a student explains that omega-3 fatty acids help lower LDL by raising HDL levels.

Award 1 mark if a student mentions omega-3 reduces heart disease risk with no explanation.

ii. Accept any 1 of the following or any relevant answer for 1 mark (Total = 2 marks)

a. Nuts and seeds: almonds, walnuts, chia seeds, flaxseeds

b. Healthy fats: avocados, olive oil, canola oil

c. Fatty fish (rich in omega-3 fatty acids): salmon, mackerel, sardines, tuna, herring

Question 2

Award 2 marks for each of the following.

1. Structural difference between phospholipids and triglycerides (2 marks): Correctly identifies that phospholipids have a hydrophilic phosphate group and two hydrophobic fatty acid tails, while triglycerides have three hydrophobic fatty acid tails and lack a polar head.
2. Impact on membrane formation (2 marks): Explains that triglycerides cannot form bilayers due to the absence of a polar (hydrophilic) head, unlike phospholipids.
3. Functional consequences (2 marks): Predicts loss of selective permeability or inability to form a functional membrane barrier due to the lack of amphipathic structure.

Example full-mark response: Phospholipids have a hydrophilic phosphate head and two hydrophobic tails, allowing them to form bilayers. Triglycerides, with three hydrophobic tails and no polar head, cannot form a bilayer. Replacing phospholipids with triglycerides would prevent membrane formation, thereby reducing selective permeability.

Question 3

1. Identification of lipid types and their biological roles (3 marks)

Award 1 mark for each role correctly identified. Accept these or any other relevant answers

- **a.** Triglycerides are the main energy storage form of lipids, consisting of one glycerol and three fatty acids.
- **b.** Identifies those phospholipids that form the structural basis of cell membranes due to the amphipathic nature of the bilayer.
- **c.** States that cholesterol regulates membrane fluidity and is a precursor for steroid hormones.

2. Analysis of consequences of lipid imbalance (3 marks)

Award 1 mark for each correctly analysed consequence. Accept these or any other relevant answers

- **a.** Explains that excess triglycerides may lead to obesity, fatty liver, and increased cardiovascular risk.
- **b.** Explains that low phospholipids may cause impaired membrane function, affecting cell transport, signalling, and membrane integrity.
- **c.** States that low cholesterol reduces the synthesis of essential hormones (e.g., oestrogen, testosterone, cortisol) and vitamin D, affecting metabolism, reproduction, and immune function.

WEEK 10

Question 1

Award 2 marks for each correct consequence. Accept any of the following consequences, rightly predicted and well explained or any other relevant answer.

1. Identification of lipoprotein function correctly states that lipoproteins transport lipids (triglycerides and cholesterol) in the bloodstream.
2. Prediction of transport disruption predicts that defective lipoproteins would impair the transport of lipids, leading to accumulation in the blood vessels or poor lipid delivery to cells.
3. Health consequences: explains that this disruption can lead to cardiovascular problems (e.g., atherosclerosis, heart disease), reduced energy production, as well as synthesis issues for some hormone and fat-soluble vitamins (A, D, E, K).

Question 2

- **a.** Explanation of triglycerides, cholesterol, and LDLs with their roles (6 marks). *Award 2 marks for each correct definition and corresponding role*
  - Clear and accurate explanation of triglycerides as the main form of stored fat in the body, used for long-term energy storage.
  - Clear and accurate description of cholesterol as a lipid-derived molecule essential for building cell membranes and producing hormones and vitamin D.
  - Explanation of LDLs as specialised protein-lipid complexes that act as sophisticated transport vehicles to transport cholesterol from its site of synthesis in the liver to the cells; commonly labelled "bad cholesterol" because high levels can lead to plaque build-up in arteries.
- **b.** Reasons lipoproteins are needed to transport triglycerides and cholesterol (2 marks)

  Award 1 mark for each reason.
  - Explanation that triglycerides and cholesterol are lipids, which are hydrophobic (insoluble in water), so they cannot move freely in the aqueous plasma of blood.
  - Lipoproteins serve as specialised carriers that encase these lipids, making them soluble enough to be transported through the circulatory system.
- **c.** Implications of Kojo's lipid levels and lifestyle recommendation(s) (2 marks).

  Award 1 mark for any relevant explanation given
  - Explanation that elevated triglycerides and LDL levels are primarily responsible for plaque build-up of fatty deposits on the blood vessel walls (atherosclerosis), narrowing them, restricting blood flow, increasing blood pressure, and eventually increasing Kojo's risk of cardiovascular diseases.

  Proposed lifestyle recommendation(s). Award 1 mark for any correct recommendation
  - Accept any of the following lifestyle recommendations or any other relevant recommendations.
    - reducing intake of saturated fats,
    - increasing physical activity, or
    - incorporating more fibre-rich foods to help regulate lipid levels.

Question 3

- **a.** Roles of VLDL and triglyceride in energy metabolism (4 marks).

Award 2 marks for 1 correct explanation. Accept any of the following roles, well-explained, or any other relevant answer.

i. Explanation of triglycerides as a major energy store. During fasting or prolonged exercise, they are broken down into fatty acids and glycerol to provide energy.

ii. Explanation of VLDL as lipoproteins produced by the liver for transporting triglycerides through the bloodstream to peripheral tissues for energy use or storage.

b. Discussion on how reduced VLDL production could contribute to fatigue.

Award 2 marks for each correct analysis (Total = 4 marks).

i. Identify that low-fat intake leads to reduced synthesis of lipids (e. g., VLDLs).

ii. Associate low VLDL levels with reduced delivery of triglycerides to tissues.

iii. Link less triglyceride availability to reduced energy production, particularly when glucose levels are low, contributing to fatigue.

c. Potential long-term risks of an extremely low-fat diet. Award 1 mark for each potential risk. (Total = 2 marks)

i. Deficiency in essential fatty acids and fat-soluble vitamins (A, D, E, K).

ii. Disruption of hormone production, especially sex hormones, which require cholesterol and fatty acids.

iii. Disruption in physical protection and thermoregulation.

WEEK 11

Question 1

a. *Award 3 marks for each lipoprotein level correctly interpreted and analysed.* Accept any of the following or any other relevant answer.

- Interpretation and analysis of HDL level
  - Identifies that HDL = 35 mg/dL is low (normal is ≥ 60 mg/dL). Award 1 mark.
  - Award 2 marks for analysis: indicates reduced ability to remove excess cholesterol from arterial walls.
  - Indicates that low HDL levels will increase atherosclerosis, stroke, and cardiovascular disease risks.
- Interpretation and analysis of LDL level
  - Identifies that LDL = 180 mg/dL is high (above the ideal <100 mg/dL). Award 1 mark
  - Award 2 marks for analysis: explains that elevated LDL increases cholesterol deposition in arterial walls.
  - Links cholesterol deposition to increased atherosclerosis risk.

b. Award 1 mark for each point raised. Accept any of the following or any other relevant answer.

- Danger of imbalance (Award 1 mark): Explains that high LDL deposits cholesterol in arteries, while low HDL fails to remove it, promoting plaque formation and narrowing of arteries (atherosclerosis).
- Effect of high LDL (Award 1 mark): Leads to fatty plaque build-up, increased risk of heart attack or stroke due to narrowed or blocked arteries.
- Effect of low HDL (Award 1 mark): Impairs reverse cholesterol transport, allowing more cholesterol to remain in circulation, worsening plaque build-up.

Question 2

Identification and interpretation of abnormal values (2 marks)

(Award 1 mark for each interpretation correctly identified). Accept any of the following for 1 mark each:

- identifies that LDL (165 mg/dL) is significantly above the healthy limit and HDL (35 mg/dL) is below the protective threshold.
- interprets that this pattern indicates a high cardiovascular risk due to elevated LDL and insufficient HDL.

Justification with reference to the lab report (2 marks)

(Award 1 mark for each correct justification). Accept any of the following for 1 mark each:

- uses the provided reference ranges to support the evaluation (e.g., "The patient's LDL is 65 mg/dL above the recommended maximum").
- clearly links the abnormal values to increased atherosclerotic risk based on the lipid profile data.

Explanation of lipoprotein function and atherosclerosis mechanism (2 marks)

(Award 1 mark for each correct explanation). Accept any of the following for 1 mark each:

- explains that LDL contributes to plaque formation in arteries by depositing cholesterol in vessel walls.
- explains that HDL removes cholesterol from the bloodstream and plaques, reducing the risk of atherosclerosis.

Question 3

Group Presentation Rubric (20 marks total):

1. Content Knowledge (10 marks)

- Demonstrates clear understanding of the roles of HDL ("good cholesterol") and LDL ("bad cholesterol").
- Accurately explains how their concentrations influence plaque build-up, atherosclerosis, and heart disease risk.
- Uses correct biological terminology and integrates relevant scientific evidence.

2. Analysis and Evaluation (4 marks)
   - Critically evaluates how different interventions (e.g., diet, exercise, medications like statins) affect HDL and LDL levels.
   - Makes connections between these interventions and their physiological impact.
   - Supports claims with data or referenced research where appropriate.
3. Community Strategy (6 marks)
   - Proposes a culturally relevant, realistic action plan for promoting heart health in your local context (e.g., dietary habits, access to healthcare, socioeconomic considerations).
   - Shows creativity and practicality in proposed solutions.
   - Addresses possible challenges and suggests ways to overcome them.

WEEK 12

KEY

1. C	**4.** B	**7.** A	**10.** D
2. B	**5.** A	**8.** D	
3. D	**6.** C	**9.** B	

Additional Reading

QR Code 17 Structure of lipids

QR Code 18 Cholesterol transport

QR Code 19 LDL and HDL

QR Code 20 Reverse cholesterol transport

QR Code 21: Cholesterol levels explained.

SECTION 5: MEDICAL DIAGNOSTIC AND THERAPEUTIC DEVICES

Strand: Biomedical Intervention

Sub-Strand: Diagnostic Devices

Learning Outcome: *Design and construct some basic medical devices and pitch them to potential investors.*

Content Standard: *Demonstrate understanding of the knowledge and skills required to design and construct some basic medical devices*

INTRODUCTION AND SECTION SUMMARY

Innovation in diagnostic medical devices represents a critical frontier in biomedical science, where technical expertise meets entrepreneurial vision to advance healthcare delivery and patient outcomes. The ability to conceptualise, design, construct, and market effective diagnostic tools requires a unique blend of scientific knowledge, engineering principles, and business acumen. This section empowers biomedical science students to bridge theoretical understanding with practical application by engaging in the complete development cycle of diagnostic medical devices. The learning outcome for this section is the ability to design functional diagnostic devices that address real healthcare needs and effectively communicate their clinical and commercial value to potential stakeholders. Students will explore the roles of biomedical engineers in device development, apply design principles to construct working prototypes, and develop persuasive presentation skills to pitch their innovations, preparing them for the interdisciplinary demands of the medical technology sector where scientific credibility meets market viability.

The weeks covered by the section are:

Week 13: *Evaluate the role of biomedical engineers in the production, acquisition, and maintenance of medical devices*

Week 14: *Design and construct a simple diagnostic device and assemble the units of a medical device*

Week 15: *Develop a marketing plan to pitch the designed device to potential investors*

Week 16: *Disassemble and assemble components of the therapeutic device*

Week 17: Develop an operating manual for a therapeutic device.

Week 18: *Discuss the role of regulatory agencies in the production and marketing of medical devices.*

SUMMARY OF PEDAGOGICAL EXEMPLARS

To achieve the content standard for this section, the following pedagogical exemplars are recommended. Through exploratory learning, learners visit medical and production centres to observe the stages of medical device production, acquisition, and maintenance, analysing real-world processes such as design, prototyping, safety evaluation, and repairs to understand how medical technologies are developed and sustained. Following these visits, learners work in groups to prepare presentations that foster critical discussion and deeper insight into biomedical engineering practices. Initiating talk/ sign for learning guides learners to explore the guidelines and requirements for writing operating manuals for medical devices. Using activity-based learning, mixed-ability groups review relevant documents and collaborate to develop clear, user-friendly operating manuals for specified devices. Experiential learning is integrated by inviting resource persons to demonstrate device disassembly and reassembly, deepening learners' understanding of device components and functions. Additionally, project-based learning engages groups in designing and building functional diagnostic medical devices, alongside developing marketing plans and delivering pitches to simulated investors. Together, these strategies promote active investigation, practical skills, collaborative learning, and real-world application within biomedical engineering contexts.

ASSESSMENT SUMMARY

To assess learners' understanding of biomedical engineering roles and the lifecycle of medical technologies, DOK Level 4 assessment strategies are recommended. These assessments require learners to apply extended thinking and synthesis skills to demonstrate how biomedical engineers contribute to healthcare solutions from concept to clinical use. Learners explain the involvement of different types of biomedical engineers at each stage of device development, from identifying medical needs to ensuring maintenance and safe use in hospitals. They create labelled flow diagrams or timelines to illustrate these stages and engineer roles. Learners develop educational activities that highlight the problem-solving impact of biomedical engineers. They analyse the critical role of interdisciplinary teamwork in ensuring medical devices are safe and clinically viable, while examining case studies involving failed collaboration that led to compromised device efficacy or patient risk. Through project work, presentations, and design tasks, learners engage critically with real-world biomedical engineering challenges, fostering a deeper comprehension of multidisciplinary roles in healthcare technology development.

Provide a summary of the assessment used against the indicator.

Indicators	DOK Level	Assessment Strategy and/or Mode
Evaluate the role of biomedical engineers in the production, acquisition, and maintenance of medical devices.	4	Structured written response as individual classwork.
Design and construct a simple diagnostic device and assemble the units of a medical device.	4	Structured written report as a group project
Develop a marketing plan to pitch the designed device to potential investors.	4	Structured written response as an individual project.
Disassemble and assemble the components of the therapeutic device.	4	Structured written report as a group project

Develop an operating manual for a therapeutic device.	4	Structured written response as individual classwork.
Discuss the role of regulatory agencies in the production and marketing of medical devices.	3	Individual structured written response

WEEK 13

Learning Indicator: *Evaluate the role of biomedical engineers in the production, acquisition, and maintenance of medical devices*

Recap Weeks

Year 1	**Week 13**: Explain medical intervention in relation to diagnosis, therapy, and prevention.
Year 2	**Week 1**: Investigate and discuss a variety of biomedical science careers that relate to the prevention, diagnosis, and treatment of diseases. **Week 3**: Explore any two/three biomedical career fields related to clinical or research studies and describe these career fields.

FOCAL AREA 1: THE ROLE OF BIOMEDICAL ENGINEERS IN BUILDING A HEALTHIER FUTURE

Introduce biomedical engineers and their diverse roles in the medical device field

Biomedical science and biomedical engineering work closely together to improve healthcare. Biomedical engineers use knowledge from both science and engineering to solve medical problems. They design tools, machines, and systems that support accurate diagnosis, effective treatment, and faster recovery. Biomedical scientists help by providing a deep understanding of how the body works, how diseases affect it, and how treatments should respond at the biological level. In the medical device field, biomedical engineers rely on this scientific knowledge to identify health problems, design practical solutions, test devices, and ensure they are safe and effective for use in real healthcare settings (Scan **QR Code 22**). The work of biomedical engineers is crucial to improving the quality of healthcare. The following are some of the key areas where biomedical engineers contribute.

1. **Bioinstrumentation**: Involves designing and developing tools that measure biological signals from the body, such as heart rate, brain activity, or blood oxygen levels (**Figure 34**). For example, biomedical engineers may develop wearable sensors that track a patient's heart rate in real time and send alerts to healthcare providers if irregular patterns are detected, helping with early diagnosis and timely intervention.

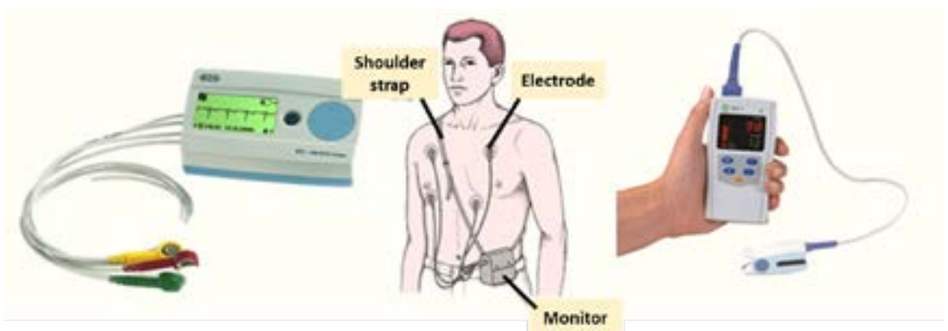


Figure 34: *Equipment for measuring biological signals (such as heart rate) from the body*

2. **Clinical engineering**: This is an area where biomedical science and biomedical engineering come together to support patient care. Clinical engineers work in hospitals to manage, maintain, and improve the use of medical equipment (**Figure 35**). They use engineering skills along with biomedical knowledge to ensure that devices are safe, accurate, and reliable. For example, a clinical engineer might work with a laboratory team to ensure that a blood analyser used in diagnostic testing is properly calibrated, maintained, and provides correct results, helping healthcare staff make accurate decisions based on biomedical data.



Figure 35: *Medical equipment opened for maintenance and repair*

3. **Biomechanics**: This area focuses on how the body moves. Biomedical engineers study bones, muscles, and joints to understand movement (**Figure 36**). They may design artificial knees or hips that help elderly people walk again after surgery, or study how people walk to improve supportive footwear.



Figure 36: *Studying body movements*

4. **Medical imaging**: Involves taking pictures of the inside of the body to help doctors diagnose illness. Biomedical engineers develop and improve machines such as X-rays, magnetic resonance imaging (MRI), ultrasound, and computed tomography (CT) scanners (**Figure 37**). They might work on improving the quality of images produced by a CT scanner so that doctors can see a tumour more clearly.



Figure 37: *Medical imaging devices*

5. **Biomaterials and tissue engineering**: Biomedical engineers in this area develop materials and tissues that are safe to use inside the human body. They work with materials that can replace or repair damaged body parts (**Figure 38**). For example, Biomedical engineers create artificial skin for burn victims and may be involved in designing materials for heart valves that the body will not reject.

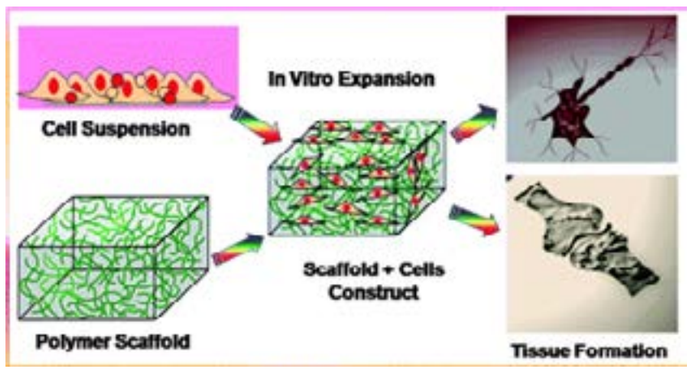


Figure 38: *Tissue formation using cells and a scaffold*

6. **Rehabilitation engineering**: This area focuses on helping people regain movement or function after an accident or illness. Biomedical engineers in rehabilitation may design prosthetic limbs or special wheelchairs that help people with disabilities live more independently (**Figure 39**).



Figure 39: *Prosthetic limb to make movement easier*

7. **Neural engineering**: Biomedical engineers in this field study the brain and nerves. They design devices that help restore brain or nerve function (**Figure 40**). For example, they may be involved in working on systems that allow people who are paralysed to control a computer using their thoughts.

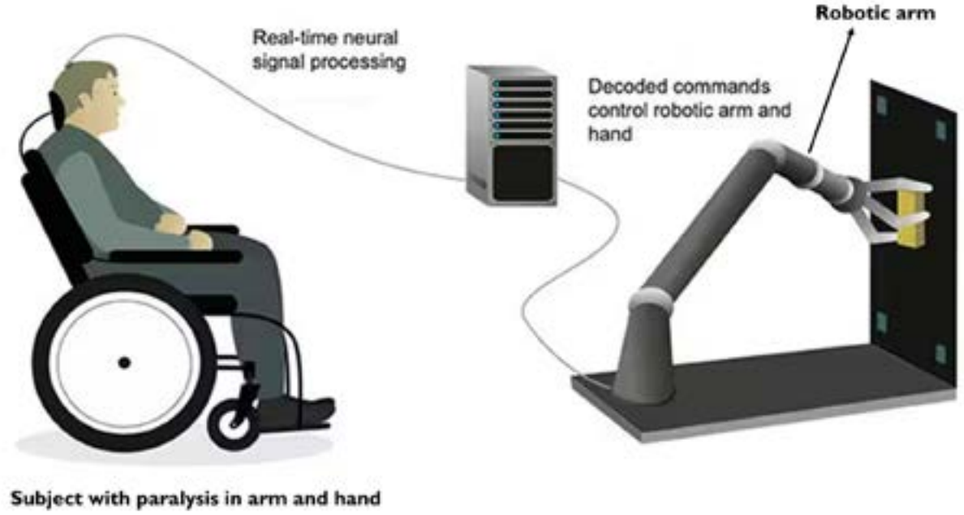


Figure 40: *Neural engineering enables humans to control a robotic arm with thought*

8. **Systems physiology**: In this area, engineers build computer models to understand how the body's systems (like the heart, lungs, and kidneys) work together. Example: They might model the heart (**Figure 41**) to understand the effects of treatments on certain heart diseases.

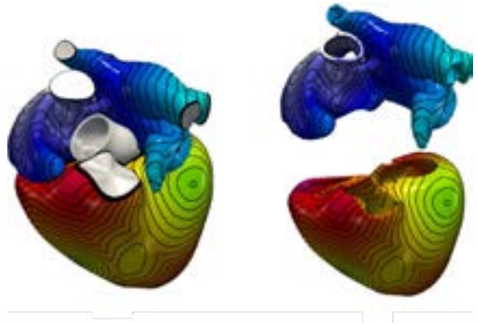


Figure 41: Computer model of the human heart

9. **Bioinformatics and computational biology**: These engineers use computer tools to study biology and health data. They help scientists understand diseases and how the body responds to different treatments. Biomedical engineers in this field use computer programmes to study biological data (genetic information) and predict how a person might respond to a medicine (**Figure 42**).

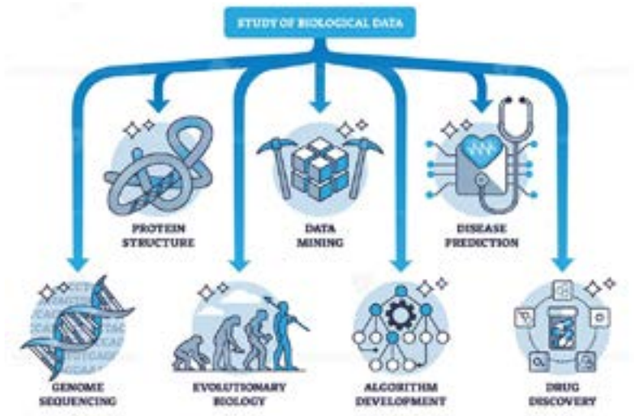


Figure 42: Bioinformatics and computational biology

QR Code 23 provides an overview of some of the roles biomedical engineers play in healthcare delivery.

Briefly discuss their contributions throughout the device lifecycle, from identifying a need to production and maintenance.

Biomedical engineers play a critical role in every stage of a medical device's development and use. From identifying health challenges to ensuring devices work properly in hospitals, they help turn ideas into life-saving tools.

1. **Identification of medical need**: This step initiates the design of a medical device. Biomedical engineers often work closely with doctors, nurses, and patients to understand what is missing or what can be improved in patient care. For example, if a hospital struggles with patient monitoring during surgery, engineers may begin developing a better monitoring device.
2. **Research and development (R&D)**: Once a need is identified, research and development engineers explore new technologies or materials that could solve the problem. This might involve studying how the body responds to certain substances or designing new ways to deliver medicine. Design engineers take the best ideas and turn them into detailed technical plans. 3D modelling software and engineering principles are used to build devices such as artificial limbs, pacemakers, or diagnostic tools. The goal is to make devices that are safe, effective, comfortable for the human body, and suitable for long-term use.
3. **Testing and quality assurance**: Before a device can be used on patients, it must be tested thoroughly. Quality assurance engineers test devices to ensure they work properly under different conditions. They also ensure that the device meets strict safety standards. If any issues are found, the design is improved and retested.
4. **Regulatory approval**: Regulatory affairs engineers prepare all the necessary documentation to show that the device is safe and effective. They work to meet the rules set by national health agencies such as the Food and Drugs Authority (FDA) in Ghana or the Ghana Standards Authority (GSA). Without their approval, a medical device cannot be sold or used in hospitals.
5. **Manufacturing and production**: Once approved, the device is produced in large quantities. Manufacturing engineers develop systems that build devices in factories for efficiency and safety. They plan how materials will be used, ensure cleanliness (especially for devices that go inside the body), and find ways to keep costs low without reducing quality.
6. **Clinical use and maintenance**: After devices are delivered to hospitals, clinical engineers ensure they are installed correctly and safely. They teach hospital staff how to use the devices and regularly check that they are working well. If something breaks, clinical engineers handle repairs and maintenance to keep the equipment safe for patients.

Learning Tasks

1. Explain how different biomedical science careers support diagnosis, treatment, and prevention of diseases, and describe how each specialist helps in managing health problems.
2. Identify the diverse roles of biomedical engineers within the medical device industry and explain their importance to healthcare delivery.
3. Describe how biomedical engineers contribute to each stage of the medical device lifecycle, from initial needs assessment through to maintenance and monitoring.

Pedagogical Exemplars

Exploratory learning: In groups, visit various medical or production centres to learn about the activities in the production (e.g., medical need, design, prototyping, etc.), acquisition (e.g., advice on new medical technology, safety, efficacy, and cost-effectiveness), and maintenance (e.g., testing, software upgrade, repairs, calibration, etc.) of medical devices. Subsequently, the individual groups make presentations to the class for further discussion.

Key Assessment: Structured Written Report

Level 4 (Extended thinking): A national health challenge has highlighted the need for improved technologies to support diagnosis, treatment, and patient care. A team of biomedical engineers is formed to respond. Using your knowledge of biomedical engineering roles and the

lifecycle of medical technologies, demonstrate how engineers contribute to creating effective healthcare solutions from idea to hospital use.

1. Explain how different types of biomedical engineers contribute during each stage of developing a healthcare technology, from identifying a medical need to ensuring its usage and maintenance in hospitals.
2. Create a labelled flow diagram or timeline showing the stages in the development of a healthcare technology. Indicate the key roles of biomedical engineers at each stage.
3. Design a classroom learning activity that helps students understand how biomedical engineers contribute to solving health problems. Include the aim, key steps, and what students are expected to learn.
4. Evaluate how teamwork among different biomedical engineers helps ensure that healthcare technologies are safe, effective, and useful in clinical settings. Give two examples to show how poor collaboration could affect the success or safety of a technology.

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 ***structured written report***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the assessment (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 14

Learning Indicator: *Design and construct a simple diagnostic device and assemble the units of a medical device*

Recap Weeks

Year 1	**Week 3**: Explain how the scientific method can be applied to undertake investigations or address problems in biomedical science. **Week 21**: Use different approaches to propose solutions to healthcare problems in the country.
Year 2	**Week 3**: Explore various biomedical career fields related to clinical or research studies and describe these career fields. **Week 18**: Investigate the application of technology in the provision of healthcare. **Week 19**: Identify the components of a typical diagnostic device and its functions. **Week 19**: Discuss the bio-instrumentation principles used in the construction of a diagnostic device.

FOCAL AREA 1: DESIGN THINKING FOR MEDICAL DEVICES

Introduce the concept of design thinking, a human-centred approach to problem-solving

Design thinking is a human-centred approach to solving problems. It focuses on understanding the people affected by a problem, such as patients, nurses, or doctors, and working towards solutions that truly meet their needs (See **Figure 43**).

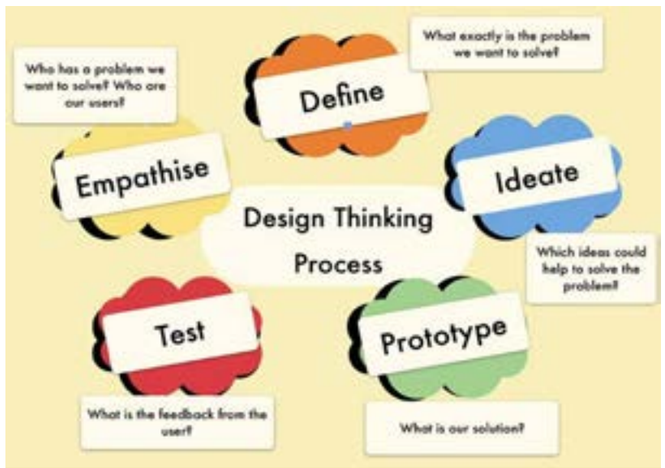


Figure 43*: Design thinking for medical devices*

In biomedical engineering, this method helps in developing medical devices that are not only functional but also safe and practical for everyday healthcare use. For example, instead of designing a new walking aid based on technical ideas, engineers would first study how elderly patients use current walking frames and what struggles they face. Each step in design thinking helps to ensure that the final medical device is practical, safe, and tailored to user needs. The following describes the steps in the design thinking process (**Figure 43**).

1. **Empathise**: In this first step, engineers learn about the experiences of the people facing the problem. They observe how patients interact with existing tools and listen to healthcare providers who use medical equipment. This helps the engineers to understand daily challenges. For example, if engineers are designing a better walking aid, they might visit a hospital, observe elderly patients using walking frames, and enquire from them whether it feels heavy or uncomfortable.
2. **Define**: After collecting insights, the team defines a specific and clear problem to focus on. This ensures they are solving the real issue rather than making assumptions. For instance, after observing patients using walking frames, the engineers might identify the problem as: "Elderly patients struggle to lift standard walking frames because they are too heavy and difficult to move."
3. **Ideate**: Now, the team brainstorms possible ways to solve the defined problem. They list all ideas, no matter how unusual, and explore different directions for solutions. In the walking aid example, the team might come up with ideas such as designing a foldable walking frame, using lightweight recycled plastic, or adding wheels that can lock when not in use.
4. **Prototype**: At this stage, the team builds a basic model of the best idea. It does not need to be perfect. The aim is to test how well the idea works in real situations. For instance, they might build a lightweight walking frame using plastic pipes, foam, and tape. This prototype allows users to try out the design and offer feedback before moving to a final version.
5. **Test**: The prototype is tested by users, and their feedback is used for improvements. Sometimes the feedback leads to small adjustments. Other times, the idea may need a major change. In the example of the walking frame, an elderly patient might say the new frame is easier to lift but still difficult to fold. With this feedback, engineers can redesign the folding mechanism before building the next version.

Learning Tasks

1. Integrate knowledge of scientific methodology, healthcare problem-solving approaches, biomedical technology applications, and diagnostic device components to apply the design thinking process (empathise, define, ideate, prototype, and test) in developing innovative medical device solutions that address specific healthcare challenges.
2. Explain the five key stages of design thinking (empathise, define, ideate, prototype, and test) as a human-centred approach to problem-solving in healthcare.
3. Apply the design thinking process to develop a medical device solution that addresses a specific healthcare challenge, incorporating user feedback throughout the development cycle.

Pedagogical Exemplars

Project-based learning: Learners collaborate in mixed-ability groups to design and build a functional diagnostic medical device, such as a digital thermometer, heartbeat monitor, breath alcohol detector, or paper-based colorimetric sensor. During the process, learners explore existing devices, review relevant literature, and consult experts to understand the underlying technologies and identify opportunities for improvement. Each group develops a working

model or prototype and prepares a presentation to showcase their design, function, and innovation. Final presentations are delivered at the end of the assigned project period to encourage peer learning and feedback.

Experiential learning: A resource person is invited to engage the class in a discussion on diagnostic medical devices. The session introduces key concepts in device design, function, and real-world application. The class is guided through the safe disassembly of a selected diagnostic device to examine and identify its key components and their respective functions. The device is then reassembled, with emphasis placed on correct part alignment and safe handling. The disassembly and reassembly process is repeated under supervision to help learners become more familiar with the internal structure and operation of the device, reinforcing both technical understanding and hands-on skills.

Key Assessment: Structured Written Report

Level 4 (Extended thinking): Your team has been tasked with developing a new assistive medical device to support patients in a low-resource healthcare setting. The goal is to design a simple, affordable, and user-friendly tool, such as a lightweight walking aid, a basic diagnostic device, or a medicine dispenser that directly meets the practical needs of patients, caregivers, or healthcare workers in a local clinic or community.

Working collaboratively, use the design thinking process to research, design, test, and improve a user-centred healthcare solution by completing the following tasks as a group:

4. Investigate and document the experiences of potential users (e.g., elderly patients, nurses, caregivers) through interviews, observations, or secondary research.
5. Based on your findings, clearly state one problem to solve.
6. Brainstorm and document three creative ideas for solving the defined problem. Include sketches or rough diagrams showing how each idea would function. Justify why each idea might help address the user's challenge.
7. Create a simple model of your best idea using local materials, include labelled sketches or photos, and clearly explain how the design works and how it solves the user's problem.
8. Show your prototype to others, write down what they say about how it works, feels, and how easy it is to use, then use their feedback to suggest changes and explain what you would add or fix in the next version.

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 ***structured written report***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the report writing (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

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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 15

Learning Indicator: *Develop a marketing plan to pitch the designed device to potential investors*

Recap Weeks

Year 1	**Week 21**: Use different approaches to propose solutions to healthcare problems in the country.
Year 2	**Week 3**: Explore various biomedical career fields related to clinical or research studies and describe these career fields.

FOCAL AREA 1: THE POWER OF PITCHING – MARKETING FOR MEDICAL DEVICES

Discuss the importance of marketing in securing funding and bringing a new device to market.

Marketing plays a crucial role in the design and development of new medical devices. It goes beyond simply selling the product; marketing demonstrates how the device can improve healthcare and benefit patients. This is especially important when companies seek funding and aim to introduce their devices to hospitals and clinics. Understanding the importance of marketing reveals how it connects innovation with real healthcare needs. Below are some key points, supported by examples, that illustrate this role clearly:

1. **Demonstrating the value of the device to investors**: Many companies need financial support to develop new medical devices. Marketing helps explain why the device is useful and needed. For example, a company developing a new type of hearing aid that provides clearer sound for people with hearing loss will use marketing to show how it improves users' lives. This helps convince investors to provide funding because they see the device has a real purpose and potential to succeed.
2. **Understanding the needs of users**: Marketing research collects information from doctors, nurses, and patients about what they want and need in a medical device. For instance, if students learn about artificial limbs, they should understand how marketing helps designers know what features users find most important, such as comfort or ease of movement. This helps ensure the device works well and meets users' expectations, increasing the chances of success.
3. **Building awareness and trust**: Marketing spreads information about the device's benefits to healthcare workers and decision makers. For example, when a new portable defibrillator is created, marketing efforts might include demonstrations and training for ambulance teams. This builds trust and encourages healthcare providers to adopt the device. It also helps gain approval from health authorities who ensure that devices are safe.
4. **Planning for market entry**: Marketing analyses the competition and identifies what makes the new device different or better. For example, a company may develop a new wound dressing that heals faster than existing products. Marketing will highlight these advantages to help the product stand out and attract customers.
5. **Supporting success after development**: Marketing continues after the device is made. It helps train healthcare professionals and promotes the device to hospitals and clinics. For example, when a new insulin pump is introduced, marketing teams may organise workshops

to teach patients and nurses how to use it properly. This helps ensure the device is used effectively and improves patient care.

Guide students in developing a marketing plan to present their proposed device to potential investors.

Creating a marketing plan is a key step in developing and promoting a new medical device. It helps explain the purpose and value of the device, identifies the intended users, and shows how the device can succeed in a real healthcare market. A strong marketing plan is essential not only for gaining investor support but also for ensuring that the device reaches the people who need it most. The steps below outline how to build a detailed and convincing plan, with examples to show how each step might look in practice:

1. **Define the device and its benefits**: Start by clearly explaining what the medical device is, what health-related problem it solves, and how it improves patient care or healthcare services. Focus on how the device will bring value to patients or healthcare workers. Example: A portable blood pressure monitor allows people to measure their blood pressure at home, helping patients manage hypertension more consistently. This reduces the burden on clinics and improves early detection of dangerous blood pressure spikes.
2. **Analyse the target market**: Identify who will use the device (this could include hospitals, clinics, doctors, nurses, or patients themselves). Also consider where these users are located and how many potential users exist. This step ensures that the device is well matched to the needs of a specific group. Example: A low-cost diagnostic device for malaria may be most needed in rural clinics across northern Ghana. The target market includes healthcare workers in small health posts and non-governmental organisations distributing healthcare supplies in malaria-prone areas.
3. **Assess competitors**: Research similar products that already exist and examine their strengths and weaknesses. Show how your device offers something better, such as improved usability, lower cost, easier maintenance, or more reliable results. Example: If other asthma inhalers require manual dose tracking, a new digital smart inhaler that tracks dosage and sends reminders via mobile phone could be more effective, especially for young or elderly patients who struggle with consistency.
4. **Plan pricing and funding needs**: Estimate the total cost of developing, testing, and producing the device, and explain how funding will be used. Include costs for raw materials, assembly, testing, packaging, and promotion. Provide realistic pricing based on your target market's ability to pay. Example: A community health monitor may cost GH₵20 per unit to produce, and an initial batch of 500 units will require GH₵50,000 in materials and manufacturing. If investors contribute GH₵20,000, the remaining funds might be allocated to field testing, feedback collection, and promotional campaigns.
5. **Outline marketing strategies**: Describe how the device will be introduced to users and how it will be promoted. This could include attending health conferences, using posters or videos in hospitals, working with medical NGOs, or using social media campaigns. Choose strategies that suit your target users and your budget. Example: A new maternal health tracker app might be promoted through partnerships with antenatal clinics, with midwives demonstrating how to use it during appointments. Flyers and radio messages could be used in rural areas with limited internet access.

6. **Set goals and timelines**: Create a clear roadmap with short- and long-term goals and indicate when each goal should be achieved. This includes steps such as prototype completion, regulatory approvals, field testing, and the start of full-scale production and distribution. Example: Within three months, the team aims to complete initial testing. By month six, they plan to secure approval from the national health regulatory body. By the end of the first year, they aim to distribute 2,000 units and receive feedback from at least 50 users. Scan **QR Code 243** to watch a video on the power of medical devices marketing.

Learning Tasks

1. Apply knowledge of healthcare problem-solving approaches and biomedical career specialisations to develop effective marketing strategies for medical devices, demonstrating how proposed solutions address specific healthcare challenges, appeal to relevant professional stakeholders, and create measurable impact on patient outcomes and healthcare delivery systems.
2. Explain why effective marketing is essential for securing investment funding and bringing new medical devices to market, focusing on how marketing demonstrates healthcare outcome improvements rather than just commercial benefits.
3. Create a comprehensive marketing plan for a medical device that includes a clear value proposition, target market analysis and evidence of potential positive impact on patient care and healthcare delivery.

Pedagogical Exemplars

Project-based Learning: Learners collaborate in mixed-ability groups to develop a marketing plan for a designed or specified therapeutic device. Each group prepares a pitch aimed at convincing a class audience, who take on the role of potential investors. The presentation includes key elements such as the device's purpose, target users, competitive advantages, and market potential. After the pitch, the class provides constructive feedback, simulating a real-world investor review process.

Key Assessment: Individual Structured Written Response

Level 4 (Extended thinking): You are preparing to launch a new solar-powered, low-cost digital thermometer designed to improve fever detection in rural clinics without reliable electricity.

1. Identify and explain the health problem your device addresses.
2. Describe the target market and users for your device.
3. Analyse at least two competing products and explain how your device is different or better.
4. Develop a persuasive pitch aimed at investors, outlining funding needs and benefits of your device.
5. Create a market entry plan with key activities, partnerships, and a timeline.

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).
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   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 ***individual structured written response***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the assessment (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)
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30 minutes	Enactment

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5 minutes	Reflection

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

WEEK 16

Learning Indicator: *Disassemble and assemble components of the therapeutic device.*

Recap Weeks

Year 1	**Week 15**: Explore the significance of the various diagnostic devices used for medical intervention.
Year 2	**Week 5**: Demonstrate proper setup of the biosafety cabinet and its environment. Demonstrate proper methods for donning and removal of personal protective equipment (PPE) such as gloves, lab coats, eye protection and respiratory protection.

FOCAL AREA 1: UNDERSTANDING DISASSEMBLY AND ASSEMBLY OF DEVICES

Understanding how therapeutic devices are built and how their parts work together is an important part of biomedical engineering. Taking these devices apart (disassembly) and putting them back together (assembly) helps reveal how design, safety, ease of use, and performance are connected. Closely examining each component makes the interaction between mechanical, electrical, and user-friendly features clearer (Scan **QR code 25**).

Safe disassembly of therapeutic devices

Therapeutic devices such as digital thermometers, nebulisers (devices that deliver medicine as vapour so it can be inhaled directly into the lungs), and digital blood pressure monitors provide accessible opportunities to examine internal components. These devices are often compact and designed with user safety in mind, which makes them suitable for safe disassembly. Disassembly begins with careful handling, highlighting the importance of preventing damage to internal systems and keeping each part intact (**Figure 44**). Below are steps for safe disassembly of a therapeutic device.

1. **Review manufacturer's instructions**: Read and understand the device's user manual or service guide to know the correct disassembly procedure and precautions.
2. **Ensure the device is powered off and unplugged**: Disconnect the device from any power source to prevent electrical hazards.
3. **Wear appropriate personal protective equipment**: Use gloves, eye protection, or lab coats as necessary to protect against contamination, injury, or exposure to harmful substances.
4. **Work in a clean and designated area**: Use a clean, well-lit workspace with appropriate ventilation and safety measures.
5. **Label and document each Step**: Take notes or photos as components are removed to ensure correct reassembly.
6. **Use the right tools**: Choose tools recommended by the manufacturer to avoid damaging parts.

7. **Remove components in sequence**: Disassemble the device in the correct order, starting with outer covers or housings and progressing to internal components.
8. **Handle components carefully**: Avoid using excessive force. Handle sensitive parts, such as sensors and electronic boards, with care to prevent damage.
9. **Store removed parts securely**: Place disassembled parts in labelled containers or trays to prevent loss or contamination.
10. **Dispose of single-use or contaminated parts properly**: Follow institutional and regulatory guidelines for disposing of waste or biohazardous materials.



Figure 44: *Components of a CPAP Nasal Mask Showing the Disassembled Parts (A) and the Correctly Reassembled Device (B).*

The disassembling process often reveals several essential elements, such as the following.

1. **Power source**: This may include batteries, a rechargeable unit, or a plug-in connection. It supplies the electrical energy required for the device to operate. The power system often incorporates safety features, such as fuses and protective covers, to prevent damage or hazards. Examining the power source provides insight into how electrical energy is supplied and controlled within the device, and how safety is maintained.
2. **Delivery mechanism**: The therapeutic function of the device is achieved through specific components. In a nebuliser, for example, the compressor, tubing, and mask deliver medication as a mist. In a hot water bottle, the rubber container and secure stopper allow the safe delivery of heat to soothe muscle pain. These mechanisms demonstrate how treatment is delivered and controlled.
3. **Control panel elements**: The user interface allows the device to be operated safely and effectively. Common features include on/off buttons, LED indicators, digital displays, and adjustable dials or switches. These controls are designed to be easy to understand, helping users set treatment levels or monitor performance. Clear labelling and intuitive layout are especially important in healthcare settings, where ease of use and accuracy can prevent errors.

4. **Component labelling and identification**: During disassembly, identifying and labelling parts such as circuit boards, connectors, sensors, or tubing supports a better understanding of their roles. Sketching or photographing the components helps record their structure and position. This documentation supports correct reassembly and builds an understanding of how each part contributes to the overall function.

Reassembly of the therapeutic device

Reassembling a therapeutic device is not just about putting the parts back together. It is a critical stage that ensures the device remains safe, functional, and reliable after disassembly. Any mistakes during this process can pose serious safety risks or reduce the device's effectiveness. Below are the steps for safe assembly of a therapeutic device

1. **Confirm all parts are available and clean**: Ensure all components are present, intact, and disinfected or sterilised as required.
2. **Wear appropriate PPE**: Use gloves and any other required protection to prevent contamination or injury during reassembly.
3. **Follow the manufacturer's assembly guide**: Use the official assembly instructions to ensure parts are correctly aligned and fitted.
4. **Use the right tools**: Employ tools that are clean and suitable for the specific components to avoid damage.
5. **Assemble in the correct order**: Start with internal components and work outward. Install each part in the proper sequence.
6. **Secure connections properly**: Tighten screws, bolts, or clips as instructed without overtightening, which could damage parts.
7. **Check alignment and functionality during assembly**: Confirm that moving parts, sensors, and electrical connections are aligned and function correctly.
8. **Inspect the final assembly**: Check the device for loose parts, proper fit, and cleanliness. Reconfirm all safety features are intact.
9. **Test the device safely**: Power the device on (if applicable) in a controlled environment to check for correct operation.
10. **Document the assembly and maintenance**: Record the date, procedure, and observations for maintenance logs and quality assurance.

Key reasons why proper reassembly is essential are as follows.

1. **Ensures patient safety**: A poorly reassembled device can malfunction during use, putting the patient at risk. For example, if a digital blood pressure monitor's air tube is not properly connected to the cuff, it may give incorrect readings. This could lead to a patient receiving the wrong diagnosis or inappropriate treatment. Correct assembly helps avoid such risks and ensures the device can be used safely.
2. **Maintains device functionality:** Each component has a specific role, and when assembled incorrectly, the entire system may fail to work as intended. For instance, in a nebuliser, if the medicine cup is not properly aligned with the compressor, the mist may not be generated effectively, reducing medication delivery. Proper reassembly ensures that the device continues to function as designed.

3. **Protects electrical and mechanical integrity**: Internal systems such as seals, stoppers, or connecting parts must be securely and correctly reassembled. If the stopper of a hot water bottle is not fitted properly, it may leak and pose a risk of burns. Misaligned parts can also prevent proper sealing or cause heat loss. Proper reassembly ensures the device remains safe and effective.
4. **Supports troubleshooting and maintenance**: When a device is correctly reassembled, it becomes easier to detect and fix any real problems. For example, if a device refuses to power on even after a proper battery replacement, technicians can confidently rule out assembly errors and look for internal faults. In contrast, incorrect assembly can create confusion and make faults harder to diagnose.
5. **Meets safety and compliance standards**: Medical devices must meet strict quality and safety standards. Improper reassembly can violate these standards, making the device unsafe or unfit for use in healthcare settings. For example, leaving a component loose inside a digital thermometer may cause rattling or inaccuracy, resulting in the device failing inspection or user approval. Careful reassembly helps maintain compliance with regulations and quality expectations.

Learning Tasks

1. Apply safety principles from laboratory practice (including proper PPE use and controlled environment setup) when disassembling and reassembling diagnostic medical devices, demonstrating understanding of how component arrangement and proper handling contribute to device functionality and user safety.
2. Safely disassemble a therapeutic medical device, identifying the function of each major component, including the power source, delivery mechanism, and control elements.
3. Correctly reassemble a therapeutic medical device, explaining how proper assembly ensures safe and effective operation for patient use.

Pedagogical Exemplars

Experiential learning: Invite a resource person to speak about a specific therapeutic medical device, sharing insights into its purpose, use, and significance. Following the presentation, the resource person guides the class through a hands-on session, carefully disassembling the device and identifying its key components and their functions. Once this is complete, the device is reassembled under their supervision. To reinforce learning and build confidence, the resource person then leads the learners through repeated cycles of disassembly and reassembly, allowing them to become more familiar with the device's structure and operation.

Key Assessment: Group Structured Written Response

Level 4 (Extended thinking): Your team has been tasked with supporting a community health centre that often receives donated therapeutic devices such as hot water bottles, nebulisers, and digital blood pressure monitors. Due to frequent handling, transport, and storage, many of these devices arrive partially disassembled or develop faults during use. This poses a risk to both patients and staff, especially when non-specialist users are involved. As a group, your objective is to help the health centre improve the safety, usability, and maintenance of these devices. To do this, your team must:

1. Analyse the risks and consequences of improper disassembly and reassembly of therapeutic devices
2. Develop a step-by-step reassembly protocol for a therapeutic device studied or disassembled during class.
3. Propose two design or labelling improvements that could make the reassembly process easier and safer.
4. Evaluate how proper disassembly and reassembly practices contribute to meeting safety standards, regulatory compliance, and accessibility of healthcare technology.

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 ***group structured written response***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the assessment (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: *Develop an operating manual for a therapeutic device*

Recap Weeks

Year 1	**Week 6**: Analyse laboratory-acquired infections (LAIs), including some case studies
Year 2	**Week 5**: Demonstrate proper setup of the biosafety cabinet and its environment. Demonstrate proper methods for donning and removing personal protective equipment (PPE), such as gloves, lab coats, eye protection, and respiratory protection.

FOCAL AREA 1: CLEAR INSTRUCTIONS FOR SAFE USE: DEVELOPING AN OPERATING MANUAL

Discuss the importance of user manuals written in clear language for the intended audience.

User manuals are essential documents that help users operate medical and therapeutic devices **safely, correctly and effectively**. A good user manual should provide clear, simple and practical instructions that are appropriate for the intended audience (scan **QR code 26**).

The intended users may include patients with limited technical knowledge, caregivers, laboratory personnel, therapists, nurses, doctors and other healthcare professionals. Therefore, the language and level of detail used in the manual should match the knowledge and needs of the user.

Why clear language matters

1. For patients

Patients may use devices such as blood glucose monitors, nebulisers or digital blood pressure monitors at home. If the instructions are too technical or difficult to understand, users may operate the device incorrectly. Incorrect use may result in ineffective treatment, inaccurate results or harm.

Clear and simple language helps patients to:

- understand what they need to do;
- operate the device correctly;
- avoid unnecessary mistakes;
- feel more confident when using the device; and
- manage their health more independently.

2. For healthcare providers

Healthcare providers may have greater technical and clinical knowledge, but they still depend on accurate operating manuals. Manuals provide important information about **operation, maintenance, cleaning and troubleshooting**.

Clear instructions reduce the likelihood of errors, particularly when healthcare professionals are using unfamiliar equipment or working under time pressure.

For example, the instruction:

"Insert the electrode pads in accordance with the manufacturer's specified polarity orientation."

may be difficult for some users to understand.

A clearer instruction would be:

"Place the sticky pads on the skin as shown in the diagram. Make sure the red and black wires are connected to the correct pads."

The second instruction is easier to understand because it uses simple language and tells the user exactly what to do.

Developing an Operating Manual for a Therapeutic Device

Guide students in developing an operating manual for the chosen therapeutic device.

Developing an operating manual for a therapeutic device involves creating a **clear, concise and practical guide** that enables users to operate the device safely and effectively.

A well-designed manual should help users:

- identify the device and its major components;
- understand the purpose of the major components;
- set up the device correctly;
- operate the device safely;
- clean and maintain the device;
- recognise potential hazards;
- troubleshoot common problems; and
- know when professional assistance is required.

The manual should be organised into the following key stages.

1. Identification and labelling of the device and its major components

Before providing step by step operating instructions, the manual should first help the user **identify the device and its major components**.

The manual should contain a **clearly labelled diagram or photograph** of the device. The diagram or photograph should identify the parts that users will need to locate or interact with during operation.

Depending on the device, these may include:

- major components;
- controls;
- switches;
- buttons;
- ports;

- connectors;
- sensors;
- indicators;
- displays; and
- other user operated parts.

For example, if a therapeutic device has a power button, display, treatment control, sensor, charging port and emergency stop button, these components should be clearly labelled in the diagram before the operating instructions are presented. Figure 45 shows a transcutaneous electric nerve stimulation (TENS) unit with major components identified and labelled.



Figure 45: *Components of a therapeutic device*

Importance of identifying and labelling components

Clearly identifying the components:

- provides users with clear points of reference;
- makes the operating instructions easier to follow;
- reduces confusion between different components;
- helps users locate controls quickly;
- reduces the risk of incorrect operation; and
- improves the safety and usability of the device.

For example, rather than simply stating:

"Connect the cable to the port and switch on the device,"

the manual should first show a labelled diagram (Fig. 46 for a digital blood pressure monitor) identifying the **cable, connection port and power switch**. The user can then easily locate each component when following the instructions.



Figure 46: *Major Components of a Digital Blood Pressure Monitor*

2. Step by step instructions for use

After identifying the device and its major components, the manual should provide a clear and logical sequence for setting up, operating, cleaning and maintaining the therapeutic device.

Instructions should:

- use plain and simple language;
- use short sentences;
- present actions in a logical order;
- use numbered or bulleted steps;
- avoid unnecessary technical terms; and
- use diagrams, photographs or icons where appropriate.

The main stages are **setting up the device, using the device, and cleaning and maintaining the device**.

a. Setting up the device

This involves describing the initial steps required to prepare the device for safe and effective use.

It may include:

- inserting batteries, where applicable;
- charging the device;
- connecting cables;
- connecting tubing or nozzles;
- assembling components;
- attaching sensors or treatment accessories; and
- checking that the power supply is working correctly.

b. Using the device

This guides the user through the operation of the device.

Instructions should explain how to:

- switch the device on and off;
- select the required treatment setting;
- adjust treatment parameters;
- position or apply the device correctly;
- start and stop treatment; and
- recognise important indicators or readings.

Clear visuals or icons can be used to support understanding.

c. Cleaning and maintenance

This explains how to care for the device so that it remains safe and functional.

The manual should explain:

- which parts can be cleaned;
- how often cleaning should be performed;
- which cleaning materials should be used;
- which parts should be kept away from water;
- how the device should be stored; and
- which components should be inspected or replaced.

Users should also be told what they should **not** do. For example, electronic components should not be immersed in water.

Example: Step by Step Instructions for a Digital Blood Pressure Monitor

The following example demonstrates how the different stages can be presented clearly and practically.

a. Identifying the device and its major components

Before using the monitor, the user should be able to identify:

1. Display screen
2. Power or start button
3. Arm cuff
4. Cuff tube
5. Cuff connection port
6. Battery compartment
7. Battery cover

A clearly labelled photograph or diagram of the monitor should be provided in the manual.

b. Setting up the device

i. Place the digital blood pressure monitor on a flat, stable surface such as a desk or table.
ii. Insert the required batteries into the compartment at the back of the monitor, or connect the power adapter to a wall socket if the device is not battery operated.
iii. Attach the cuff tube to the cuff connection port on the monitor.
iv. Unroll the arm cuff and ensure that it is not twisted or damaged.
v. Press the power button briefly and check that the monitor display turns on.

c. Using the device

i. Sit upright in a chair with your feet flat on the floor.
ii. Rest your arm comfortably on a table.
iii. Wrap the cuff securely around your upper arm, just above the elbow, with the tube facing downward along your arm.
iv. Press the power or start button to begin the measurement.
v. Remain still and silent while the cuff inflates and deflates automatically.
vi. Wait for the reading to appear on the display.
vii. Read the systolic pressure, diastolic pressure and pulse rate values shown on the screen.
viii. Press the power button to turn off the device after the measurement.

d. Cleaning and maintenance

i. Detach the cuff from the monitor and gently wipe it with a soft cloth dampened with mild soapy water.
ii. Wipe the surface of the monitor with a dry or slightly damp cloth. Avoid allowing water to enter the monitor.
iii. Never immerse the monitor or other electronic components in water.
iv. Do not use strong chemicals or unsuitable cleaning agents on the cuff or monitor.
v. Store the device in a dry, dust free location when it is not being used.
vi. Check the batteries regularly and replace them when the low battery indicator appears.
vii. Inspect the cuff and cable regularly for cracks, damage or signs of wear and replace them if necessary.

3. Safety warnings and precautions

This highlights potential dangers and provides advice to prevent injury, misuse or damage to the device.

Safety warnings should be easy to identify. Symbols such as ⚠ **Caution** and ⃠ **Do not** can be used to draw attention to important information.

For example:

a. ⚠ **Caution:** Sit quietly and avoid movement or talking during the measurement to ensure accurate results.

b. 🚫 **Do not:** Place the cuff over clothing, open wounds or a recently used injection site.

c. ⚠ **Caution:** Use the device only in a dry environment. Keep it away from water, steam and high humidity.

d. ⚠ **Caution:** If you feel faint, dizzy or experience significant arm discomfort during measurement, stop using the device and rest.

e. 🚫 **Do not:** Disassemble or attempt to repair the device yourself. Contact a qualified technician if the device develops a fault.

f. ⚠ **Caution:** Regularly inspect the cuff and cable for cracks, fraying or other signs of wear and replace them if necessary.

4. Troubleshooting common issues

This identifies common problems that users may encounter and provides simple, practical solutions. It can help users resolve minor problems without immediately requiring professional assistance.

Table 5.1: Troubleshooting for a Digital Blood Pressure Monitor

Problem	Possible Cause	What to Do
Device does not turn on	Batteries are dead or incorrectly inserted	Check battery orientation or replace the batteries
Display is unclear or dim	Screen is dirty or batteries are low	Wipe the screen with a clean cloth or replace the batteries
Reading seems unusually high or low	Incorrect cuff placement or body movement	Reposition the cuff on the bare arm and remain still during measurement
Cuff does not inflate properly	Tube is loose or cuff is twisted	Check all connections and ensure that the cuff is wrapped smoothly
Error message appears on screen	Cuff is incorrectly positioned or the user moved during measurement	Reposition the cuff correctly and remain still during measurement

Learning Tasks

1. Use your knowledge of lab safety and infection prevention, including how to use PPE and set up a biosafety cabinet, to create clear safety warnings and step-by-step instructions in medical device manuals that help protect users from harm.
2. Explain why medical device user manuals must be written in clear, appropriate language for different audiences, including patients and healthcare professionals.
3. Create a comprehensive operating manual for a therapeutic device that includes setup instructions, usage guidelines, cleaning procedures, safety warnings and troubleshooting advice.

Pedagogical Exemplars

Initiating talk/ sign for learning: The teacher engages the class in a guided discussion on the purpose and importance of an operating manual, especially in the context of medical or therapeutic devices. This discussion includes key questions such as: What is an operating manual? Why is it important? Who uses it? The teacher then outlines the main components of a typical manual, such as setup, operation, cleaning, safety warnings, and troubleshooting. Learners reflect on devices they have encountered (e.g. thermometers, blood pressure monitors, nebulisers) and share the kind of instructions or safety steps they recall from those experiences.

Activity-based learning: Learners work in mixed-ability groups to review relevant documents. With help from sample manuals, simple diagrams, or teacher guidance, the groups explore how a manual is structured. They then begin to write their own simple manual for their chosen device. They include clear steps for setting up, using, and cleaning the device, as well as basic safety tips and solutions to common problems.

Key Assessment: Structured Written Response (Individual classwork)

Level 4 (Extended thinking): A local health facility has recently received a new batch of portable therapeutic devices such as nebulisers and digital blood pressure monitors. These devices are to be used by both patients at home and healthcare workers in rural clinics. However, many of the user manuals that came with the devices are too technical, written in complicated language, or lack important safety and troubleshooting information.

As part of an effort to improve patient safety and usability, the facility has asked you to develop clearer, more user-friendly operating manuals. These manuals should be accessible to both non-technical users and trained healthcare professionals.

1. Discuss the importance of using clear, simple language that is appropriate for the intended audience. (6 marks)
2. Design an outline for the operating manual of a therapeutic device that has been studied or disassembled during class activities. (8 marks)
3. Explain why it is important to include safety warnings and troubleshooting tips in a user manual. (6 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 ***structured written response***. 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 18

Learning Indicator: *Discuss the role of regulatory agencies in the production and marketing of medical devices*

Recap Weeks

Year 1	**Week 15**: Explore the significance of the various diagnostic devices used for medical intervention.
Year 2	**Week 3**: Explore various biomedical career fields related to clinical or research studies and describe these career fields.

FOCAL AREA 1: ENSURING SAFETY AND EFFICACY – THE ROLE OF REGULATORY AGENCIES

Introduce the concept of medical device regulations and the role of regulatory agencies.

Before a medical device can be used in hospitals, clinics, or homes, it must undergo a thorough approval process known as medical device regulation (see **QR code 27**). This process ensures that devices are safe, effective, and suitable for their intended purpose. Medical device regulation protects patients, healthcare workers, and the public from the harm that could result from malfunctioning or poorly designed equipment. The type and level of regulation a device must undergo depend on the degree of risk it poses to users. Devices that pose minimal risk may only require basic quality checks, while high-risk devices go through strict testing, clinical trials, and ongoing monitoring. Medical devices are classified into risk-based categories, and each class determines the depth of regulation required:

1. **In Ghana, devices are grouped into Class 1 to 4**:
    a. **Class 1 (low risk)**: Includes basic items like bandages or examination gloves. These require general safety and labelling checks.
    b. **Class 2 (moderate risk)**: Such as digital thermometers and blood pressure monitors. These undergo more detailed performance assessments.
    c. **Class 3 (higher risk)**: Like ultrasound scanners or infusion pumps. These require evidence of clinical safety and manufacturing quality.
    d. **Class 4 (highest risk)**: Includes life-supporting or implantable devices like defibrillators or heart valves. These face the strictest regulatory review, including clinical trials and factory inspections.
2. **In the United States, the FDA uses a similar three-tier system**:
    a. **Class I**: Low-risk items like surgical gloves or stethoscopes. These are subject to general controls, such as proper labelling and manufacturing practices.
    b. **Class II**: Moderate-risk devices like glucometers or powered wheelchairs. These require special controls, performance testing, and sometimes premarket notification.

    c. **Class III**: High-risk devices like pacemakers or implantable defibrillators. These require full premarket approval, including clinical data, safety studies, and post-market surveillance.

This step-by-step system makes sure that medical devices are tested and checked based on how risky they are. Devices that could cause more harm if they fail need stronger testing, clearer instructions, and regular monitoring. This helps keep patients safe and builds trust in medical technology. The following are some of the roles regulatory agencies play in ensuring the safety and efficacy of medical devices.

1. **Setting safety and quality standards**: Regulatory agencies set detailed safety and quality standards that manufacturers must follow to ensure their medical devices are safe, effective, and reliable. These standards cover everything from the materials used, accuracy of measurements, to how easily the device can be cleaned and used. For example, a manufacturer producing a clinical thermometer must ensure the device gives precise readings, uses materials that are safe on human skin, and is easy to disinfect. These rules guide the design, testing, labelling, and user instructions, helping prevent harm and support proper use in both hospitals and homes.
2. **Reviewing device safety and effectiveness before approval**: Before a medical device can be sold or used, regulators must first confirm that it works properly and is safe for its intended users. This involves reviewing results from laboratory testing and clinical trials to check how the device performs under real-life conditions. For instance, a blood glucose meter must show that it provides accurate readings not just in controlled lab settings but also when used by actual patients. Regulators like FDA Ghana or the U.S. FDA carefully examine this data before giving their approval. This step protects users from devices that might be ineffective or unsafe.
3. **Inspecting manufacturing facilities:** Regulatory bodies regularly inspect the factories where medical devices are made to ensure they meet hygiene and quality control standards. During these inspections, they look for proper staff training, safe handling of materials, accurate calibration of machines, and complete production records. For example, if a facility manufactures nebulisers, inspectors may check that workers use protective gear and that devices are built in a clean environment. These inspections help reduce the risk of defective devices being produced, ensuring that products meet the same safety level as when they were approved.
4. **Approving and licensing devices for use**: Medical devices cannot be legally sold or used without official approval or licensing from the national regulatory authority. This process confirms that the device has passed all required safety checks, performance tests, and manufacturing inspections. For example, in Ghana, a digital blood pressure monitor must receive approval from FDA Ghana before clinics can use it. Similarly, in the U.S., implants like pacemakers must be reviewed by the FDA before they reach hospitals. This ensures that only trustworthy and safe devices are allowed into the healthcare system.
5. **Monitoring devices after approval (Post – market surveillance)**: Even after a medical device has been approved and is in use, regulatory agencies continue to monitor its safety. They collect reports from hospitals, clinics, and manufacturers about any problems, unexpected effects, or failures. For example, if several hospitals report that a specific brand of blood bag leaks during transfusion, FDA Ghana can step in to investigate and take corrective action, such as requiring a product recall or an update to the packaging. This

ongoing monitoring ensures that devices remain safe throughout their use and helps fix any issues quickly.

6. **Regulating marketing, advertising, and product claims**: Regulators also control how medical devices are advertised and sold, making sure that manufacturers do not exaggerate what their products can do. All marketing claims must be based on approved uses and supported by scientific evidence. For instance, a company cannot advertise a pulse oximeter as a cure for heart disease unless such a claim has been proven and approved. Similarly, devices cannot be labelled "risk-free" without proper evidence. These rules protect buyers and patients from being misled and help maintain public trust in healthcare technology.

Scan **QR code 28** to read more on the roles of FDA, Ghana in medical device production and marketing.

Briefly discuss the different stages of the regulatory approval process for medical devices

A medical device must pass through key development and approval stages before it can be made available for use. These stages involve testing for safety, accuracy, and reliability to ensure the device does not pose risks to patients or healthcare workers.

1. **Pre-clinical testing**: During this stage, the device is tested in laboratories, often using mechanical models or animals. The goal is to check how well the device performs, whether it causes any harm or side effects, and if the materials used are safe for the body. For example, a new knee implant might be tested using machines that apply pressure to measure strength and on animal bone models to see how well it fits.
2. **Clinical trials**: Once a device passes pre-clinical testing, it is tested on a small group of human volunteers in controlled settings. This phase determines if the device is safe for use in people, how effective it is at treating or diagnosing a condition, and identifies any side effects not seen earlier. For instance, a new insulin pump might be tested on diabetic patients in a hospital to monitor how well it maintains blood sugar levels.
3. **Regulatory review**: After clinical trials, all the data is submitted to the regulatory agency. The agency carefully examines the test results and assesses the manufacturing process to ensure quality and safety standards are met. They may request additional testing or modifications before giving approval. If everything complies with regulations, the device is authorised for sale and use in healthcare.
4. **Post-market surveillance**: Even after approval, the device continues to be monitored once in regular use. Regulatory agencies collect reports from healthcare professionals, patients and manufacturers about any problems or unexpected effects. If serious issues arise, the agency can require updates to the device, revise safety instructions, or remove it from the market if necessary.

Learning Tasks

1. Revise the process that diagnostic medical devices go through for approval and connect this to your understanding of biomedical careers such as clinical research and regulatory affairs.
2. Explain the role of regulatory agencies (such as FDA or GSA in Ghana) in protecting patient safety through the oversight and approval of medical devices.

3. Describe the stages of the medical device regulatory approval process: pre-clinical testing, clinical trials, regulatory review and post-market surveillance.

Pedagogical Exemplars

Structuring talk/ sign for Learning: Learners discuss the role of regulatory agencies such as the Food and Drugs Authority and Ghana Standards Authority in ensuring that medical devices for sale and in use, are safe and effective. Class brainstorms the effect of fraudulent adverts on equipment sales and how regulatory institutions can help.

Key Assessment: Practice Paper 2

Level 3 (Strategic thinking): You are part of a student biomedical innovation team developing a new portable diagnostic device to help detect high blood pressure in rural areas. Your group plans to present this device to a medical innovation fair, where representatives from Ghana's FDA and GSA will be present. However, before the device can be promoted, your team must demonstrate a clear understanding of the regulatory approval process and how regulatory agencies ensure device safety and effectiveness. Using what you have learned about medical device regulations and the roles of regulatory agencies. Prepare a detailed report that:

1. Explains why medical device regulation is necessary, especially in the context of patient safety and healthcare trust.
2. Identifies and explains the specific roles that regulatory agencies such as the FDA, Ghana and Ghana Standards Authority (GSA) play in the medical device approval process.
3. Describes each stage of the regulatory approval process:
   a. Pre-clinical testing
   b. Clinical trials
   c. Regulatory review
   d. Post-market surveillance



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.*

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 2***. 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 Review

This section is a review of the key lessons delivered over the past weeks. It summarises the core content that should have been covered and outlines what learners should understand if teaching and differentiation have been effectively applied.

1. Explain the role of biomedical engineers in the production, acquisition, and maintenance of medical devices.
2. Apply engineering and design principles to create and assemble a simple, functional diagnostic device that meets a real healthcare need.
3. Demonstrate an understanding of how different components of a therapeutic or diagnostic device are assembled and disassembled for maintenance and repair.
4. Develop a basic marketing plan and present the designed device to potential stakeholders or investors, showing its clinical value and potential market impact.
5. Write a clear, user-friendly operating manual for a therapeutic device that includes essential safety and troubleshooting information.
6. Discuss the roles of regulatory bodies such as the FDA and Ghana Standards Authority in ensuring the safety, effectiveness, and approval of medical devices before and after they enter the market.

Innovation in diagnostic and therapeutic medical devices is an important part of biomedical science, where science, engineering, and business come together to improve healthcare and patient outcomes. In this section, students learned how to take a medical device from an idea to a finished product ready for use. They explored the full development process, identifying real healthcare needs, designing and building simple working prototypes, and learning how to present their devices to potential users or investors. The aim was to help students connect theory with practice by understanding the roles of biomedical engineers, using design principles, and developing clear communication skills. By the end of the section, students should be able to design safe, effective, and user-friendly diagnostic tools that meet clinical needs and follow basic regulatory standards.

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEK 13

Question 1

4 marks: Explanation includes contributions of at least five engineering roles (such as R&D, design, quality assurance, regulatory, clinical) across the full development process with clear and relevant examples.

3 marks: Covers at least four roles with correct role-to-stage matching and adequate detail.

2 marks: Describes at least three roles with partial relevance or missing stage connections.

1 mark: Describes at least two roles with basic understanding of their involvement.

Question 2

4 marks: A complete, well-labelled sequence showing all key stages (such as need identification, R&D, design, testing, approval, production, use, and maintenance), with roles clearly assigned and explained.

3 marks: Shows most stages (minimum of six), with accurate role matching and basic explanations.

2 marks: Includes four or more stages, though role matching may be unclear or lack depth.

1 mark: Includes at least three stages, showing some understanding of sequence or engineering involvement.

Question 3

4 marks: A realistic, well-structured activity with clear steps, a strong educational aim, and meaningful connections to biomedical engineering processes or roles.

3 marks: A meaningful activity with a defined purpose and logical steps, though with limited detail.

2 marks: A partially relevant activity with vague structure or weak learning connections.

1 mark: A basic idea that reflects some understanding of the work biomedical engineers do.

Question 4

4 marks: Two well-explained, realistic examples showing how teamwork improves outcomes, with clear reference to engineering roles and the impact of poor collaboration.

3 marks: Two examples included, with some explanation of how team effort influences safety or quality.

2 marks: One detailed or two general examples provided, though partly relevant or lacking depth.

1 mark: At least one example included, showing some awareness of the importance of collaboration.

WEEK 14

Question 1 (8 marks)

8 marks: Thorough investigation using multiple sources (e.g. interviews, observations, literature). Provides detailed insight into user experiences and clearly identifies a realistic and relevant problem supported by evidence.

5–7 marks: Research shows good effort using at least one method (e.g. interviews or secondary research). The problem is clearly stated and somewhat supported by user insights.

2–4 marks: Limited research with vague or general user observations. The problem is broadly defined with little connection to user needs.

1 mark: Minimal research. Problem is weakly defined with little relevance to user needs.

Question 2 (8 marks)

8 marks: Three well-developed and creative ideas with clear, labelled sketches. Justifies each idea by linking it to the defined user problem with thoughtful reasoning.

5–7 marks: Presents three reasonable ideas with sketches. Some justification provided, though not all ideas are well-linked to user challenges.

2–4 marks: Fewer than three ideas or underdeveloped. Sketches may be missing or unclear. Limited or weak justification.

1 mark: One basic idea is presented with minimal explanation or sketch.

Question 3 (8 marks)

8 marks: Prototype is clearly constructed, realistic, and creatively uses local materials. Labelled sketches or photos are provided. Explanation clearly shows how the prototype works and meets the user's needs.

5–7 marks: A functional prototype is presented with basic labels or explanations. Some connection to user needs is evident.

2–4 marks: Prototype is incomplete or lacks clarity. Sketches/photos or explanations may be missing or weakly linked to user needs.

1 mark: Prototype attempt is present but very limited in clarity or relevance.

Question 4 (8 marks)

8 marks: Comprehensive feedback collected from at least two users. Suggestions for improvement are specific and show clear reflection. Proposed changes logically enhance the design.

5–7 marks: Feedback is collected and some suggestions are made. Shows effort to reflect on the user experience and propose improvements.

2–4 marks: Limited or vague feedback. Suggested changes are general or only partially based on the feedback.

1 mark: Brief or unclear feedback with minimal connection to proposed changes.

Question 5 (8 marks)

8 marks: All steps are well-organised, clearly presented, and easy to understand. Technical terms are used appropriately. Presentation is engaging and follows a logical sequence.

5–7 marks: The work is generally well-organised and clear. Some technical details may be missing or underdeveloped.

2–4 marks: Presentation lacks structure or clarity in places. Communication of ideas may be weak or disorganised.

1 mark: Presentation is minimal or difficult to follow, but some effort is evident.

WEEK 15

Question 1 (4 marks)

4 marks: Clearly identifies a relevant health problem with detailed explanation and examples. Sample: "Many rural clinics lack reliable electricity, making it difficult to use standard digital thermometers. This leads to inaccurate fever detection, delaying treatment and increasing health risks."

3 marks: Identifies the problem with some explanation but less detail. Sample: "Rural areas have trouble checking fever because they don't always have electricity."

2 marks: Vague statement of a health problem with little explanation. Sample: "People in some places need thermometers."

1 mark: Minimal or unclear description. Sample: "Thermometers are needed."

Question 2 (4 marks)

4 marks: Clearly defines the users and location with a good understanding of needs. Sample: "The device targets nurses and patients in rural clinics in Ghana, where electricity is unreliable and affordable, easy-to-use thermometers are needed."

3 marks: Describes users and locations with some detail. Sample: "People in rural clinics will use the thermometer."

2 marks: Basic or incomplete description. Sample: "The thermometer is for hospitals."

1 mark: Little or no relevant detail. Sample: "It is for people."

Question 3 (4 marks)

4 marks: Detailed comparison of two competing products, with clear differentiation. Sample: "Current digital thermometers require batteries or mains power, which

rural clinics lack. Our solar-powered thermometer does not need electricity and is more affordable."

3 marks: Some comparison with limited detail. Sample: "Other thermometers need power. Ours uses solar energy."

2 marks: Mentions competitors but lacks clear comparison. Sample: "There are other thermometers, but ours is different."

1 mark: No meaningful competitor analysis. Sample: "There are many thermometers."

Question 4 (4 marks)

4 marks: Clear and persuasive pitch including funding needs and expected benefits. Sample: "We need Ghc10,000 to build prototypes and conduct testing. This thermometer will improve early fever detection, reduce illness and save lives in off-grid clinics."

3 marks: Reasonable pitch but lacks full detail or persuasiveness. Sample: "Funding will help us make the thermometer, which will help patients."

2 marks: Basic or vague pitch with little justification. Sample: "We want money to make the device."

1 mark: Incomplete or unclear pitch. Sample: "We need funds."

Question 5 (4 marks)

4 marks: Detailed, realistic plan including promotional activities, partnerships, and clear timeline. Sample: "We will partner with rural health NGOs to distribute devices and hold training sessions. Prototype testing in 3 months, full launch in 9 months."

3 marks: Mostly complete plan with some gaps. Sample: "We will tell clinics about the device and train nurses soon."

2 marks: Basic plan with limited detail. Sample: "We will sell the thermometer to clinics."

1 mark: Minimal or unclear plan. Sample: "We want to sell it."

WEEK 16

Question 1 (5 marks)

5 marks: Clearly analyses multiple real-world consequences, with detailed examples (e.g., "If the hot water bottle is overfilled or sealed improperly, it may leak, leading to burns or discomfort"). Demonstrates excellent understanding of device function, clinical risks, and user outcomes.

3–4 marks: Explains key risks with some relevant examples. Shows good understanding of cause and effect but lacks depth in one area (e.g., might mention safety risks but not discuss implications for user confidence or hygiene).

1–2 marks: General or vague explanation. May state that "it could be dangerous" but does not give specific scenarios or examples.

Question 2 (6 marks)

6 marks: Clearly identifies and explains at least five components (e.g., rubber body, screw cap, sealing washer, cover, fill line). Describes correct placement and explains the impact of misplacement or misuse (e.g., "If the screw cap is not tightly secured, hot water may leak and cause burns").

4–5 marks: Identifies at least four components with mostly correct placement and function. It may not explain all impacts in detail.

2–3 marks: Describes fewer than four components or gives unclear explanations—limited connection between incorrect assembly and device safety.

1 mark: Attempt made but with minimal clarity, incorrect sequencing, or components not explained.

Question 3 (5 marks)

5 marks: Creative, feasible solutions (e.g. "Use of clear 'fill line' markings and tactile indicators for tightening the cap"). Strong justification focused on rural healthcare, limited training, or low literacy environments.

3–4 marks: Suggestions are relevant and realistic (e.g., "Add instructions on the cover") but may lack detailed justification or user context.

1–2 marks: General suggestions (e.g., "make it safer to use") without specifics or relevant rationale.

Question 4 (4 marks)

4 marks: Insightful evaluation linking proper assembly and usage to wider biomedical engineering goals (e.g., improving safety, reducing avoidable injuries, supporting inclusive design). May mention the importance of health education or cultural adaptation.

3 marks: Good explanation of how basic device knowledge contributes to safety and public health. May overlook a broader biomedical objective.

2 marks: Basic link to health or safety without deeper insight.

1 mark: Minimal or superficial reflection.

WEEK 17

Question 1 (6 marks)

6 marks: Provides a clear, well-structured explanation addressing both patients and healthcare workers. Demonstrates a strong understanding of how unclear instructions can lead to misuse, harm, or decreased confidence. Includes specific and relevant examples.

5 marks: Gives a solid explanation covering both user groups, with clear points on risks and the benefits of clarity. Includes at least one relevant example.

4 marks: Offers a general but accurate explanation. May focus more on one user group, with limited detail or only partial examples.

3 marks: Presents a basic explanation with some relevant ideas. May lack detail or clarity, and examples are vague or underdeveloped.

2 marks: Attempts an explanation but lacks depth. Limited reference to either audience or safety, and examples may be missing or unclear.

1 mark: Response shows minimal understanding with vague statements and little connection to the question.

Question 2 (8 marks)

8 marks: Provides a clear, well-organised outline including at least three key manual sections, each clearly explained. Offers well-written, easy-to-follow example instructions using simple, audience-appropriate language.

7 marks: Gives a well-structured outline with three relevant sections and mostly appropriate sample instructions. Some minor gaps in clarity or user focus.

6 marks: Presents a reasonable outline with at least two valid sections and some explanation. Instructions are generally clear but may lack structure or full simplicity.

4–5 marks: Includes some valid manual sections, but explanations or instructions are either incomplete or uneven in quality. Some clarity issues may be present.

2–3 marks: Attempts to list sections or provide instructions, but the outline lacks organisation or relevance. Instructions may be vague or too technical.

1 mark: A minimal response that shows limited understanding, with brief or unrelated content.

Question 3 (6 marks)

6 marks: Clearly explains the value of both safety warnings and troubleshooting tips. Provides two appropriate examples for each, directly related to the device and user context.

5 marks: Strong explanation with appropriate examples. Shows good understanding of why each element is necessary for user safety and confidence.

4 marks: Offers a reasonable explanation of either safety or troubleshooting, or addresses both briefly. Examples are included but may lack depth.

3 marks: Demonstrates basic understanding with some reference to importance. May focus on only one area or give weak examples.

2 marks: Minimal explanation with vague or incomplete examples. May refer to safety or troubleshooting without clearly explaining their role.

1 mark: Limited understanding shown. Response includes general statements with little clarity or relevance.

WEEK 18

Question 1

5 marks: Clear, well-structured explanation of why regulation is essential, with strong focus on patient safety and healthcare trust; includes specific examples.

4 marks: Good explanation with mostly relevant points and some supporting examples.

3 marks: General explanation with limited clarity or examples.

2 marks: Partial or basic explanation with minimal depth.

1 mark: Attempted explanation with weak understanding or vague statements.

Question 2

5 marks: Accurately identifies both agencies and clearly explains their main roles, including setting standards, inspecting, approving, and monitoring.

4 marks: Both agencies identified with mostly accurate role descriptions.

3 marks: At least one agency explained with a general understanding.

2 marks: Some attempt to describe roles but lack accuracy or detail.

1 mark: Minimal attempt to describe agency roles.

Question 3

Each of the four stages below is marked out of 2 marks:

Pre-clinical testing – 2 marks

2 marks: Clearly explains testing methods, safety checks, and provides a relevant example.

1 mark: Gives a basic explanation with limited detail.

Clinical trials – 2 marks

2 marks: Explains testing on humans, purpose, and effectiveness with a clear example.

1 mark: General description with limited clarity or no example.

Regulatory review – 2 marks

2 marks: Describes how agencies review data and approve devices.

1 mark: Basic explanation with minor omissions.

Post-market surveillance – 2 marks

2 marks: Explains how devices are monitored after approval and what actions may follow.

1 mark: General or incomplete explanation.

Additional Reading

QR Code 22:Who is a Biomedical engineer?

QR Code 23: Biomedical engineer roles.

QR Code 24: Medical device marketing

QR Code 25: Disassemble and assembly

QR Code 26: Medical device manual

QR Code 27: Medical device regulation

QR Code 28: FDA Ghana's role

SECTION 6: RESEARCH AND DESIGN IN BIOMEDICAL SCIENCE

Strand: Biomedical Innovation

Sub-Strand: Research and Design in Biomedical Science

Learning Outcome: *Use scientific literature and statistics to design experiments and analyse results.*

Content Standard: *Demonstrate understanding and application of a variety of biomedical experimental designs*

INTRODUCTION AND SECTION SUMMARY

In this section, learners apply statistical methods to analyse biomedical data sets. They calculate basic statistics, such as mean, range, and standard deviation, to explore how results vary between participants. Learners also interpret these results in relation to the original research question and consider limitations such as a small sample size. The section also introduces learners to designing simple biomedical experiments. Students brainstorm real-world health-related questions and develop a structured plan using the scientific method to answer them. By the end of this section, learners are expected to design and analyse small-scale experiments and apply appropriate statistical tools to interpret their findings clearly. They will also begin to think critically about the strengths and weaknesses of their experimental design and data, fostering a deeper understanding of evidence-based research.

The weeks covered by the section are:

Weeks 19 & 20: Apply knowledge of specified statistical analysis methods to analyse the results of experimental studies

Weeks 21 & 22: Design and analyse an experimental study to answer a question relating to human health

SUMMARY OF PEDAGOGICAL EXEMPLARS

The following pedagogical exemplars are recommended to support learning outcomes and meet the content standard. Through structured talk for learning, learners engage in guided discussions to identify and explain dependent and independent variables in sample biomedical studies. They also explore the role of statistical measures and how sample size influences data interpretation and population representation. Activity-based learning is recommended to help learners calculate measures of central tendency and variability using data from actual studies. They manipulate visual representations of data to observe how scale can distort or clarify outcomes.

With project-based learning, learners work in groups to design and conduct small-scale health-related experiments. They gather primary or secondary data, apply appropriate statistical tools to analyse the data, and present their findings in a report. These approaches foster collaboration, analytical thinking, and scientific communication skills.

ASSESSMENT SUMMARY

To assess learners' understanding of statistical analysis and experimental study design in human health, DOK Level 4 assessment strategies are recommended. These require learners to apply extended thinking and synthesis skills to demonstrate how scientific methodology informs healthcare solutions from research questions to impactful findings. Learners calculate and interpret basic statistics (mean, median, range, standard deviation) from provided biomedical datasets, drawing conclusions and acknowledging study limitations. They then design and conduct comprehensive experimental studies addressing real-world community health questions, formulating hypotheses, outlining procedures, collecting and analysing data, and interpreting results. Learners document their findings in reports and effectively communicate complex scientific information to diverse audiences, fostering deeper comprehension of evidence-based health improvements.

Indicators	DOK Level	*Assessment Strategy and/or Mode*
Apply knowledge of specified statistical analysis methods to analyse the result of experimental studies	4	Structured written response as group project.
Design and analyse an experimental study to answer a question relating to human health	4	Structured written response as an individual project.

WEEKS 19 & 20

Learning Indicator: *Apply knowledge of specified statistical analysis methods to analyse the result of experimental studies*

Recap Weeks

Year 1	**Week 3**: Explain how the scientific method can be applied to undertake investigations or address problems in Biomedical Science.
Year 2	**Week 23**: Critique and compare science data presented in popular media with data presented in scientific journals **Week 24**: Apply knowledge of specified statistical analysis methods to analyse the results of experimental studies.

FOCAL AREA 1: STATISTICAL ANALYSIS OF RESULTS

Analysis of biomedical research data

Datasets analysis is a critical part of biomedical research. It involves organising, interpreting and drawing conclusions from data collected during experiments or clinical studies. Biomedical researchers use data to identify patterns, test hypotheses, evaluate the effectiveness of treatments and support evidence-based decision-making in healthcare. In biomedical research, data may come from laboratory experiments, patient surveys, clinical trials, diagnostic tests, or public health studies. To ensure accuracy and reliability, researchers apply statistical methods such as calculating averages (mean), determining variability (standard deviation), and performing hypothesis testing (*p*-values). Proper analysis of datasets allows scientists to:

1. detect trends in disease occurrence and treatment responses.
2. evaluate relationships between variables (e.g., dosage vs. symptom relief).
3. make predictions about health outcomes.
4. support medical innovation and public health policies.

Understanding how to analyse biomedical datasets equips learners with skills needed to participate in real-world research, interpret scientific results and contribute to improving healthcare outcomes. Researchers in the biomedical field rely on data to answer questions like: "*Does a new drug reduce symptoms?", "What is the average blood pressure in a particular age group?" and "Is there a link between lifestyle and disease risk?".*

Calculation of basic statistics to understand the distribution of results

Statistics help us summarise and understand data, such as test scores, temperatures, or survey responses. To understand the distribution of results obtained in biomedical research, calculating basic statistics is crucial. These statistics help us summarise complex datasets, identify patterns, and draw initial conclusions before more advanced analyses. By calculating measures like mean, median, mode, range, and standard deviation, we can describe where data tends to cluster (central tendency) and how spread out it is (variability). Guidance on these calculations and how to use them to analyse data distributions are as follows.

1. Mean (Average)

The mean is the sum of all data values divided by the number of values ($\frac{\text{sum of all values}}{\text{number of values}}$). It represents the "average" value of the dataset.

Formula:

Ungrouped data: Mean $(x) = \frac{x1 + x2 + x3 + \ldots xn}{n}$

Grouped data: Mean $(x) = \frac{\Sigma fx}{n}$

Where: f = frequency

x = value of each observation

n = total number of values

Example: Calculate the mean heart rate (beats per minute, bpm) of five patients: 72, 78, 65, 80, 70.

$x = \frac{72 + 78 + 65 + 80 + 70}{5} = \frac{365}{5} = 73$ bpm

2. Median

The median is the middle value when the data is ordered from smallest to largest. It is useful in biomedical data when extreme values (e.g., unusually high blood pressure) might skew the mean.

Steps

1. Arrange data in ascending order.
2. If the number of values (n) is odd, the median is the middle value.
3. If (n) is even, the median is the average of the two middle values.

Example

(Odd n): Find the median heart rate: 70, 72, 68, 74, 76, 72, 70.

Arrange data in ascending order: 68, 70, 70, **72**, 72, 74, 76 → middle value = 72 bpm

(Even n): A biomedical student measured the blood glucose levels (in mmol/L) of patients after fasting for 12 hours. The recorded values were: 4.8, 5.1, 4.6, 5.3, 4.9, 5.0, 4.7, 5.2. What is the median?

Steps: Arrange data in ascending order: 4.6, 4.7, 4.8, **4.9**, **5.0**, 5.1, 5.2, 5.3

Find average of middle values $= \frac{4.9 + 5.0}{2} = \frac{9.9}{2} = 4.95$ mmol/L

3. Mode

The mode is the value that appears most often. A dataset may have one mode, multiple modes, or no mode if all values are unique.

Example: Find the mode of the quiz scores: 80, 85, 90, 70, 95.

Solution: Each score appears once. Mode: No mode.

Example with mode: Scores: 80, 85, 90, 85, 70.

Solution: 85 appears twice; others appear once. Therefore, mode = 85

4. Range

The range measures the spread of data by finding the difference between the maximum and minimum values.

Formula: Range = Maximum value - Minimum value

Example: A biomedical science class recorded the body temperatures (in °C) of 6 patients during a fever study. The readings were: 38.2, 37.6, 39.0, 38.5, 37.9, 38.7. Find the range.

Step 1: Identify the highest and lowest values

Highest value = 39.0°C

Lowest value = 37.6°C

Step 2: Subtract the lowest value from the highest value

Range = 39.0 - 37.6 = 1.4°C

5. Standard Deviation

The standard deviation measures how much the data values deviate from the mean. A low standard deviation means data is clustered near the mean; a high one means data is more spread out. The standard deviation is the square root of the variance, expressing the spread in the original units, making it easier to interpret.

The formula for finding the standard $SD = \sqrt{\frac{\sum (x-\bar{x})^2}{N-1}}$ deviation

Where x = each value

x = mean

n = number of values

Example: A biomedical science student measured the resting respiratory rates (in breaths per minute) of 5 patients: 16, 18, 17, 20, 19. Calculate the standard deviation.

Step 1: Find the mean

$x = \frac{16 + 18 + 17 + 20 + 19}{5} = \frac{90}{5}$ 18

Step 2: Subtract the mean and square the result for each value

Value (x)	$(x - \underline{x})$ = x - 18	$(x - \underline{x})^2 = (x-18)^2$
16	-2	4
18	0	0
17	-1	1
20	2	4
19	1	1
		$\Sigma(x - \underline{x})^2 = 10$

Step 3: Divide by n–1 = $\frac{10}{5-1} = \frac{10}{4} = 2.5$

Step 4: Take the square root = $\sqrt{2.5} \approx 1.58$

This means that the typical difference between each patient's respiratory rate and the average rate is about 1.58 breaths per minute. A small standard deviation like this means the values are close together (low variability). If the SD were larger, it would mean the respiratory rates vary more widely between patients.

Uses of measures of central tendency and dispersion

In biomedical science, numerical data such as blood pressure, heart rate, body temperature, or glucose levels are often collected. To make sense of this data, basic statistical methods (such as mean, mode, median, range, and standard deviation) are used to describe how the values are spread out and to identify common patterns and trends.

1. The **mean**, also known as the average, gives us a general idea of the central value in a data set. However, the mean can be affected by very high or very low values, known as outliers. For instance, if a group of patients has heart rates between 68 and 75 beats per minute, but one patient has a rate of 110 bpm, the mean may not accurately represent the group.
2. The **median** is the middle value when the data is arranged in ascending or descending order. If there is an even number of values, the median is the average of the two middle numbers. The median is useful when the data includes outliers or is skewed, because it is not affected by extreme values. For example, in a dataset of glucose levels, most patients are around 5.0 mmol/L, but one is 15.0 mmol/L; the median gives a more typical value than the mean.
3. The **mode** is the value that appears most frequently in the data set. It is useful for identifying the most common result, especially in categorical data or when data values repeat. For example, if the most frequent blood group recorded in a clinic is O+, then O+ is the mode. Unlike the mean, the mode is not influenced by extreme values.
4. The **range** is the difference between the highest and lowest values in the data set. It provides a quick measure of how spread out the data is. For example, if respiratory rates in a study range from 12 to 24 breaths per minute, the range is 12. Although easy to calculate, the range only considers the two extreme values and may not fully represent the variation in the data set.
5. The **standard deviation** is a more precise measure of how spread out the values are from the mean. A small standard deviation means most values are close to the mean, indicating low variability. A large standard deviation means the data points are widely spread, indicating high variability. For instance, if systolic blood pressure readings average 120mmHg with a standard deviation of 2mmHg, most readings fall between 118 and 122 mmHg, that is ±2mmHg, showing that the results are consistent.

Interpreting results using mean, median, mode, range, and standard deviation

If the mean respiratory rate among patients was found to be 18 breaths per minute with a standard deviation of 1.58, for instance, this suggests that most patients had similar breathing rates, with only slight variation. The median and mode are also close to the mean, which reinforces that the data is symmetrical, and there are no extreme outliers affecting the results. In the context of the experiment, if the aim were to assess whether a treatment stabilises respiratory rate in patients, the low standard deviation and narrow range would suggest that the

treatment may be effective in producing consistent outcomes. However, it is important to acknowledge that the sample size was small (only 5 patients), which limits the reliability and generalisability of the findings. A small sample may not accurately represent the wider population and can make the data more sensitive to individual variations. Furthermore, because this was a simple observational experiment, other factors that could influence the results, such as age, physical activity, or underlying health conditions, may not have been controlled. Future studies with a larger sample size, more diverse participants, and a controlled design would help strengthen the conclusions and provide more reliable evidence.

Data visualisation

Visual tools are indispensable in biomedical research for making complex data understandable, identifying patterns, and communicating findings effectively. They transform raw numbers into insights, facilitating interpretation and decision-making. Choosing the right type of graph depends on the nature of the data and the message you want to convey. Choosing the right visual tool is paramount. An appropriately selected chart simplifies complex biomedical science data, highlights key findings, and allows for quicker and more accurate interpretation by both researchers and a broader audience. Commonly used visual tools include pie charts, bar graphs, and scatter plots.

1. **Pie Charts**: Pie charts display how parts contribute to a whole, with each slice representing a category's share of the total. They work best when comparing how distinct groups or categories make up a whole, particularly with categorical or percentage-based data. These charts are most effective with a limited number of categories, ideally between 2 and 5, as a greater number of slices can make the chart visually crowded and difficult to interpret.
2. In biomedical science research, pie charts are commonly used to illustrate the distribution of blood types within a patient cohort, the proportion of patients experiencing different treatment outcomes (such as improvement, stability, or deterioration), and the breakdown of causes of mortality in a given population. For instance, a study examining the distribution of blood types at a clinic can be visualized as shown in Figure 47.

Blood Group	Frequency (%)
O+	40
A+	25
B+	20
AB	15

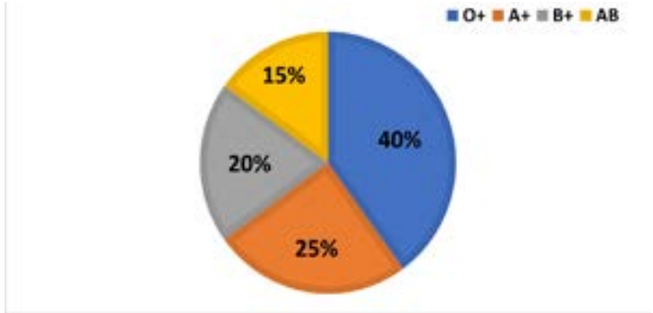


Figure 47: *Pie chart for blood type distribution*

3. **Bar graphs** (e. g. bar chart and histogram): display quantities or frequencies of various categories or groups using rectangular bars. Can be vertical or horizontal. The height or length of each bar represents the value. They are used to compare the size or frequency of various categories and so suitable for discrete or categorical data. Bar graphs are excellent for comparing quantities across distinct categories. They clearly show differences in magnitude between groups and can be used to display changes over time for discrete intervals. They are most suitable for presenting frequencies or counts. Examples in Biomedical science research include: average drug dosage administered across different age groups; number of cases of a specific disease per year; comparison of mean cholesterol levels between a control group and a treatment group; and frequency of different genetic mutations in a study population. For example, A study records the number of patients reporting side effects from three different medications:

Medication	No. of side effect cases
Drug A	12
Drug B	8
Drug C	15

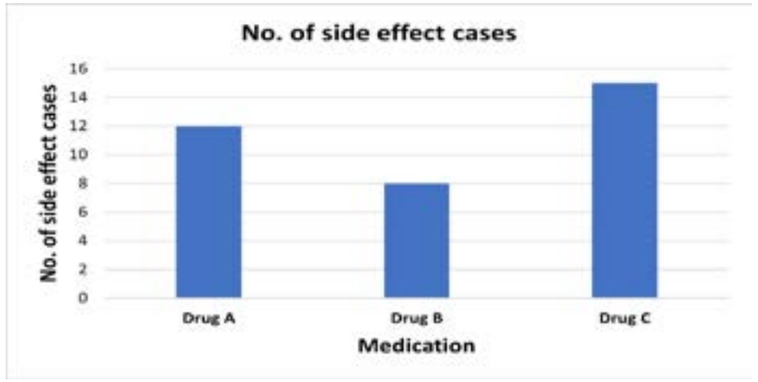


Figure 48: *Bar graph*

Figure 48 is a bar graph that reveals the comparison, helping identify which drug had the most side effects.

4. Scatter plots are graphs that use dots to represent the values for two different numerical variables. Each dot's position on the horizontal axis (X-axis) corresponds to one variable, and its position on the vertical axis (Y-axis) corresponds to the other. Scatter plots show the relationship between two continuous variables by plotting individual data points on a graph. They are used to observe correlations or trends between variables (e.g., as one increases, does the other increase too?). Scatter plots reveal the relationship or correlation between two continuous variables and help identify trends (positive, negative, or no correlation). They can also show the spread or clustering of data points and help identify outliers (data points far from the general trend). Examples in biomedical science research:

   a. Relationship between daily exercise minutes and blood pressure.
   b. Correlation between drug concentration in blood and patient response.
   c. Association between age and bone density.

d. Visualising individual patient data points in a clinical trial to see response variation.

Example

A researcher investigates the relationship between hours of sleep and reaction time in a memory test:

Hours of sleep	Reaction time (s)
3	0.5
4	2.5
5	2.3
6	2.1
7	1.8
8	1.5
9	5.6

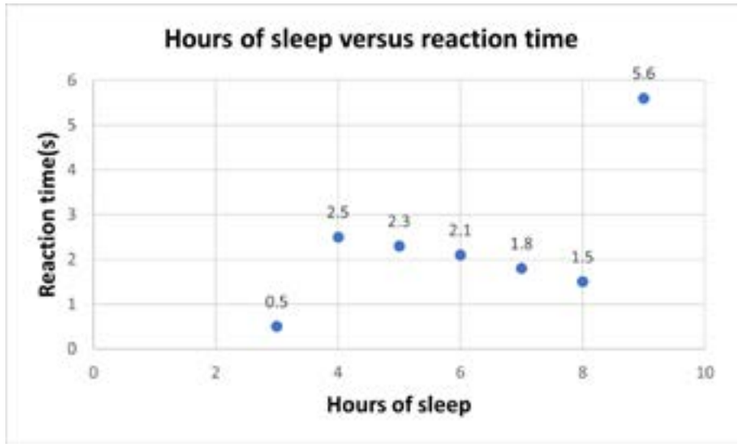


Figure 49: *Scatter Plot*

Figure 49 is a scatter plot showing the relationship between hours of sleep and reaction time. Take note of the outliers.

Summary Table

Graph Type	Best used for	Data type	Example(s)
Pie	Showing proportions of a whole	Categorical (%)	Blood group distribution
Bar	Comparing frequency or quantity	Categorical	Number of patients reporting side effects
Scatter	Showing relationships between variables	Continuous	Sleep hours versus memory test reaction time

Why the need for a larger sample size

1. A larger sample size is important in biomedical science experiments because it increases the reliability and accuracy of the results. When only a few people are used in a study, the results can be easily influenced by individual differences such as age, lifestyle, or underlying health conditions. These differences may not reflect what would happen in the general population.
2. With a larger sample, the results are more likely to represent a wider group, which makes the findings more valid and trustworthy. In addition, a larger sample size reduces the effect of outliers, those unusual values that can skew the average or make the data seem more varied than it really is.
3. It also makes statistical calculations, like the mean and standard deviation, more stable. Scientists can be more confident that the patterns they observe are real and not just due to chance.
4. Finally, a large sample size increases the power of the study, which means it becomes easier to detect real differences or changes caused by treatments or conditions being tested. Without enough participants, meaningful effects might be missed or results may appear inconsistent.

Learning Tasks

1. Revise with the students by asking them to recall how the scientific method guides biomedical investigations, then have them review examples of the same research presented in media versus journals and finally guide them through practicing statistical analysis of experimental data.
2. Organise and simplify biomedical research data sets and calculate appropriate descriptive statistics (mean, median, range) to accurately summarize the distribution of results.
3. Interpret statistical findings in relation to the original research question and identify at least three limitations that might affect the validity or reliability of the experimental conclusions.

Pedagogical Exemplars

Structured Talk / Sign for Learning: Facilitate a formal academic discussion in which students examine and identify dependent and independent variables across a selection of biomedical research studies. The dialogue should then progress to explore core principles of statistical measurement and critically assess how sample size affects how well a sample represents the broader population in scientific research.

Activity-Based Learning: Provide students with real biomedical research datasets to analyse statistically. Students should calculate relevant measures of central tendency, namely the mean, mode, and median, as well as measures of dispersion, including the range and standard deviation. Sample datasets are available in the Additional Reading section. Following this, students should construct scatter plots or histograms from the data, then deliberately vary the y-axis scale for the ordinate. Through this exercise, students should observe and record how adjusting the graphical scale can substantially alter the visual interpretation of scientific results, either amplifying or downplaying the apparent magnitude of effects.

Key Assessment: Structured Written Response (Group)

Level 4 (Extended thinking): A group of biomedical science students is studying the effect of a new herbal drink on lowering blood pressure. They selected 10 adult patients with slightly high blood pressure. Each patient drank the herbal mixture once a day for two weeks. The students measured each patient's systolic blood pressure (the top number in a BP reading) before and after the treatment. They now want to analyse the data to find out whether the herbal drink was helpful.

Dataset: Systolic Blood Pressure (mmHg)

Patient	Before Drink	After Drink
1	142	136
2	150	144
3	138	135
4	145	140
5	147	141
6	140	135
7	143	140
8	139	134
9	144	139
10	141	135

1. Using the data above, calculate and compare the mean, median, range, and standard deviation of the blood pressure readings before and after the herbal drink. What do your results say about the effect of the drink?
2. Would you say the herbal drink helped lower blood pressure based on the data? Explain your answer clearly using evidence from your calculations.
3. If you were to repeat this study, what would you do differently to make the results more reliable, and why would those changes matter?
4. How would you explain your findings and the meaning of the numbers (like average and standard deviation) to someone without a science background?

PLC Session 19 & 20

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 structured written response***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the assessment (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.

WEEKS 21 & 22

Learning Indicator: *Design and analyse an experimental study to answer a question relating to human health*

Recap Weeks

Year 1	**Week 3**: Explain how the scientific method can be applied to undertake investigations or address problems in Biomedical Science.
Year 2	**Week 23**: Critique and compare science data presented in popular media with data presented in scientific journals **Week 24**: Apply knowledge of specified statistical analysis methods to analyse the results of experimental studies.

FOCAL AREA 1: FROM QUESTION TO EXPERIMENT – DESIGN AND ANALYSIS

The foundation of scientific discovery begins with a question. In biomedical science, research questions often arise from observations of health-related practices, behaviours, and conditions within communities. For example, observations may be made about the use of traditional herbal remedies, dietary habits, patterns of physical activity, or other factors that may influence health and wellbeing. Scientists transform such observations into specific, testable questions that can be investigated systematically through research.

Before beginning an investigation, it is important to bridge the gap between existing knowledge and new inquiry by reviewing relevant literature and previous research findings. This helps researchers identify what is already known, refine the research question, and ensure that the study addresses a meaningful gap in knowledge. A well-formulated research question should be clear, specific, measurable, and capable of being investigated using a structured methodology that generates reliable data.

Once a research question has been established, the next step is to design an experiment. This process involves formulating a hypothesis, making predictions, identifying variables, selecting participants, collecting data, and analysing results. Careful experimental design ensures that conclusions drawn from the study are valid, reliable, and evidence-based.

Example: Quantitative Analysis of Sucrose Consumption on Selective Attention and Cognitive Processing Speed

1. Observation and Questioning

a. Observation:

Teachers at a Senior High School in Ho Municipality observe that some students who frequently consume sugary soft drinks during break periods report experiencing fluctuations in attention and concentration during classroom activities.

b. Research Question:

Does the consumption of a high-sugar beverage affect the short-term selective attention and cognitive processing speed of Senior High School students in Ho Municipality?

2. Hypothesis and Prediction

a. Hypothesis:

Senior High School students who consume a high-sugar beverage will demonstrate lower levels of short-term selective attention and cognitive processing speed thirty minutes after consumption than students who consume water. This may occur because a rapid rise in blood glucose concentration can be followed by a subsequent decline that may temporarily affect cognitive performance.

b. Prediction:

Students who consume a high-sugar beverage will obtain lower scores on a standardised attention and processing-speed task administered thirty minutes after consumption compared with students who consume water.

3. Experimentation (Methods and Data Collection)

a. Participants:

Forty Senior High School students aged 15–17 years from one selected Senior High School in Ho Municipality will participate in the study.

b. Independent Variable:

Type of beverage consumed (high-sugar beverage or water).

c. Dependent Variable:

Short-term selective attention and cognitive processing speed, measured using the number of correct responses on a five-minute standardised cognitive task.

d. Controlled Variables:

- Time of testing
- Quantity of beverage consumed
- Time interval between beverage consumption and testing
- Testing environment
- Difficulty level of the cognitive task
- Prior food intake
- Participant age range

e. Control Group:

Twenty students will consume water only.

f. Experimental Group:

Twenty students will consume a high-sugar beverage.

g. Methodology:

i. Randomly assign participants to either the control group or the experimental group.

ii. Ensure all participants follow the same pre-test instructions regarding food and beverage intake.

iii. Administer the assigned beverage to each participant.

iv. Wait thirty minutes after consumption.

v. Administer the same five-minute standardised attention and processing-speed assessment to all participants.

vi. Record the number of correct responses obtained by each participant.

4. Analysis and Conclusion

a. Analysis

To evaluate the results, calculate the mean score for both the control and experimental groups. Compare the group means to determine whether a meaningful difference exists between students who consumed water and those who consumed the high-sugar beverage.

Measures of variability, such as the range and standard deviation, may also be calculated to determine how consistent the scores are within each group. Graphical representations such as bar charts or box plots can be used to visualise differences between the groups.

For example, if the water group obtains a mean score of 8 out of 10 and the high-sugar beverage group obtains a mean score of 5 out of 10, this may suggest that beverage type influenced performance on the cognitive task.

b. Conclusion

The conclusion should be based on the evidence obtained from the analysis.

If the experimental group performs significantly worse than the control group, the results may support the hypothesis that consumption of a high-sugar beverage negatively affects short-term selective attention and cognitive processing speed.

If little or no difference is observed between the groups, the hypothesis is not supported, and further investigation may be required.

This example demonstrates how a simple observation can be transformed into a structured scientific investigation through the application of the scientific method.

FOCAL AREA 2: ANALYSING THE DATA

Once data have been collected, the next critical stage is data interpretation. Data interpretation involves organising, analysing, and drawing meaning from the information gathered during an investigation. The purpose is to determine whether the evidence answers the research question and supports or refutes the hypothesis.

Effective interpretation goes beyond simply examining individual results. Researchers look for patterns, trends, relationships, and possible sources of error within the data. Statistical methods help summarise findings, while visual representations such as tables, graphs, and charts make patterns easier to identify and communicate.

Researchers must also consider the limitations of the study, including sample size, measurement errors, and uncontrolled variables that may have influenced the results. By critically evaluating the evidence, learners develop a deeper understanding of scientific reasoning and the importance of drawing conclusions based on data rather than assumptions.

Note: *Guide students to interpret their findings based on the data analysis. Did their results support the hypothesis? What are the limitations of their experiment?*

Revisit the experiment to investigate if high-sugar drinks affect the short-term concentration of SHS students in Accra. After collecting the number of correct answers on the mental mathematics test from both control and experimental groups, the data can be interpreted as discussed below.

1. **Organise the data**

   First, list the score for each student in both groups.

   Control group (scores out of 10): 8, 7, 9, 8, 7, 10, 6, 8, 9, 7, 8, 9, 7, 6, 8, 9, 10, 7, 8, 9.

   Experimental group (scores out of 10): 5, 4, 6, 5, 3, 7, 4, 5, 6, 4, 5, 3, 6, 5, 4, 7, 5, 6, 4, 3.

2. **Calculate Averages (Mean) –** *Refer learners to Year 2 content on statistics and calculation of central tendencies in Weeks 19 and 20.*

   Control group: 8.0

   Experimental group: 4.85

3. **Visualise the data**

   In this case, a simple bar chart is a fantastic way to compare the average scores of the two groups. See **Figure 50**.

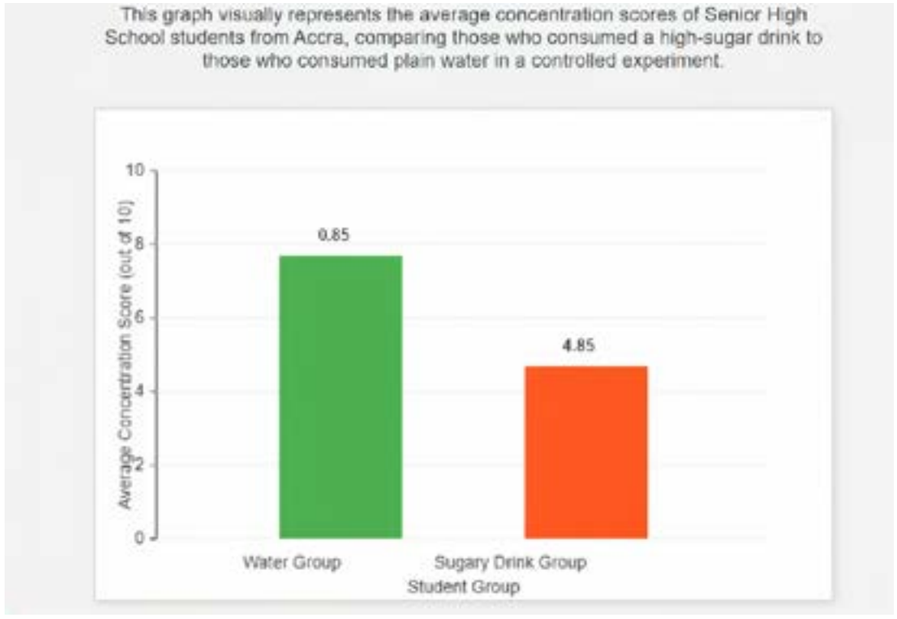


Figure 50: *Bar Chart*

4. **Interpret the results and draw a conclusion**

   Looking at the averages and the bar chart, a noticeable difference is observed. The water group, on average, scored significantly higher (8.0) on the concentration test compared to the sugary drink group (4.85).

   a. Did the result support the hypothesis? Yes, these results supported the hypothesis that consuming a high-sugar drink negatively affects the short-term concentration levels of SHS students in Accra. The students who consumed the sugary drink performed notably worse on the concentration task.

   b. What are the limitations of the experiment? It is important to acknowledge that this was a small-scale experiment with limitations. For example:

   i. ***Sample Size:*** Only 40 students were tested; a larger sample might provide more generalisable results.

   ii. ***Specific Drink:*** Only one type of high-sugar drink was used. Different sugary drinks might have varying effects.

   iii. ***Concentration Test:*** The 5-minute mental arithmetic test might not fully capture all aspects of concentration.

   iv. ***Short-term Effect:*** Only short-term concentration (30 minutes after consumption) was measured. Longer-term effects were not observed.

   v. ***Individual Differences:*** Students' prior health conditions, sleep, or usual sugar intake could influence their individual responses, even though fasting was tried as a control.

This straightforward analysis, using simple averages and a visual chart, helps to clearly interpret the data, conclude the hypothesis, and critically evaluate the experiment's limitations, just as a real biomedical scientist would.

Learning Tasks

1. Review how to design a scientific investigation, analyse experimental data using appropriate statistics, and critically evaluate the findings and their limitations.
2. Formulate a testable health-related question and design a structured experiment to investigate it, applying the scientific method from hypothesis to data analysis.
3. Apply appropriate statistical methods to analyse experimental data and interpret the significance of the results.

Pedagogical Exemplars

Project-Based Learning: Students work in small research teams to investigate a relevant health problem (such as BMI patterns, effects of breakfast on concentration, or blood pressure profiles) within their school community. Teams progress through the complete research cycle, formulating hypotheses, designing appropriate experimental protocols with ethical considerations, collecting primary data from peers, analysing results using statistical methods learned in class, and supplementing findings with secondary data from textbooks and online resources. The learning culminates in a documented research report and brief presentation where students communicate their methodology, findings, and health implications to peers and teachers, demonstrating authentic application of scientific research methods to real-world health questions.

Project-Based Learning: In groups, learners propose a research topic (for example, BMI of a learner population, the effect of skipping breakfast on mood, or blood pressure profiles of learners). They design their experiment by progressing through the complete research cycle. That is to formulate hypotheses, design appropriate experimental protocols with ethical considerations, collect primary data from peers, analyse results using statistical methods, and

supplement their findings with secondary data from textbooks and online resources. Finally, they document their findings in a comprehensive report, where students communicate their methodology, findings, and health implications to peers and teachers.

Key Assessment: Structured Written Response (Individual)

Level 4 (Extended thinking): The local health clinic in your community has noticed an increase in preventable health issues. The clinic director believes that simple scientific investigations could help address these problems. The director has asked your class to help by conducting small-scale health research projects.

"Many of our community's health problems could be solved through better understanding," explains the director. "We need young scientists like you to investigate questions that matter to our people, using resources we already have."

You have been selected to design and conduct a scientific investigation that could improve health in your community. Your investigation must be completed with locally available materials and provide practical information that could help community members make better health decisions.

Using scientific methods and basic statistical analysis, you will develop and conduct a complete investigation into a local health question. Share your results in a way that everyone in our community can easily understand.

Developing a research question (8 marks)

1. What health-related question will you investigate? Explain why this question is important to your community.
2. What is your hypothesis (prediction) about the answer to this question? Include both the independent variable (what you will change) and the dependent variable (what you will measure).
3. What background information did you find about this topic? List at least two facts that helped you form your hypothesis.

Experimental design (12 marks)

4. What materials will you need for your investigation? List everything required and explain why these materials are appropriate for your community setting.
5. Write a step-by-step procedure that another person could follow to repeat your experiment. Include how many people or trials you will include and why.
6. Identify:
   - The independent variable (what you will change)
   - The dependent variable (what you will measure)
   - Three control variables (what you will keep the same)
   - Your control group (if applicable)
7. What safety concerns or ethical issues might arise in your investigation? How will you address them?

Data collection and analysis (12 marks)

8. Create a blank data table that you will use to record your observations and measurements.
9. After conducting your investigation, present your data in a completed table.
10. Calculate appropriate statistics from your data (such as averages, ranges, or percentages).
11. Create a graph that clearly shows your results. Explain why you chose this type of graph.

Interpretation and evaluation (8 marks)

12. Based on your results, is your hypothesis supported or not? Explain your answer using specific data.
13. What do your findings mean for people in your community? Explain in simple terms that anyone could understand.
14. What were three limitations of your investigation? How might these limitations have affected your results?
15. If you could continue this research, what would you do differently or what new questions would you investigate?

PLC Session 21 & 22

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.
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   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 ***individual structured written response***. Chat with your app to plan this assessment, indicating what you and your learners will do before, during and after the assessment (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 6 Review

This section is a review of all the lessons taught for the last four weeks and a summary of what should have been taught and what each learner should have learnt if differentiation had been done.

1. Why is it important to simplify biomedical data sets, and how does this help in analysing and understanding results?
2. How are measures of central tendency and measures of dispersion calculated, and why are they important?
3. How can visual tools like pie charts, bar graphs, and scatter plots help present biomedical data clearly, and when is each most suitable?
4. How can learners design an experiment using the scientific method to investigate a health question and apply statistical tools to interpret results accurately?

Additional Reading

Sample Dataset 1: Effect of a Lifestyle Intervention on BMI

Scenario: A small pilot study was conducted in a community in Ghana to assess the impact of a 3-month healthy lifestyle intervention program on participants' Body Mass Index (BMI). BMI was recorded for 15 participants before the intervention and again after 3 months.

Data (BMI in kg/m²):

Participant ID	BMI Before intervention	BMI After 3 months

Participant ID	BMI Before intervention	BMI After 3 months
1	28.5	27.1
2	31.2	29.8
3	25.0	24.5
4	33.1	31.5
5	27.8	26.9
6	30.5	28.9
7	26.7	26.0

8	29.3	28.0
9	32.8	31.0
10	24.5	24.1
11	29.9	28.5
12	27.0	26.2
13	31.8	30.2
14	26.5	25.8
15	28.2	27.5

For both "BMI Before Intervention" and "BMI After 3 Months" columns, students should calculate:

1. Measures of central tendency:
   - Mean
   - Median
   - Mode
2. Measures of Dispersion:
   - Range
   - Variance
   - Standard Deviation

Discussion Points after Calculation:

- How did the measures of central tendency change from before to after the intervention? What does this suggest about the programme's effectiveness?
- How do the measures of dispersion compare? What does this tell you about the consistency of the intervention's effect among participants?
- Are there any outliers? How might they affect the mean versus the median?
- What are the limitations of concluding from such a small dataset?

Sample Dataset 2: Blood Pressure Readings in Hypertensive Patients

Scenario: Blood pressure readings (systolic, in mmHg) were taken from a group of 20 patients diagnosed with hypertension during their routine clinic visit. This is a single snapshot of data.

Data (Systolic Blood Pressure in mmHg):

142, 138, 150, 145, 160, 135, 148, 152, 140, 155, 143, 139, 147, 151, 144, 158, 137, 149, 146, 153

Student Task:

For this unorganised data of systolic blood pressure readings, students should calculate:

1. Measures of Central Tendency:
   i. Mean

   ii. Median
   iii. Mode
2. Measures of Dispersion:
   i. Range
   ii. Variance
   iii. Standard Deviation

Discussion Points after Calculation:

- What does the mean blood pressure tell us about this group of patients?
- How does the median compare to the mean, and what does that suggest about the distribution of blood pressure values?
- What does the standard deviation tell you about the variability of blood pressure within this group?
- If this data were part of a larger study, how would these basic statistics contribute to a preliminary understanding?

MARKING SCHEMES FOR THE KEY ASSESSMENTS

WEEKS 19 & 20

Question 1 (8 marks)

8 marks: The mean systolic blood pressure before the drink was 142.9 mmHg, and after the drink it was 137.9 mmHg. The median dropped from 142.5 to 137.5 The range decreased from 12 mmHg to 10 mmHg. The standard deviation was approximately 3.55 before and 3.28 after. These results show a consistent decrease in blood pressure and reduced variability, indicating a potential effect of the herbal drink in lowering blood pressure.

7 marks: The calculated mean and median values both decreased after the treatment. The mean changed from 142.9 to 137.9, and the median from 142.5 to 137.5. The range also reduced slightly. Although the standard deviation was not calculated, the trend in central tendency suggests the herbal drink may have had a lower effect on blood pressure.

6 marks: The mean decreased from 142.9 to 137.9, and the median from 142.5 to 137.5 While the other values were not calculated, the reduction in average blood pressure indicates an effect of the herbal mixture.

4–5 marks: A decrease was observed in the mean blood pressure. However, other statistical measures, such as standard deviation, were not included. The general trend suggests an improvement after the drink."

2–3 marks: There appears to be a drop in blood pressure after treatment, based on the lower figures. However, calculations were incomplete or inaccurate, and interpretation was limited.

1 mark: The blood pressure was lower after the drink, but no accurate calculations or detailed comparison were provided.

Question 2 (6 marks)

6 marks: The herbal drink is effective. The mean dropped by 5 mmHg, and the median was decreased. The slight change in standard deviation indicates more consistent results. These statistical outcomes provide compelling evidence that the drink may help lower blood pressure.

5 marks: The drop in average blood pressure and similar reductions across most patients suggest the drink had a positive effect. The data support this interpretation, though not all statistical details were included.

4 marks: The blood pressure readings after the treatment were lower. This points to a benefit, though the explanation was not detailed.

3 marks: The blood pressure results improved after the drink. A clearer link to specific data would improve the explanation.

2 marks: Some improvement in results was noted, but the explanation lacked clarity or reference to actual data.

1 mark: The answer was based on an assumption with no evidence provided.

Question 3 (6 marks)

Sample answers

6 marks: The study could be improved by increasing the sample size to reduce the influence of individual variation and by including a control group for comparison. These changes would strengthen the reliability and validity of the findings.

5 marks: Using more participants and comparing with a group that does not take the herbal drink would improve accuracy and confidence in the results. These changes would reduce bias and increase scientific value.

4 marks: Increasing the number of participants would make the results more trustworthy. The use of a control group was mentioned but not explained fully.

3 marks: Adding more participants was suggested to improve the study, with some reasoning given.

2 marks: One change was mentioned, but the reasoning was unclear or incomplete.

1 mark: The suggestion lacked relevance or was too vague to demonstrate understanding.

Question 4 (6 marks)

6 marks: The average blood pressure dropped after using the herbal drink, meaning most people had lower readings. The standard deviation was small, showing that results were similar for most people. These findings suggest that the drink may have had a consistent and positive effect.

5 marks: The blood pressure readings improved overall, and the average reveals the typical result. The small spread in results means most people responded comparably.

4 marks: There was a drop in the main blood pressure numbers, and most people had similar outcomes. The explanation of the average and spread was clear.

3 marks: The main blood pressure reading was lower. One or two terms were explained, but not in much detail.

2 marks: A basic attempt was made to describe the results, but key terms were not explained clearly.

1 mark: The explanation was vague and did not show an understanding of the numbers.

WEEKS 21 & 22

Developing a research question (8 marks)

Question 1: Health question and importance (3 marks)

Sample Answer: "*Does washing hands with locally made soap reduce bacterial growth compared to washing with water alone? This is important because diarrheal diseases are common in our community, and local soap is affordable.*"

- Full marks (3): Clear, specific question with strong community relevance
- Partial marks (1-2): Basic question with some community relevance
- Zero marks: Vague question or no community relevance

Question 2: Hypothesis with variables (3 marks)

Sample Answer: "*I hypothesize that washing with local soap will reduce bacteria by at least 50% compared to water alone. Independent variable: washing method. Dependent variable: bacterial growth.*"

- Full marks (3): Clear hypothesis with both variables correctly identified
- Partial marks (1-2): Basic hypothesis with at least one variable identified
- Zero marks: Missing or invalid hypothesis

Question 3: Background information (2 mark)

Sample Answer: "*Soap breaks down bacterial membranes. Hand washing can reduce diarrheal disease by 30-50%.*"

- Full mark (2): Two or more relevant facts that inform the hypothesis
- Partial mark (1): One relevant fact related to the hypothesis
- Zero marks: No relevant facts provided

Experimental design (12 marks)

Question 4: Materials list (2 mark)

Sample Answer: "*Materials: local soap, water, 20 glass jars, cotton swabs, potato slices (for growth medium), labels, ruler, notebook. These are appropriate because they're all available locally.*"

- Full mark (2): Comprehensive list with explanation of local appropriateness
- Partial mark (1): Basic list with limited explanation
- Zero marks: Incomplete list or unavailable materials

Question 5: Procedure and sample size (4 marks)

Sample Answer: "*Procedure: 1) Recruit 10 students with dirty hands, 2) Divide into soap and water-only groups, 3) Take before samples on potato slices, 4) Have them wash hands, 5) Take after samples, 6) Measure bacterial growth after 48 hours. Using 10 participants provides enough data while keeping the experiment manageable.*"

- Full marks (4): Clear, detailed procedure with appropriate sample size justification
- Partial marks (2-3): Basic procedure with some justification
- Zero marks: Missing or unworkable procedure

Question 6: Variables identification (4 marks)

Sample Answer: "*Independent variable: washing method. Dependent variable: bacterial growth. Control variables: washing time (20 seconds), water temperature, and initial hand dirtiness. Control group: water-only group.*"

- Full marks (4): All variables correctly identified with appropriate controls
- Partial marks (2-3): Most variables identified with some controls
- Zero marks: Incorrect identification of variables

Question 7: Safety and ethics (2 mark)

Sample Answer: "*Safety concerns: infection risk - will ensure thorough hand washing after experiment. Ethics: will get permission from participants and not record names.*"

- Full mark (2): Clear safety and ethical considerations with specific solutions
- Partial mark (1): Basic consideration of safety or ethics
- Zero marks: No consideration of safety and ethics

Data collection and analysis (12 marks)

Questions 8-9: Data tables (4 marks)

Sample Answer: *Student provides organized tables showing before/after measurements for both soap and water groups.*

- Full marks (4): Well-organized tables with all data clearly presented
- Partial marks (2): Basic tables with some organization
- Zero marks: Missing or unusable tables

Question 10: Statistical calculations (4 marks)

Sample Answer: "*Average bacterial colony size before washing: both groups 11.2mm. After washing, soap group 2.8mm (75% reduction), water group 8.4mm (25% reduction. Soaps reduced bacteria by 50% more than water alone.*"

- Full marks (4): Multiple correct calculations with clear explanation
- Partial marks (2): Basic calculations with limited explanation
- Zero marks: No calculations or all incorrect

Question 11: Graph with explanation (4 marks)

Sample Answer: Student provides a bar graph comparing before/after results for both groups with explanation: "*I chose a bar graph because it clearly shows the comparison between conditions and is easy to understand.*"

- Full marks (4): Appropriate graph with correct data, proper labels, and clear explanation
- Partial marks (2): Basic graph with some errors and limited explanation

- Zero marks: Missing or inappropriate graph

Interpretation and evaluation (8 marks)

Question 12: Hypothesis evaluation (1 mark)

Sample Answer: "*My hypothesis is supported. I predicted soap would reduce bacteria by at least 50% compared to water alone, and results show 75% reduction with soap versus 25% with water.*"

- Full mark (2): Clear evaluation with specific reference to data and hypothesis
- Partial mark (1): Basic evaluation with some reference to data
- Zero marks: Incorrect evaluation or no reference to data

Question 13: Community implications (2 mark)

Sample Answer: "*Local soap effectively removes germs. Families do not need expensive commercial soap to prevent disease. Using local soap could reduce illness and save money.*"

- Full mark (2): Clear explanation of meaningful community implications
- Partial mark (1): Basic explanation of some community implications
- Zero marks: No meaningful community implications identified

Question 14: Limitations (2 mark)

Sample Answer: "*Small sample size (only 10 people). Using potato slices instead of a proper growth medium. Measured only colony size, not types of bacteria.*"

- Full mark (2): Three valid limitations with explanation of potential impact
- Partial mark (1): One or two limitations with some explanation
- Zero marks: No valid limitations identified

Question 15: Future directions (2 mark)

Sample Answer: "*Would include more participants from different age groups. Test different soap recipes. Compared to commercial soap. Track actual illness rates in families.*"

- Full mark (2): Thoughtful suggestions for improvement with clear rationale
- Partial mark (1): Basic suggestions with limited rationale
- Zero marks: No valid suggestions or irrelevant ideas

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