MINISTRY OF EDUCATION

GHANA ASSOCIATION OF SCIENCE TEACHERS

(GAST)

Biomedical Science

for Senior High Schools

Year 3

Writers

Dr. Daniel Akwei Addo

Susuana Nyankom

Reviewer

Dr. Irene Adzo Agbo

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FOREWORD

Ghana's new Senior High School Curriculum aims to ensure that all learners achieve their potential by equipping them with 21st Century skills, knowledge, character qualities and shared Ghanaian values. This will prepare learners to live a responsible adult life, progress to further studies and enter the world of work. This is the first time that Ghana has developed a Senior High School Curriculum which focuses on national values, attempting to educate a generation of Ghanaian youth who are proud of our country and can contribute effectively to its development.

The Ministry of Education is proud to have overseen the production of these Learner Materials which can be used in class and for self-study and revision. These materials have been developed through a partnership between the Ghana Education Service, teacher unions (Ghana National Association of Teachers- GNAT, National Association of Graduate Teacher -NAGRAT and the Pre-Tertiary Teachers Association of Ghana-PRETAG) and National Subject Associations. These materials are informative and of high quality because they have been written by teachers for teachers with the expert backing of each subject association.

I believe that, if used appropriately, these materials will go a long way to transforming our Senior High Schools and developing Ghana so that we become a proud, prosperous and values-driven nation where our people are our greatest national asset.

Haruna Iddrisu MP
Minister for Education

SECTION 1

PROFESSIONAL PRACTICE IN BIOMEDICAL SCIENCE

BIOMEDICAL SCIENCE IN SOCIETY

Biomedical Science Practice

INTRODUCTION

In the field of biomedical science, the stakes are high, as ethical practices and safety protocols directly impact patient care and research outcomes. Understanding the complexities of malpractice, liability, and negligence is essential for anyone entering this vital field. This discussion will explore common practices that can lead to ethical breaches, the importance of informed consent from both patient and healthcare provider perspectives, and the personal and long-term consequences of unethical or illegal behaviour in the workplace. In Year 1, you were introduced to biomedical science, emphasising its critical role in diagnosing and treating diseases. As your studies advanced, you learned about biosafety levels and the necessity of adhering to proper practices to ensure laboratory safety. You focused on the correct setup of biosafety cabinets and the appropriate use of personal protective equipment (PPE), which are crucial for minimising exposure to hazardous materials. Additionally, your exploration of laboratory-acquired infections (LAIs) highlighted how even minor oversights can lead to significant consequences. This foundation sets the stage for a deeper understanding of the ethical responsibilities that come with working in biomedical science.

KEY IDEAS

- Failing to follow correct procedures when handling samples may result in wrong diagnoses or contamination.
- Informed consent allows patients to fully understand and agree to a treatment or procedure before it begins.
- It protects patients' rights by making sure they know the risks, benefits, and alternatives.
- Skipping regular maintenance or checks on medical equipment can cause harm and lead to legal problems.
- The impact of one unethical decision may affect patient safety, public health, and future career opportunities.
- Unethical behaviour can lead to losing a job, a professional licence, or the chance to work in the field again.

AVOIDING MISTAKES - NEGLIGENCE, MALPRACTICE AND LIABILITY

Negligence

This means not being careful enough, which causes harm or injury to someone else. It happens when a person does something carelessly or fails to do what a careful person would do. Negligence in healthcare practice is when a health practitioner fails to exercise the standard level of care, and that failure causes harm to a client or patient.

Example: Not cleaning a spill in the lab and someone slips; using the wrong chemical because instructions were not followed; or not sterilising lab tools before an experiment, causing dirty samples. This can give wrong test results and affect patient care.

Malpractice

It is a serious mistake made by a trained professional, like a lab technician, nurse, or doctor. It happens when the person does not follow the correct steps or rules, and someone gets harmed as a result.

Example: A lab technician skipping safety checks, changing test results, or not following lab procedures. A doctor making a big mistake during treatment or writing false medical reports.

Malpractice in health or science laboratories can delay proper treatment and put lives at risk, especially in places with limited medical resources. It is a violation of professional ethics and can lead to suspension, job loss, or even arrest.

Liability

This means being legally responsible when your actions cause harm to someone else. If you are liable, the law may require you to face consequences such as fines or other punishments.

Key Points About Liability

1. *Legal responsibility:* You are responsible by law if your actions or mistakes cause harm.
2. *Duty and failure*: If you are trained to do a task properly but fail to do so, you can be held liable.
3. *Consequences:* If found liable, you may have to pay money (called damages), face court actions, or lose your job.

Professionals in biomedical science fields are expected to follow safety and ethical rules. If someone's mistake causes serious harm, they can be taken to court. Public trust in healthcare and laboratory results depends on responsible behaviour.

Note

As future biomedical science professionals, always follow safety rules, use your training well, and act responsibly. Your actions can protect or harm lives, and in Ghana, the law holds you accountable.

Common Situations in Biomedical Science That Result in Malpractices, Negligence, and Liability

In biomedical science, following professional and ethical standards is very important to protect patients, healthcare workers, and the public. Malpractice, negligence, and liability can happen when professionals do not follow established protocols. This can lead to harm, incorrect results, or legal problems.

Here are some similar situations that could result in malpractice, negligence, and liability:

1. **Mistakes in Sample Handling**

   A common problem in biomedical science is mishandling patient samples. This can happen when samples are collected, labelled, or stored incorrectly. For example, if a scientist labels a blood sample incorrectly, it might end up with the wrong patient. This can lead to wrong diagnoses or treatments, especially in serious cases like blood transfusions, infections, or managing chronic diseases. Such mistakes may be seen as negligence if care was not taken, and they could lead to legal issues if they cause harm. Here are some examples of mishandling samples:

   a. Contamination: If sterile techniques are not used while handling samples, it can lead to contamination, making test results unreliable.

   b. Improper Storage: Keeping samples at the wrong temperature or humidity can ruin their quality and affect test accuracy.

   c. Mislabelling: Labelling mistakes can mix up patient samples, which may result in wrong diagnoses and treatments.

   d. Expiration Issues: Using expired materials or poorly preserved samples can lead to incorrect test results.

1. **Inaccurate Data Analysis**

   Another issue arises when scientists misinterpret lab results. This can happen due to carelessness, not calibrating equipment properly, or not checking data. For example, if test results for diseases like tuberculosis or HIV are read incorrectly, a healthy person might receive unnecessary treatment, or an infected person might not get the help they need. This can endanger patients and even affect public health. Professionals could face legal consequences depending on how serious the mistake is.

   Some examples of inaccurate data analysis include the following:

   a. Human Error in Measurement: Simple mistakes in calculations or interpretations can lead to wrong conclusions, affecting patient care and research.

   b. Instrument Calibration Failures: Using equipment that is not calibrated correctly can give false readings.

c. Data Manipulation or Fraud: Changing data on purpose for research or tests can lead to serious ethical and legal problems.

d. Lack of Standardisation: Not following set procedures for analysing results can cause variability, making findings less reliable.

2. **Failure to Follow Proper Safety Procedures**

Neglecting safety protocols in the lab can be like playing with fire—dangerous and reckless. When lab workers skip essential steps like wearing personal protective equipment (PPE), mishandle hazardous samples, or fail to dispose of biohazardous waste properly, they put themselves and their patients in harm's way. Contracting a laboratory-acquired infection through the deliberate neglect of safety mandates is a clear failure of duty. Such actions represent a breach of professional standards, shifting liability toward the individual for disregarding their specialised training. Here are some clear examples of failing to follow proper safety procedures:

a. Exposure to Hazardous Materials: Imagine a scientist diving into a chemical experiment without their gloves or goggles. A careless mistake could lead to a painful burn from a toxic spill, turning a day of discovery into a trip to the hospital.

b. Poor Infection Control: Picture a lab bench cluttered with unclean equipment. If workers do not maintain strict aseptic techniques, they risk inviting harmful bacteria into their precious samples, potentially leading to serious infections that could have been easily prevented.

c. Inadequate Training: Without proper training, a new employee may feel like a ship lost at sea. Mixing incompatible chemicals might create a hazardous reaction, causing chaos in the lab and endangering everyone around them.

d. Failure to Report Incidents: Ignoring or hiding safety violations is like sweeping dirt under a rug—eventually, it will come back to haunt you. If a spill goes unreported, it may occur again, leading to repeated accidents and increasing the lab's 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.

Strategies for Biomedical Scientists to Avoid These Pitfalls

Biomedical scientists need to take specific actions to prevent common mistakes that can lead to malpractice, negligence, and liability. This is important for keeping patients and coworkers safe, as well as maintaining trust in the healthcare system and protecting their professional reputation. By following these steps, biomedical scientists can reduce errors and maintain high ethical and professional standards.

1. Adhere to Established Protocols: Always follow the approved procedures and standard operating protocols (SOPs) for handling samples, equipment, and data to ensure consistency and safety.

2. Double-Check Sample Identification: Before processing, verify patient names, test requests, and sample containers to prevent misidentification and mix-ups.
3. Document Thoroughly and Promptly: Keep accurate records of all test results, observations, and actions. Clear documentation is key to accountability and legal protection.
4. Ensure Equipment is Calibrated: Regularly check that all instruments are in working order and receive routine maintenance from qualified personnel to guarantee accurate results.
5. Use Proper Personal Protective Equipment (PPE): Always wear the correct PPE for your tasks to safeguard yourself and others, adhering strictly to biosafety protocols.
6. Report Mistakes Immediately: If you notice an error or unsafe practice, notify a supervisor or relevant authority right away. Quick reporting can prevent further issues.
7. Seek Clarification When Needed: Do not hesitate to ask questions if you are unsure about a procedure or task. Seeking guidance helps avoid mistakes.
8. Participate in Regular Training: Stay current with the latest procedures, technologies, and ethical standards through regular professional development opportunities.
9. Collaborate and Communicate Openly: Build a culture of teamwork by maintaining clear and respectful communication with colleagues, ensuring everyone is on the same page.
10. Engage in Safety Activities: Regularly participate in safety activities to prepare for emergencies and reinforce the correct response protocols, ensuring everyone knows their role.

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

Note

Use this link to learn more about patient rights and responsibilities

(https://nyahomedical.com/2018/05/the-patient-charter-ghana)

Let us explore further with ***Activities 1.1*** and ***1.2***.

Activity 1.1 Investigating Malpractice in Biomedical Science

Objective: To identify and analyse examples of malpractice in a biomedical science setting and educate others on how to prevent such mistakes.

Materials needed

1. Notebook
2. Pen or pencil
3. Access to the internet or textbooks (for extra research)
4. A4 paper or chart paper (for creating a poster)
5. Optional: phone or laptop (for digital presentation or infographic)

Procedure

1. **Analyse the following incident carefully.**
   a. A lab technician did not sterilise test tubes before running blood samples. This led to contaminated results, and a patient was wrongly diagnosed with a serious disease.
   b. A worker ignored biosafety rules and handled a high-risk sample without proper protective gear, exposing others to danger.
   c. A new intern used a medical device without training, which led to wrong results being sent to a patient.
   d. A doctor prescribed the wrong medicine due to poor handwriting and no verification.
   e. Important patient records were missing, causing treatment delays.
   f. A staff member shared laboratory results using a personal phone, which violated patient privacy.
2. For each incidence,
   a. propose what went wrong (the malpractice)
   b. explain what the possible consequence could be
   c. suggest one way to avoid or fix the mistake
3. Choose one of the following to summarise your findings:
   a. Short report: *"How to Avoid Malpractice in Biomedical Science"*
   b. Poster or infographic showing the problems, consequences, and solutions.
4. Present or display your work to someone for feedback.

Activity 1.2 Scenario Analysis on Malpractice, Negligence and Liability

Objective: You will identify the differences between malpractice, negligence, and liability, and explain why understanding these terms is important in science and healthcare.

Materials needed

1. Access to videos or articles (via library or free online resources)
2. Notebook, pen or pencil

Procedure

1. Find free videos or articles discussing malpractice, negligence, and liability.
2. Alternatively, use the case scenarios A and B.
3. Create a table in your notebook with three columns labelled *Malpractice*, *Negligence*, and *Liability*.
4. Note examples and key differences for each category based on your learning or the scenarios.
5. Write a brief paragraph explaining why understanding these concepts is important in biomedical science.

Scenario A: The Confused Lab Intern

Adwoa is a biomedical science intern working in a busy lab at a district hospital. On Monday, she was asked to help process blood samples for malaria testing. She was in a rush, so she didn't double-check the labels on the tubes. Later, she placed two samples in the wrong fridge with no temperature control. Afterwards, she didn't wear gloves while disposing of a broken glass pipette and got a small cut on her hand. She didn't report the injury to her supervisor.

Think about:

a. what went wrong?

b. what are the risks to Adwoa, the patients, and the lab?

c. what would you have done differently?

Scenario B: The Shortcut Technician

Kwabena is an experienced lab technician. One day, he skips the calibration of a spectrophotometer because he "knows it always works fine." He also shares a colleague's password to access lab software. Later that day, a test result for a patient with suspected TB comes back negative. Kwabena assumes it's accurate and signs the report without reviewing the raw data. A week later, the patient is admitted in serious condition with advanced TB.

Think about:

d. which actions show malpractice, negligence, or liability?

e. how might these actions affect the patient?

f. what rules or strategies could have prevented this?

INFORMED CONSENT - PROTECTING PATIENTS AND PROFESSIONALS

Understanding Informed Consent

Imagine you are sitting in a hospital room waiting to be seen. A nurse walks in and says, "We need to run a quick test." Before doing anything, the nurse explains everything: what the test is for, how it will be done, what the possible risks and benefits are, if there are any other options, and what might happen if you decide not to take the test. You listen carefully, ask a few questions, and then say yes only after you feel comfortable with the information given. That moment of agreement, made after getting all the facts, is called *informed consent.* **Informed consent** means you give permission for something to be done to your body, health, or personal data after receiving full and clear information. It is not just about signing a form. It is about understanding what will happen and choosing whether to agree or not. Whether you are being asked to take part in a blood test, a surgery, or a medical research study, informed consent ensures that your voice matters in decisions about your body and health. (See ***extended reading*** for sample of consent form).

Key Principles of Informed Consent

To be meaningful and fair, informed consent must follow three important rules:

1. Voluntary: You must decide for yourself, freely, without any pressure, fear, or trickery. Example: A nurse must not say, "If you do not agree, we will not treat you." Instead, they must explain your options calmly and let you choose.
2. Competent: You must be able to understand the information and make a clear decision. This usually means being of the right age and having a sound mind. Example: An 18-year-old who fully understands the explanation can choose whether to take part in a study.
3. Informed: You must receive all the important facts in a language you understand. No difficult science words or unclear terms should be used. Example: Instead of saying, "We will perform a venepuncture," a doctor should say, "We will take a small amount of blood using a needle."

When is Informed Consent Needed?

Informed consent is needed whenever a decision could affect your body, your health, or your personal choices. You must be fully informed and agree before:

1. Your blood is taken for a test
2. You are given a scan, an injection, or a surgical operation
3. Your tissue (for example, blood or skin samples) is used for research or diagnosis
4. You join a medical or science study
5. Your private health information is shared with anyone outside the care team
6. You are given treatment, especially if there are side effects or options to choose from

In simple terms, informed consent is needed any time something will affect a person's body, personal health information, or medical decisions. The person must be given all the facts and allowed to make their own choice willingly and with understanding. You can explore the Additional Reading section to see examples of patient-informed consent forms.

Are There Any Exceptions?

Yes, but only in rare and serious cases. These are called **exceptions**, and they must be handled with care. Here are some examples:

1. Emergencies: If you are unconscious and in danger, doctors may act quickly to save your life without asking first. Example: Someone badly hurt in an accident may need immediate surgery.
2. No guardian or representative available: If you cannot decide for yourself and no family member is around, healthcare workers may act in your best interest.
3. Public health risks: If you have a disease that could harm others, like COVID-19, doctors may test or treat you without asking.
4. Therapeutic privilege (very rare): A doctor might choose not to tell the full truth if it could seriously upset or harm your mental or physical health. But this is rarely allowed and must be carefully reviewed.

Why Informed Consent Matters

Informed consent protects both you and the people caring for you. It is not just a form to sign. It means you understand what is happening and make your own choice. Here is why informed consent is so important:

1. Protects your rights: You have control over your body and personal information.
2. Gives you power to choose: You can say yes or no based on what you know.
3. Builds trust: Clear explanations help you feel safe and respected.
4. Follows ethical rules: It helps health workers do what is right and fair.
5. Protects health workers too: If anything goes wrong, they can show that you agreed with full knowledge.
6. Avoids confusion: Everyone knows what was agreed on, so there are no surprises later.
7. Meets legal rules: In Ghana and many other countries, getting informed consent is the law.

What if Informed Consent is NOT Collected?

If a health worker or scientist skips the consent process, it can lead to serious problems:

1. Battery (unlawful touching): Doing something to your body without your permission can be seen as assault.
2. Negligence or malpractice: If you get hurt and were not informed, the health worker could be blamed.
3. Breaking the duty of care: Health professionals must protect patients. Ignoring this duty can lead to punishment.
4. Losing a job or licence: A biomedical scientist who does not follow consent rules might be banned from working.

Activity 1.3 Creating a Simple Consent Form with a Case Scenario

Objective: To help you understand the meaning and importance of informed consent by creating a simple consent form that explains a medical procedure, its risks and benefits, alternatives, and checks for patient understanding.

Materials needed

1. Pen or pencil
2. Exercise book or blank sheet of paper
3. Ruler (optional – for neatness)
4. Sample case scenario (provided below)
5. A quiet space to think and write

Procedure

Follow the steps carefully and take your time to think

Case Scenario

A woman named Akosua, age 35, has a lump in her breast. The doctor suspects it could be cancer and recommends a biopsy, that is, a small surgery to remove a piece of the lump for testing.

1. Write a Title followed by patient details.

   Example: "Informed Consent Form for Medical Treatment– Breast Biopsy for Akosua"

   Patient's Full Name: _____

   Hospital Number: _____

   Date of Birth/Age: _____

   Gender: ☐ Male ☐ Female

   Address: _____

   Phone Number: _____

2. Describe the Problem

   Example: "You have a lump in your breast that might be cancer."

3. State the Proposed Treatment

   Example: "We recommend a biopsy to remove part of the lump for testing."

   List Alternatives (including doing nothing)

   Example:

   a. Wait and monitor the lump
   b. Do imaging tests only
   c. No treatment

4. Explain Risks and Benefits of the Biopsy

   Example:

   a. Benefit: "It helps to confirm if the lump is cancer."
   b. Risk: "There may be pain, infection, or bleeding."

5. Compare with Risks and Benefits of the Alternatives

   Example: Waiting may delay diagnosis, imaging is safer but may not give clear answers

6. Mention Any Uncertainties

   Example: "The test might not give a clear result."

7. Check Understanding

   Write a question like: "Do you understand what the biopsy is for?"

8. Write a Consent Statement: I, ... agree or disagree with the procedure.

   Example: "I, Akosua, understand the information and agree to the biopsy."

9. Leave Space for Signatures. Draw lines for:

   a. Patient's Signature .....
   b. Date .....

Activity 1.4 Creating an Informed Consent Form on Your own

Objective: To help you understand how to explain medical procedures clearly and respectfully through an informed consent form.

Materials needed

1. Plain paper or notebook
2. Pen or pencil

Procedure

1. Choose a health issue by selecting one example below or thinking of your own:

   a. Taking blood for a malaria test
   b. Having a tooth removed
   c. Receiving an injection
   d. Joining healthcare research

2. Fill in the consent form sections below by writing short and clear sentences for each part:

   a. What is the problem?
   b. What is the test or treatment?

c. What could go wrong or go well?

d. What other choices are there?

e. What happens if they say no?

f. Do they agree? (Write: I agree / I do not agree)

Name:_____
Date: _____
Signature/Thumbprint: _____

POTENTIAL CONSEQUENCES OF UNETHICAL/ ILLEGAL BEHAVIOUR IN BIOMEDICAL SCIENCE PRACTICE

Consequences of Unethical or Illegal Behaviour

Unethical or illegal behaviour happens when someone in the workplace breaks professional rules, moral values, or the law. In biomedical science, this could be something small, like not following proper safety steps, or something very serious, like changing test results or sharing private patient information. These behaviours can lead to problems for both the worker and the patient. It is important to always act responsibly and follow the rules to protect patients, other staff, and yourself.

Short-Term Consequences

To the Biomedical Science Worker

1. Immediate suspension from work: If your behaviour could harm others or affect test results, you may be asked to stop working right away. Example: A worker who mixes up blood samples might be removed from duty immediately.
2. Formal investigation and questioning: You may be investigated by your employer or a professional group. This can involve interviews and checking your past work.
3. Damage to your reputation: Other workers may lose trust in you and avoid working with you. This could make your work environment very uncomfortable.
4. More checks on your work: Everything you do may be closely watched. Your reports, results, and actions may be reviewed regularly.
5. Counselling or retraining: You may need to go for training to help you understand the correct behaviour. You may also be asked to attend counselling sessions.

To the Patient or Research Participant

1. Delayed or wrong diagnosis: If test results are wrong, patients may not get the right diagnosis. Example: A patient might be told they do not have a disease when they do.
2. Wrong treatment: Doctors may give the wrong medicine or therapy based on false results. This can be dangerous. Example: A patient might be treated for malaria when they have typhoid.

3. Stress and confusion: Patients may feel very worried if results keep changing or if the treatment does not help.
4. Repeat tests or procedures: The patient might need to do the test again, which can be uncomfortable and cause delay. Example: Repeating a blood test because the first one was spoiled.
5. Late medical care: If the correct results come late, the patient might wait too long to get the help they really need.

Long-Term Consequences

To the Biomedical Science Worker

1. Loss of job: If your actions are very serious, you could be sacked (fired) from your job and may not be hired again.
2. Loss of professional licence: You may no longer be allowed to work as a biomedical scientist. This means you cannot practise legally.
3. Legal and financial trouble: A patient or their family can take you to court. You might have to pay a lot of money. If the behaviour was criminal, you could also go to prison.
4. Damage to your name: Once you are known for unethical behaviour, people will find it hard to trust you. *Example: Even if you apply for a new job, employers may not accept you because of your past actions.*
5. Emotional and mental problems: Losing your job, going to court, and being blamed can cause stress, depression, or anxiety.

To the Patient or Participant

1. Worse health condition: If a problem is not found early or is treated the wrong way, the disease may get worse. Example: Cancer might spread because it was not found early.
2. Expensive and difficult treatment: Fixing a mistake can require more advanced treatment, which costs more and may be painful.
3. Loss of trust: Patients may stop trusting healthcare workers and avoid going to hospitals or clinics. Example: A person might refuse a test next time, even if they are sick.
4. Permanent health damage: The wrong treatment can cause lasting problems. Some patients may become disabled or need life-long care.
5. Emotional pain: Suffering because of someone else's mistake can cause sadness, anger, and fear.

It is very important for biomedical science workers to always follow ethical and legal rules. Mistakes and bad behaviour can cause serious harm to both the worker and the patient. Acting responsibly helps everyone stay safe, healthy, and respected. As a student, learning these lessons early will help you grow into a careful and trusted professional.

Activity 1.5 Code of Ethics & Conduct of Ghana Health Service (GHS)

Objective: To help you understand what the code of ethics and code of conduct mean for biomedical science professionals and why following them matters.

Materials needed

1. A printed sample of the GHS Code of Conduct (included below)
2. A notebook and pen/pencil
3. A quiet space for thinking and writing

Procedure

1. Take 3 minutes and answer this in your notebook: "What does it mean to behave ethically and professionally in a lab or hospital?"
2. Now explore the sample of the GHS Code of Conduct. Analyse it carefully and underline or highlight:
   a. 2 rules that protect patients
   b. 1 rule that protects you (the worker)
   c. 1 rule that keeps the lab or clinic safe
3. Explain why you think the Code of Conduct is important for healthcare and biomedical science professionals in Ghana.

Sample of GHS Code of Conduct (Simplified)

1. **Respect Everyone**: Always treat patients, families, and colleagues with kindness and dignity.
2. **Maintain Confidentiality**: Never share patients' private information without their permission.
3. **Be Honest and Accurate**: Always report test results truthfully. Never change or hide information.
4. **Follow Lab Rules and Safety Procedures**: Use protective gear, sterilise tools, and dispose of waste safely.
5. **Take Responsibility**: Report mistakes or unsafe acts immediately. Learn from errors.
6. **Keep Learning**: Only perform tasks you are trained for and update your skills regularly.
7. **Avoid Conflict of Interest**: Do not use your position for personal gain. Be fair and transparent.
8. **Follow the Law**: Know and obey Ghana's health laws and work regulations.

Activity 1.6 The Effects of Unethical Behaviour in Biomedical Science

Objective: To help you explain how unethical or illegal actions in biomedical science can affect both the worker and the patient in the short and long term.

Materials needed

1. Pen or pencil
2. Notebook or exercise book,

Procedure

1. In your notebook, draw a table like the one below. Then fill it with at least three examples.

Unethical or Illegal Action	Effect on the Worker	Effect on the Patient
Example: Mixing up blood samples	Suspended from work and investigated	May get the wrong diagnosis and wrong treatment
…	…	…

2. Think of other examples such as:
   a. Giving out private patient information
   b. Falsifying results in a test
   c. Ignoring safety procedures when handling samples

   Use these to complete the table.
3. Write short answers in your notebook to the following:
   a. Why is it important for biomedical science workers to follow ethical rules?
   b. What might happen if a biomedical scientist gives false test results?
   c. How can unethical behaviour affect a patient's future health?
4. Write a short story about a young biomedical science student who makes an ethical mistake. Explain:
   a. What they did
   b. What happened to them
   c. What happened to the patient
   d. What they learned in the end
5. You may discuss your answers with a classmate or family member.

Activity 1.7 The Biomedical Science Exploration

Objective: To explore key concepts in biomedical science through creative and engaging activities.

Materials needed

1. Pen or pencil
2. Notebook or paper
3. Art supplies (coloured pencils, markers, etc.)

Procedure

1. Create a Biomedical Science Poster
   a. Title your poster "Biomedical Science Exploration."
   b. In the centre, write a fun definition of biomedical science (e.g., "The science that helps make people healthier!").
2. Discover Roles
   a. Draw three fun characters representing biomedical scientists (like a lab superhero, a researcher, and a technician).
   b. Next to each character, write what they do and the cool products they create (like tests and vaccines).
3. Lab Safety Mission
   a. Sketch a lab with a sign that says, "No to LAIs!"
   b. Write down a few risks (like spills or contamination) and one fun way to stay safe (like wearing a superhero lab coat!).
4. Biosafety Cabinet (BSC) Fun Fact
   a. Draw a cartoon version of a BSC and label its parts (like "safety shield").
   b. Write one fun fact about why it's important for keeping labs safe.
5. Create a mini fashion guide for PPE. Draw each item (gloves, masks, gowns) and write a catchy phrase for using them (e.g., "Dress for success in the lab!").
6. Ethics Scenario Game:
   a. Write down three "What Would You Do?" scenarios related to ethics in biomedical science (like dealing with patient information).
   b. Share these with friends or family and discuss the best responses.
7. Present your poster to friends or family. Explain what you learned and share your favourite part of the exploration.
8. At the bottom of your poster, write one exciting thing you learned about biomedical science and one question you still have.

EXTENDED READING

QR Code 1 Video 1 Medical malpractice **QR Code 2** Video 2 Case of malpractice

QR Code 3 Video 3 Case Medical Negligence **QR Code 4:** Video 4 GHS Code of Conduct

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 the purpose of providing safe and effective care.

REVIEW QUESTIONS 1

Multiple Choice Questions

1. A biomedical scientist uses an expired reagent, leading to slightly inaccurate results. A treatment error follows. What does this situation illustrate best?

   A. A case of laboratory negligence and risk
   B. A failure to follow safety procedures
   C. A personal judgement that was reasonable
   D. A rare technical error without major risk

2. A lab worker mentions a patient's condition to someone outside the care team. What professional concern is most relevant here?

   A. Confidentiality rules were not followed
   B. Consent procedures were misunderstood.
   C. Patient information was shared casually
   D. Team discussion was poorly structured

3. A technician performs a test without formal training. The process fails and results are invalid. What issue does this represent?

   A. Basic error with minor outcome
   B. Good effort lacking expert input
   C. Initiative without full instructions
   D. Neglect of training requirements

4. A patient's blood sample is used for research without consent. What issue is most important in this scenario?

   A. Consent for use was not obtained
   B. No signed form was given to staff
   C. Participation was misunderstood early
   D. Risk details were not explained clearly

5. A scientist chooses not to follow a safety step for a low-risk chemical. An accident occurs. What would matter most in review?

   A. How experienced the worker was
   B. The safety officer's past training
   C. Whether the risk was documented
   D. Who approved the experiment plan

6. A scientist alters test readings to match expectations, thinking the device is inaccurate. What was the ethical error here?

A. The original data were not protected
B. The protocol was not discussed fully
C. The report was not objective or true
D. The results were not reviewed clearly

7. A lab technician forgets to check a patient's label and reports the wrong result. What best describes this mistake?

A. Misjudgement of sample handling step
B. Negligence in basic verification task
C. Oversight in checking patient identity
D. Unclear protocol during the handover

8. A patient signs a general hospital form. Later, a biomedical procedure is done without further explanation. What was missing?

A. Clarity on who provides the form
B. Explanation of risks and choices
C. Opportunity to ask health questions
D. Review of the patient's background

9. A faulty centrifuge guard is ignored on a busy day. An injury occurs. Who is most likely responsible in this situation?

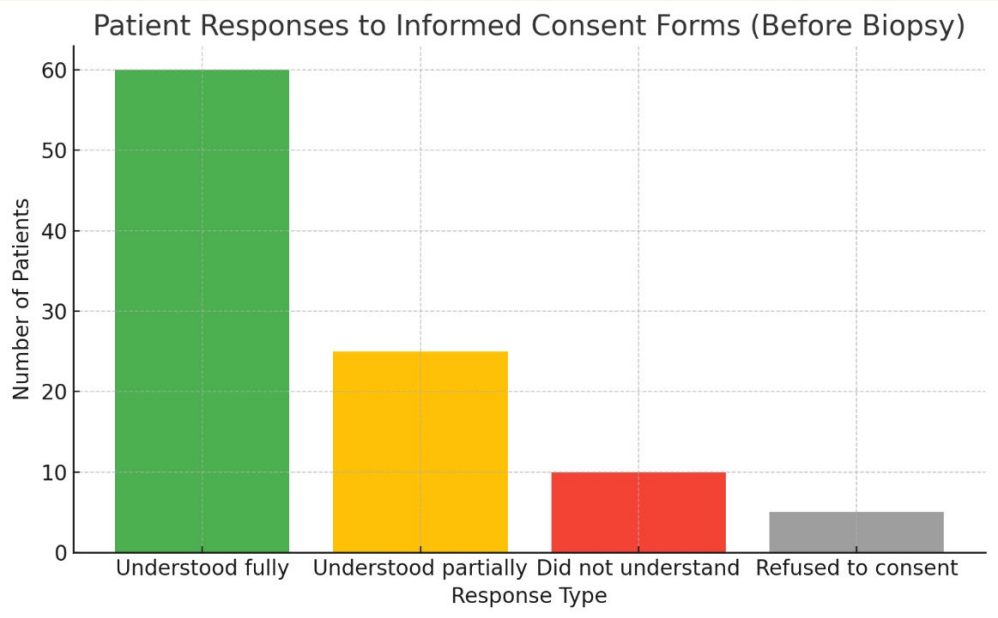
A. Both senior and junior lab workers
B. The institution that owns the lab
C. The junior staff who followed orders
D. The supervisor who was not present

10. A scientist sees that wrong patient data was sent but does not report it. What is the most concerning aspect here?

A. The ethical duty to report errors
B. The failure to notify the clinician
C. The possibility of patient harm
D. The risk of disciplinary hearings

Essay Type Questions

Examine the bar graph and use it to answer ***questions 1*** and ***2***.



1. Using the bar graph:

a. Compare the number of patients who "understood partially" and those who "refused to consent." What might this suggest about how consent forms are explained based on the data?

b. Analyse two possible communication barriers that may have led to patients not fully understanding the consent form.

c. Propose one strategy that biomedical professionals in Ghana can use to ensure patients understand consent, especially in areas with limited literacy or language barriers.

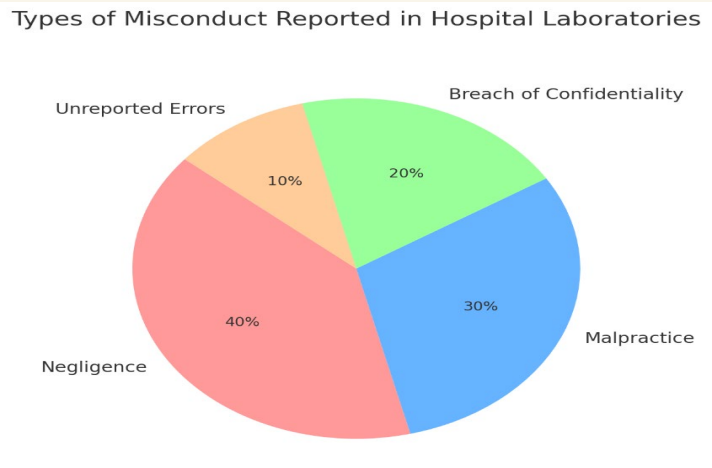
2.

a. Evaluate how having 35% of patients who either do not fully understand or refuse consent can affect legal protection for both the lab and the patient.

b. Explain how an incomplete understanding of informed consent can affect trust and safety in healthcare.

c. Suggest one step that biomedical labs in Ghana could take to improve patient understanding and reduce liability.

Analyse the pie chart and use it to answer questions 3 and 4



3.

a. Using the pie chart, compare the occurrence of negligence and malpractice in hospital laboratories. What does this suggest about everyday lab practices?
b. Explain one possible reason why negligence is more commonly reported than malpractice.
c. Suggest one training focus that could help reduce negligence in Ghanaian biomedical laboratories.
a. Evaluate why "Breach of Confidentiality" and "Unreported Errors," although reported less often, still require serious attention.
b. Use the data to argue whether these less-reported issues should receive **equal focus** during professional training.
c. Recommend one practical way to encourage biomedical staff to report errors honestly without fear of punishment.

Case Scenario 1

A nurse at a busy urban hospital in Accra mistakenly administers the wrong medication to a patient due to a miscommunication during a shift change. The patient experiences severe side effects and complications.

a. What immediate actions should the nurse take upon realising the mistake?
b. How can the hospital improve communication protocols to prevent such errors in the future?

Case Scenario 2

A surgeon in Kumasi performs a surgical procedure without properly explaining the risks and alternatives to the patient, who later suffers from unexpected complications related to the surgery.

a. What steps should the surgeon have taken to ensure informed consent was obtained?
b. How can hospitals ensure that all patients fully understand the consent process?

Case Scenario 3

In a regional clinic, a lab technician labels a blood sample incorrectly, leading to a healthy patient being diagnosed with a serious illness. The patient undergoes unnecessary treatment before the error is discovered.

a. What protocols should have been in place to prevent this error?
b. What are the potential legal implications for the technician and the clinic?

Case Scenario 4

A healthcare worker in a rural health centre discusses a patient's medical condition in a public setting, breaching the patient's confidentiality. This leads to the patient feeling violated and considering legal action.

a. What are the ethical and legal responsibilities of healthcare workers regarding patient confidentiality
b. How should the health centre address this breach?

Case Scenario 5

During a research project in a biomedical lab, a technician neglects to wear appropriate personal protective equipment (PPE) while handling hazardous materials. This oversight results in a minor injury and potential exposure to toxic substances.

a. What safety protocols should have been followed?
b. What consequences could arise for the technician and the laboratory if this behaviour continues?

Case Scenario 6

You are a biomedical science student working in a hospital laboratory. One day, a biomedical scientist is asked to test a blood sample for HIV. After completing the test, he tells other staff members about the patient's results, even though they are not part of the case. The patient later finds out that her private health information was shared without permission. She becomes upset and refuses to return for further care.

a. List three professional or ethical responsibilities that the biomedical scientist did not follow. (3 marks)
b. Describe two short-term effects this behaviour may have on the patient.
c. Explain two long-term consequences this action could have on the biomedical scientist. Include legal and professional outcomes.
d. Give two things the biomedical scientist should have done to protect the patient's privacy.

Case Scenario 7

Biomedical scientists have a professional duty to avoid negligence, malpractice, and unethical behaviour, while patients have the right to be fully informed before any medical procedure or participation in research.

Compare and contrast the perspectives of a biomedical scientist and a patient on the issues of

a. Negligence and malpractice in laboratory practice
b. Informed consent before undergoing a medical procedure

In your response,

i. identify two expectations or responsibilities of the biomedical scientist in both situations
ii. identify two expectations or concerns of the patient in both situations
iii. explain one way in which the scientist's failure in either case can affect the patient's trust or health outcome

Case Scenario 8

A biomedical scientist is running late and decides to skip reviewing the lab's standard operating procedure (SOP) for a test they have not performed in a while. They do not check whether the reagent is expired and fail to label the collected samples correctly. Later, a patient receives the wrong diagnosis because their test results were mixed up with someone else's. The scientist argues that because the procedure was familiar, checking the SOP was unnecessary and the mistake was minor.

Carefully examine the scenario above and …

a. identify three errors in reasoning or laboratory procedures made by the biomedical scientist.
b. explain whether the scientist's actions represent negligence or malpractice. Justify your answer.
c. discuss two potential consequences for the patient and two for the scientist.

Case Scenario 9

A hospital laboratory has experienced an increase in errors related to mislabelled samples and delayed reporting of test results. Management suspects that poor adherence to safety protocols and documentation procedures may be causing negligence and increasing liability risks.

As a student biomedical scientist, design an investigation to help identify the possible causes of these problems and recommend strategies to avoid future negligence or malpractice. Your investigation design must include,

a. a clear problem statement explaining why the investigation is needed.
b. three methods you will use to collect data
c. how you will identify whether errors were caused by negligence, malpractice, or system failure.
d. how you will present your findings to help improve lab practices and reduce liability.

SECTION 2

BIOSAFETY

BIOMEDICAL SCIENCE IN SOCIETY

Biosafety

INTRODUCTION

Have you ever wondered what could go wrong if someone in a laboratory handled dangerous materials without following safety rules?

The truth is, even one small mistake could lead to accidents, serious illness, or harm to the environment. That is why biosafety is so important. Biosafety helps ensure that biomedical science activities are carried out in a safe environment for everyone involved. In this section, you will learn how to plan experiments properly to avoid accidents, how to identify the correct waste streams, how to dispose of harmful materials safely, and how biosafety professionals help maintain safety in laboratories.

To get the most out of this section, take some time to revise what you learned in the past. In Year 1, you explored biohazards and risk groups. In Year 2, you learned about biosafety levels, using biosafety cabinets, and putting on and removing protective gear. This knowledge will help you succeed in this new learning.

KEY IDEAS

- Before you experiment, you need to identify hazards, measure how dangerous they are, and decide how to control or reduce those dangers.
- Hazardous waste like used needles, chemicals, or infectious materials must be placed in colour-coded bins to prevent harm to people and the environment.
- Planning your experiment includes thinking ahead about what waste will be created and how you will dispose of it safely and responsibly.
- Safe experiments begin with proper planning. You must assess the risks, choose the right equipment, and prepare for emergencies before starting any laboratory activity.
- These trained experts make sure everyone follows safety rules and help prevent accidents, infections, or harm in research and healthcare labs.
- Wearing the correct PPE, like gloves, goggles, and lab coats, helps protect you from harmful substances and accidents during experiments.

PLANNING FOR SAFE EXPERIMENTS

Why Does Safety Matter Before an Experiment Begins?

Within a laboratory setting, waiting until something goes wrong can be dangerous and even deadly. That is why planning for safety must happen before the experiment starts, not after.

In biomedical science, responsible scientific practice and safety always go together. Planning for safety helps protect you, your classmates, your teacher, your school, your community or facility. Below, you will learn the main reasons why putting safety first is so important, along with real examples.

1. **Protecting people in the laboratory**

   Biomedical laboratories can be full of hazards. These include:

   a. Infectious agents, such as bacteria from a patient sample
   b. Harmful chemicals, such as strong acids or cleaning solutions
   c. Sharp tools, such as needles or glass slides
   d. Electricity, such as faulty equipment

   Example: Imagine spilling a chemical on your hand because you were not wearing gloves.

   With proper planning, you would have worn gloves and avoided the injury. Proper planning helps prevent accidents like these by making sure protective gear, emergency kits, and safety steps are ready before you start.

2. **Keeping the scientific results reliable**

   Reliable results depend on a safe laboratory environment. When accidents happen during an experiment, results can be lost or equipment damaged. Sometimes, you may need to stop the experiment or begin again from the start.

   Example: A test tube that falls and breaks because it was not placed properly can destroy your samples and delay your work.

   This is why planning for safety is not only about protecting people; it also supports good science. Organised and careful experiments produce the most accurate and useful data.

3. **Protecting the Institution**

   Your school or lab is responsible for keeping everyone safe. If someone is hurt or something goes wrong:

   a. The school could face legal action
   b. Research funding could be taken away
   c. The school's reputation could be damaged

   Example: A fire caused by poor lab safety could lead to the science lab being closed.

4. **Following the rules (regulatory compliance)**

   In Ghana, laboratory safety is managed by organisations such as:

   a. Ghana Standards Authority (GSA)
   b. Environmental Protection Agency (EPA)

   They create rules to keep people and the environment safe. There are also international bodies like the World Health Organization (WHO). Breaking these rules can lead to serious consequences such as:

   i. Laboratory closure
   ii. Fines or punishment
   iii. Personal legal action

   Example: If a lab disposes of dangerous chemicals improperly, it could be shut down by authorities.

5. **Protecting the community and environment**

   Did you know that what happens in the lab can affect people outside the lab?

   Example: If harmful bacteria or chemicals are released into a drain or into the air, they can cause illness in nearby communities or harm plants and water sources.

   Responsible scientists always ask: "Could this experiment harm anyone outside the lab?" This is part of your ethical duty as a future biomedical scientist.

Note
You are exploring real-world professional standards. What you learn about safety now is the same as what professionals use in hospitals, universities, and research centres.

Understanding the Hierarchy of Controls

To help decide how to stay safe, scientists use a special model called the Hierarchy of Controls (**Figure 2.1**). It looks like a pyramid and shows which safety actions are most effective.

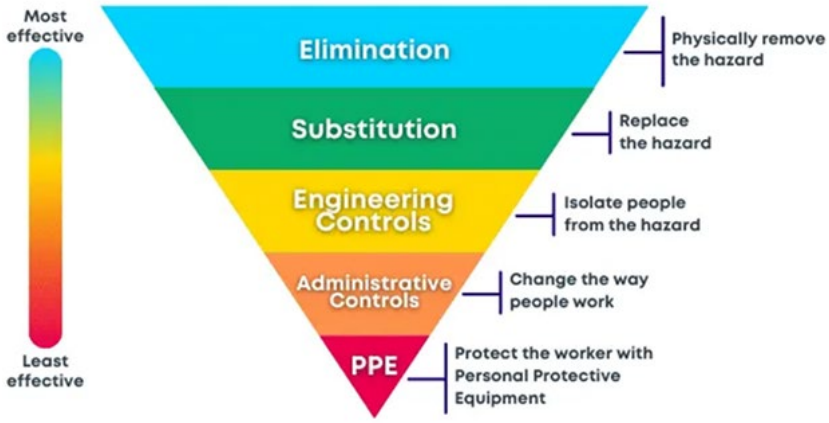


Figure 2.1: Hierarchy of Laboratory Safety Controls

The levels from most to least effective

1. Elimination – Remove the hazard completely
   Example: Use a non-toxic chemical instead of a harmful one
2. Substitution – Replace the hazard with something safer
   Example: Using a plastic tool instead of a glass one to avoid breakage
3. Engineering controls – Use equipment to reduce the risk
   Example: Using a fume hood to avoid breathing in chemicals
4. Administrative controls – Change how people work
   Example: Limiting how long someone works with a harmful substance
5. Personal protective equipment (PPE) – Use gear such as gloves, coats, or goggles
   Example: Wearing safety goggles when handling acids

Note

The top of the pyramid, elimination, is the best option. The bottom, PPE, should always be used, but is the least effective if used alone.

Planning for safety is not extra work. It is part of doing the job well. It helps protect the researcher/technician/learner, classmates, results, and the community. Every experiment must begin with a safety plan that asks:

1. What could go wrong?
2. How can I prevent it?
3. What will I do if something unexpected happens?

By learning to plan safely, you are not just preparing for school experiments. You are preparing to become a professional who can be trusted in the real world.

Planning Safe Experiments – Step-by-Step Learning

Before any experiment begins in a biomedical science laboratory, it is very important to plan for safety. Here, you will explore **four** main steps to help prevent accidents, protect people, and make sure science is done the right way.

Risk assessment

This is the first and most important part of planning safe experiments. It helps you find possible dangers and choose the best ways to stop them from causing harm. Look at Figure 2.2 – it shows how risk assessment works in a simple step-by-step flow.

Figure 2.2: Systematic Process of Risk Assessment

Steps in Risk Assessment

1. **Hazard identification**

   Think about everything that might be dangerous:

   a. Germs from patient samples (Biological hazards)

   b. Acids, flammable liquids (Chemical hazards)

   c. Broken glass, electricity (Physical hazards)

2. **Risk evaluation**

   How likely is it that something could go wrong? How bad could it be?

   a. Look at how people might be exposed (e.g. touching, breathing, swallowing)

   b. Use Figure 2.3, the risk matrix, to give each risk a score:

   Risk Score = Likelihood × Severity

3. **Control measures**

   Use the Hierarchy of Controls (see Figure 2.1) to reduce the risks. Start from the top:

   a. Eliminate the hazard

   b. Replace it with something safer (substitute)

   c. Use safety equipment (engineering controls)

   d. Change the way people work (administrative controls)

   e. Wear personal protective equipment (PPE)

4. **Review the controls**

   Make sure your safety plan is still working:

   a. Look at near misses and accidents

   b. Update your risk assessment if anything changes

   c. Make sure everyone understands what to do

		Consequence				
		1	2	3	4	5
Likelihood	Descriptor	Insignificant	Minor	Moderate	Major	Catastrophic
5	Almost Certain	5	10	15	20	25
4	Likely	4	8	12	16	20
3	Possible	3	6	9	12	15
2	Unlikely	2	4	6	8	10
1	Rare	1	2	3	4	5

Risk Rating
Extreme
High
Moderate
Low

Figure 2.3: Risk matrix for risk evaluation

Risk Assessment Form

It is like a safety checklist that shows how to work safely in the lab and protect yourself and others (sample shown in the ***Extended reading***). This form has three main parts:

1. **Hazard Identification**

   This is where you list anything that could be dangerous (hazards). For example:

   a. A chemical that can burn your skin
   b. A blood sample that might carry germs
   c. Sharp tools like broken glass
   d. Electrical equipment that might shock you

2. **Risk Evaluation Matrix**

   This component assesses both the likelihood and the consequences of the identified hazard

   You assign each hazard a score to assess its risk. The higher the score, the more careful you need to be.

3. **Control Measures**

   Here, you write down how you will stay safe. These are your safety steps, such as:

   a. Wearing gloves or goggles
   b. Using special tools instead of your hands
   c. Keeping sharp or hot items away from the edge of the table

Post-experimental cleanup requires the segregation of waste into designated containers to meet health and safety standards. Use the correct bins

Yellow for *infectious waste* (like used tissues or swabs)

Yellow box (hard container) for *sharps* like needles or broken glass

Red for *very infectious waste*

Brown for *chemical waste* like expired liquids

Black for *general waste,* like paper towels

The risk assessment form is **not** just paper. It is your **safety plan**. Filling it out properly means you are thinking like a real scientist: careful, smart, and ready to work safely.

Personal Protective Equipment (PPE)

This is your last defence if something goes wrong. But it should be chosen based on your risk assessment and not just because it is available. Figure 2.4 shows the different types of PPE for your face, hands, body, and breathing.

Figure 2.4: Basic types of PPE

Choosing the right PPE

1. Chemical hazard? → Use gloves that resist chemicals, goggles, lab coat
2. Biological samples? → Wear nitrile gloves, safety glasses, a lab coat and maybe a mask
3. Working with UV? → Use a UV face shield and a covered lab coat
4. Using sharp tools? → Wear cut-resistant gloves and safety glasses

Before you begin, practise how to: wear PPE (donning), remove PPE safely (doffing) and clean or throw away PPE

Safe Handling Procedures

Safe handling means knowing how to use tools, chemicals, and samples properly.

Here are the main areas to remember

1. **Handling Chemicals**
   a. Add acid to water, not the other way round
   b. Work in a fume hood if using smelly or harmful liquids
   c. Label everything clearly
2. **Handling Biological Materials**
   a. Use aseptic technique (keep things sterile)
   b. Wipe surfaces with disinfectant before and after
   c. Throw waste in the right bins
3. **Using Equipment**
   a. Get training before using new machines
   b. Follow instructions
   c. Check for damage first
   d. Turn off and unplug when finished
4. **Keeping the Lab Clean** (see **Figure 2.5**)
   a. Do not eat or drink
   b. Clean up spills immediately
   c. Separate clean areas from dirty areas
   d. Store dangerous items safely

Figure 2.5: Keeping the lab clean

Emergency Procedures

Be ready for accidents before they happen. Know where to go and what to do. If there is no special equipment, use safe alternatives.

Be Prepared

1. Use clean buckets for eye-washing
2. Keep cloths, bandages, and antiseptics nearby
3. Know where to go in an emergency
4. Use sand or a heavy cloth to stop small fires

Spill Response

1. Chemical? Use sawdust or sand to clean
2. Biological? Cover with paper and spray bleach

Fire Response

1. Warn others and leave the area
2. Use sand or fire blankets if trained

Injury Response

1. Skin contact? Wash with water for 20 minutes
2. Chemical in eyes? Rinse gently
3. Needlestick? Wash, report, and get medical help

Reporting

1. Tell a teacher or supervisor
2. Fill out a report
3. Help improve safety next time

Figure 2.6 shows a colour-coded emergency decision tree.

Yellow = small issue, handle safely

Orange = medium problem, act fast

Red = danger, get out and call for help

Always wear PPE when responding to any problem.

By following these four steps: risk assessment, PPE use, safe handling, and emergency preparation, you will stay safe, do better science, and become a more trusted and skilled biomedical scientist. Keep referring to **Figures 1 – 6** whenever you plan an experiment.

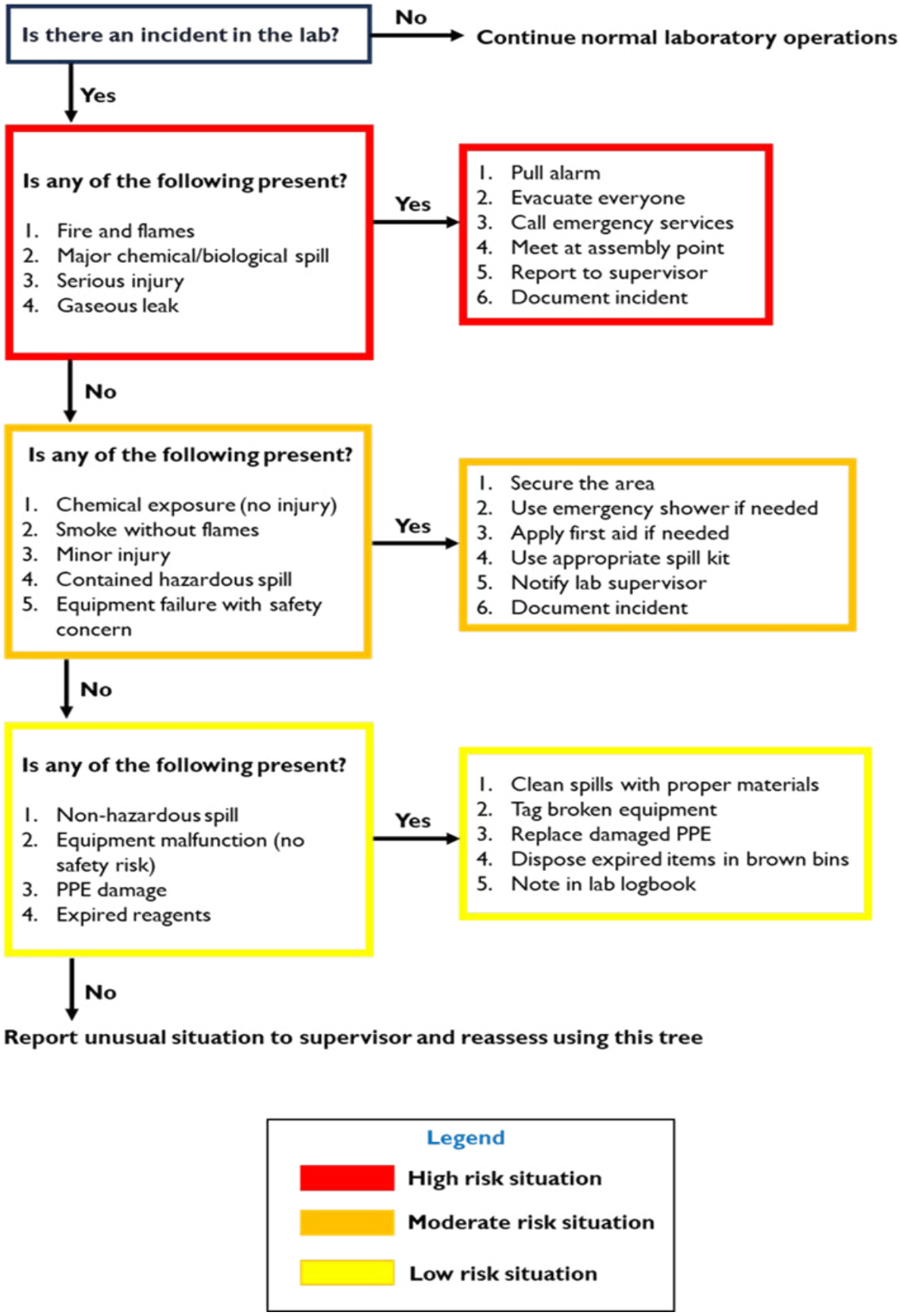


Figure 2.6: Laboratory emergency response decision tree

Activity 2.1 Staying Safe in the Lab

Objective: To help you learn how to spot possible dangers and plan a safe science experiment using a simple biological material.

Materials needed

1. Yeast, onion, or a leafy vegetable (like spinach)
2. Sugar or salt
3. Warm water
4. Clear container or glass
5. Spoon or dropper
6. Gloves
7. Apron or an old shirt
8. Notebook and pen
9. Waste container for safe disposal

Procedure

1. Choose one material for your experiment
   a. Yeast: Mix with sugar and warm water to see bubbles from fermentation.
   b. Onion: Place in salt or sugar water and look for changes (osmosis).
   c. Leafy vegetable: Place part in sunlight and part in shade, and check what happens over time.
2. Think about safety. Write down at least three things that could be risky. For example, spills, touching your eyes after handling materials, or using hot water.
3. Fill out a safety table. In it, write
   a. What the risk is
   b. What might happen
   c. What you will do to stay safe
4. Get ready. Put on your gloves and apron. Make sure your containers are clearly marked.
5. Do your experiment carefully, following your safety plan.
6. Clean up. Put waste in the right bin or container.
7. After the experiment reflect on the following
   a. What did I do to keep safe?
   b. Did anything happen that I did not expect?
   c. What would I change if I did this again?
   d. Why do I think it is important to plan for safety in science?

Activity 2.2 Find and fix the lab mistake

Objective: To help you recognise safety problems in science labs and explain how to fix them using correct safety rules.

Materials needed

1. Printed or drawn pictures of science labs with safety mistakes (sample shown below)
2. Notebook or worksheet
3. Pencil or pen
4. Coloured pencils or crayons

Procedure

1. Study 2 or 3 pictures that show science labs with safety mistakes. An example is shown below.

2. Study each picture and answer the following
   a. What danger is shown in this picture?
   b. What could happen if this is not fixed?
   c. What is the correct thing to do?
3. Choose a picture or pictures and make a **poster or safety rule** to remind others of what to do. Write a simple rule like:
   a. "Always wear gloves when handling chemicals"
   b. "Do not eat in the lab"
   c. "Label all containers before starting your experiment"
4. Explain your poster or answers to a classmate, parent, or teacher.

RESPONSIBLE WASTE MANAGEMENT

Safe Waste Disposal in the Biomedical Laboratory

In a biomedical environment, laboratory waste is not just rubbish left behind; it often contains hazardous chemical reagents, sharps, or infectious biological agents. That is why lab waste disposal is not something we can ignore. It is a critical part of laboratory safety, and it protects not just the people in the lab but also our communities and the environment.

You will be learning why proper waste disposal is so important, how to identify different types of waste, and how to manage waste safely using the correct bins and labels.

Why Waste Disposal Matters: Four Key Reasons

Let us explore four important reasons why managing lab waste properly is a must.

1. **Protecting laboratory workers**

   Think of the people working in the lab: students, scientists, and technicians. If waste is not handled correctly, it can lead to:

   a. Needlestick injuries from needles thrown in the wrong bin
   b. Chemical burns from spilt acids or cleaning agents
   c. Infections from touching biological materials without knowing

   Example: Imagine throwing a used scalpel into a regular dustbin. The next person who empties the bin might accidentally get cut. That cut could become infected with something dangerous.

2. **Protecting the Environment**

   Lab waste can have long-lasting effects on the land and water around us. Some waste materials, like chemicals and heavy metals, do not go away easily. If they are poured down the sink or thrown in the open, they can:

   a. Contaminate soil and crops
   b. Poison rivers and lakes
   c. Harm fish, animals, and plants

   This is why safe disposal matters even after the experiment is over.

3. **Keeping the Public Safe**

   People outside the lab, such as cleaners, rubbish collectors, or even children playing near a dump site, can come into contact with hazardous laboratory waste.

   In Ghana, not everyone handling waste has protective equipment. If lab waste ends up in public bins or open fields:

   a. Infectious materials could spread diseases
   b. Broken glass or needles could injure someone

   We all have a duty to protect others from harm.

4. **Following the Rules and the Law**

   In Ghana, several organisations make sure laboratories follow safety rules:

   a. The Environmental Protection Agency (EPA)
   b. The Ghana Standards Authority (GSA)
   c. The Ministry of Health (MoH)

   If a lab ignores waste rules, it could face:

   i. Fines and penalties
   ii. Closure of the facility
   iii. Damage to its reputation

Proper waste management is a legal requirement, not just a suggestion.

Types of Laboratory Waste and How to Handle Them

Biomedical laboratories produce many kinds of waste. Each type needs a special way to handle and dispose of it safely. To make things easier, Ghana uses a colour-coded bin system (See **Figure 2.7**). This helps everyone quickly identify the type of waste and choose the right disposal container.

Figure 2.7: Standard Waste Bins Used in Ghana

Each bin must be clearly marked and used only for its assigned waste type. This prevents confusion and keeps everyone safe.

Figure 2.8: Laboratory waste management cycle

Figure 2.8 shows how **all laboratory waste**, whether infectious, chemical, sharp, or general, must pass through **five** main stages.

1. Generation – when waste is created during lab activities.
2. Segregation – separating waste into the correct coloured containers.
3. Containment – securing the waste using the right bags or boxes.
4. Treatment – safely processing the waste depending on its type.
5. Disposal – removing the waste through approved methods.

While these steps apply to all types of lab waste, the way each step is done depends on what kind of waste it is.

SPECIFIC DISPOSAL PROCEDURES BY WASTE TYPE

Let us now take a closer look at **five main waste types** in the lab and how each should be handled properly.

Pathological and Highly Infectious Waste (Red Bin)

Examples: Tissues, blood-soaked items, samples with dangerous pathogens
Materials needed: Red biohazard bag, rigid container with symbol, gloves, mask, apron

Proper Steps

1. Line the hard container with a red bag and fold it over the rim (See **Figure 2.9**)
2. Fill only up to two-thirds to avoid spillage
3. Seal the bag tightly and close the container firmly
4. Label with the department and date clearly
5. Store in a cool place, away from sunlight

6. Hand over to an approved waste disposal company

Figure 2.9: Red-labelled bin

Chemical and Pharmaceutical Waste (Brown Bin)

Examples: Expired reagents, toxic chemicals, drug residues

Materials needed: Brown container, chemical labels, gloves, tape, and chemical register

Proper Steps

1. Choose a container (**Figure 2. 10**) that will not leak or react with the chemicals
2. Use a second tray or container below it to catch spills
3. Leave space in the container for expansion during heat
4. Seal the lid tightly and add a label
5. Record details in the chemical waste log
6. Store in a secure, well-ventilated room

Figure 2.10: Brown-labelled waste container

Infectious Waste (Yellow Bin)

Examples: Contaminated gloves, swabs, culture plates

Materials needed: Yellow biohazard bag, disinfectant, PPE

Proper Steps

1. Place a thick yellow bag inside the bin (**Figure 2. 11**)
2. Dispose of items directly into the bag—do not sort them
3. Spray or pour disinfectant like 0.5% bleach over the contents
4. Tie the bag tightly when it is two-thirds full
5. Add a label with your department and today's date
6. Record it in the lab's waste logbook

Figure 2.11: Yellow waste bin

Sharps Waste (Yellow Puncture-Resistant Container)

Examples: Needles, broken glass, lancets

Materials needed: Strong yellow container with lid, "SHARPS" label, gloves

Proper Steps

1. Make sure the container (**Figure 2.12**) cannot be pierced or broken
2. Write the word "SHARPS" and draw the biohazard symbol
3. Keep it close to where you are working
4. Never recap needles—drop them straight into the container
5. Fill only up to three-quarters
6. When full, seal and write the date on it

Figure 2.12: Yellow hard plastic container for sharps

General Waste (Black Bin)

Examples: Paper, packaging, non-contaminated materials

Materials needed: Black bin and black plastic bag

Proper Steps

1. Line the bin (**Figure 2.13**) with a black bag
2. Throw in only clean and safe materials
3. Check that no chemicals or sharp items are mixed in
4. Tie the bag when it is two-thirds full
5. Take it to the usual waste collection area
6. Follow local recycling rules if available

Figure 2.13: Black bin for general lab rubbish

Proper waste disposal in the laboratory is not just about keeping the room tidy. It is about protecting lives, saving the environment, and following national safety laws. Each waste type: red, yellow, brown, or black has its own rules. As a future scientist or health worker, your responsibility starts with how you treat waste.

Note: Safety begins with you!

Activity 2.3 Exploring How Hospitals Handle Waste

Objective: Learn how hospitals sort and safely dispose of different types of waste using videos, animations, or pictures.

Materials needed

1. A phone, tablet, or computer
2. Internet connection (if available)
3. Headphones (optional)
4. Notebook and pen (or note-taking app)

Procedure

1. Watch a short video, animation, or photo collection that shows how hospitals or labs throw away different types of waste.
2. Look for these waste types in the video or pictures
   a. Infectious waste (e.g. used gloves or dressings)
   b. Sharps waste (e.g. needles, blades)
   c. Chemical waste (e.g. cleaning liquids or lab spills)
   d. General waste (e.g. paper, food wrappers)
3. For each waste type, write down:
   a. What does it look like?
   b. What colour bin is it thrown into?
   c. How is it safely removed or destroyed?
4. Answer these questions after watching
   a. Which type of waste do you think is the most dangerous? Why?
   b. What might happen if waste is not handled correctly?
   c. What safety items (like gloves, masks, or goggles) did people wear during waste disposal?
5. Draw and label the colour bins
   a. Red bin – Highly infectious waste
   b. Yellow bin – Infectious waste
   c. Brown bin – Chemical waste
   d. Black bin – General waste
      → Next to each bin, draw or list examples of what goes inside.

THE ROLE OF BIOSAFETY PROFESSIONALS AND PLANNING FOR WASTE

Why Biosafety Matters

In every biomedical research laboratory, there are invisible dangers. Some of these dangers come from the very organisms and chemicals being studied. This is where biosafety professionals come in. These are trained experts whose job is to make sure the lab is a safe place to work, learn, and make scientific discoveries. Without them, harmful biological materials could escape the lab, putting people and the environment at risk.

You may have already learned about personal protective equipment (PPE), safety levels, and medical careers in earlier lessons. Now, you will discover how biosafety professionals fit into the bigger picture, and how planning and waste management help keep everyone safe.

Who Are Biosafety Professionals?

Biosafety professionals do more than wear lab coats and gloves. They use science, problem-solving, and safety knowledge to create protective systems in the lab. They train others, inspect equipment, review experiments, and help researchers follow safety laws.

Take a look at some of the important roles they play

1. Institutional Biosafety Officer: Oversees the entire biosafety programme in a research institution and works with government authorities.
2. Laboratory Biosafety Manager: Makes sure safety rules are followed daily and manages how biological materials are handled.
3. Biosafety Committee Member: Reviews research plans and checks that they meet safety standards.
4. Biosafety Training Coordinator: Teaches others how to stay safe and creates safety training materials.
5. Biosafety Equipment Specialist: Maintains and checks safety equipment like biosafety cabinets and sterilisation tools.

Many biosafety professionals have science degrees but also complete extra training in biosafety to qualify for these roles! See Table 3.1

Table 3.1: Biosafety Professionals and What They Do

Professional Title	Main Responsibilities	Qualifications Needed
Institutional Biosafety Officer	Create safety policies, lead the biosafety programme, work with health regulators	Advanced science degree, biosafety certificate, 5+ years' experience
Laboratory Biosafety Manager	Supervise daily lab safety, manage waste, enforce protocols	Science degree, lab experience, biosafety training
Biosafety Committee Member	Review lab projects, assess risks, approve containment levels	Scientific knowledge, understanding of risk assessment
Training Coordinator	Design training sessions, check safety knowledge, support lab education	Teaching experience, biosafety procedure knowledge
Equipment Specialist	Inspect and service lab safety equipment like cabinets and autoclaves	Technical certificate, equipment handling skills

How Planning and Waste Management Keep Labs Safe

In every science experiment, **planning** is key to staying safe. This includes knowing the risks, choosing the right protective gear, handling materials carefully, and having a backup plan if something goes wrong. But that is only half the story. What happens to all the waste after the experiment? Dirty gloves, leftover chemicals, used needles—these are not just trash. They can be dangerous and need to be handled properly.

To protect people and the environment, waste must be sorted, labelled, treated, and disposed of the right way. In Ghana, this is especially important because different labs have different resources.

What You Should Know About Safe Experiment Planning

Safe science begins before the experiment starts. Recall the **four planning steps** you should always follow:

1. Risk Assessment – Think ahead. What could go wrong? What could be harmful?
2. PPE Selection – Wear gloves, goggles, aprons, or masks based on your experiment.
3. Safe Handling Procedures – Use tools and materials properly to avoid spills and injuries.
4. Emergency Plan – Know where to find spill kits or fire extinguishers, and what to do in an emergency.

And when the experiment or procedure is over, use the **five waste management practices**:

1. Waste Generation
2. Waste Segregation
3. Container Preparation
4. Waste Treatment
5. Final Disposal

These two processes; **planning** and **waste disposal**, should always be linked!

Real Examples That Make a Difference

Let us look at how good planning and waste disposal work together in real life:

1. Controlling Hazards: Before using iodine, you should know it can irritate the skin and harm the environment. Planning helps you prepare the right waste bin and wear gloves in advance.
2. Using PPE Throughout: If you are cleaning with bleach, you should wear gloves while cleaning and when throwing away bleach-soaked paper towels. The waste remains hazardous.
3. Handling Waste Carefully: Pouring used liquids into a waste container should be done slowly and steadily, just like when transferring chemicals during the experiment. One wrong move could cause a spill.

4. Being Ready for Emergencies: If a chemical like formalin spills near the bin, your lab should have absorbent material nearby. Planning for this in advance keeps everyone safer.

By now, you should see how biosafety professionals and lab users like you play a role in protecting health, science, and the environment. Every experiment is an opportunity to practise safe habits, and that starts with good planning and responsible waste handling. So next time you walk into a lab, ask yourself:

1. Have I thought about safety before I begin?
2. Do I know how to dispose of everything I will use?
3. Am I acting like a future biosafety professional?

If the answer is yes, then you are well on your way to becoming a responsible and skilled biomedical science student.

Activity 2.4 Planning a Safe Science Experiment

Objective: To help you understand how to plan a safe science experiment by identifying hazards, choosing the right protective equipment, and learning safe disposal methods.

Materials Needed

1. Notebook and pen
2. A simple experiment idea (e.g. yeast and sugar, onion in saltwater)
3. A blank risk assessment table (or plain paper)
4. Pictures or samples of PPE (gloves, goggles, apron)
5. Science textbook or internet access
6. Chart or drawing paper (optional)

Procedure

1. Choose one simple experiment you want to plan. Example: Mix yeast, sugar, and warm water to observe fermentation.
2. Think about any dangers or problems that could happen during the experiment. Write down at least three possible hazards.
3. Draw a simple risk assessment table in your notebook with three columns:
   a. Hazard
   b. What might happen
   c. How to stay safe
4. Fill in your table with the hazards and safety steps.
5. List the personal protective equipment (PPE) you will need, such as gloves or goggles. Write one reason why each item is important.

6. Use your phone, computer, or textbook to learn about how laboratory waste is safely handled. Focus on one material, like bleach or broken glass. Write how to use and dispose of it safely.
7. Review your experiment plan and safety steps. Check that you have covered all risks, safety tools, and waste handling.

What did I learn from this activity?

a. Write a short reflection in your notebook. Answer the following questions:
b. What did I do to stay safe?
c. What would I improve next time?
d. Why is it important to plan before doing a science experiment?

Activity 2.5 Meet the Biosafety Officer

Objective: To learn how biosafety officers keep laboratories safe by watching what they do, asking questions, and writing a simple report about your findings.

Materials needed

1. Notebook and pen or phone/tablet for notes
2. Internet or library access
3. A chance to visit a biomedical laboratory or attend a talk by a biosafety officer
4. Chart paper (optional for class sharing)

Procedure

1. Visit a biomedical laboratory or attend a school-organised talk where a biosafety officer explains their work. Watch how safety rules are followed and what the officer does.
2. Observe the lab setting. Look at things like lab coats, gloves, labels on containers, and where waste is placed. Try to notice how safety is maintained.
3. Prepare questions such as
   a. What kind of accidents happen most in labs?
   b. How do you train people to stay safe?
   c. What is your biggest challenge as a biosafety officer?
4. After the visit or talk, write what you saw and heard in your notebook. Try to answer
   a. What does a biosafety officer do every day?
   b. Why is their job important?

5. Use the internet or a science book to learn more about biosafety officers. Find out how they help prevent disease and what they do with dangerous materials.
6. Write 1–2 pages that include
   a. What you learned from the visit/talk
   b. What you found during your research
   c. Why biosafety officers are important for the lab and the public
   d. What safety lessons you can use in your own science activities
7. You can share what you learned with your class by reading your report aloud or making a small poster or drawing that shows biosafety in action.

Activity 2.6 Plan and Present a Safe Laboratory Experiment

Objective: To help you apply all the safety knowledge you have learned by planning and presenting a safe laboratory setup, including risk assessment, use of PPE, waste disposal, and roles of biosafety professionals.

Materials needed

1. **Notebook or activity worksheet**
2. Pen or pencil
3. Internet access or textbook (to research biosafety roles)
4. Chart paper or cardboard (for poster)
5. Colouring materials (for drawing waste bins and PPE)
6. Risk assessment template (optional – teacher may provide)
7. Sample materials (optional – yeast, onion, leafy vegetable, sugar/salt, water)

Procedure

1. Choose an experiment you want to plan. For example, you can choose to grow yeast with sugar and water, observe osmosis in onion cells using salt water, or test how light affects the growth of a leafy vegetable.
2. List three possible hazards in your experiment. Think about what could go wrong; such as glass breaking, skin irritation, or spilling chemicals.
3. Fill a risk assessment table. For each hazard, write what could happen and how you will stay safe. For example, if using glass, write: “Glass may break – I will handle it carefully and wear gloves.”
4. Write down the PPE and safety tools you will need. This may include gloves, goggles, aprons, and where you will keep a spill kit or first aid box.
5. Plan how you will collect and dispose of waste properly. Think about what types of waste your experiment will make. Decide what colour bin each type goes into (e.g. black for general waste, yellow for infectious waste, red for highly infectious waste).

6. Choose one biosafety professional and describe their role. For example, write about a "Biosafety Officer" and say they help write lab safety rules and check if the lab is following them.
7. Create a short safety plan presentation or poster. Use drawings, labels, and clear steps to explain your experiment, the hazards, safety steps, waste plan, and the biosafety role.

EXTENDED READING

QR Code 5 Lab safety

QR Code 6 Safe Lab equipment use

QR Code 7 Ghana's first medical waste

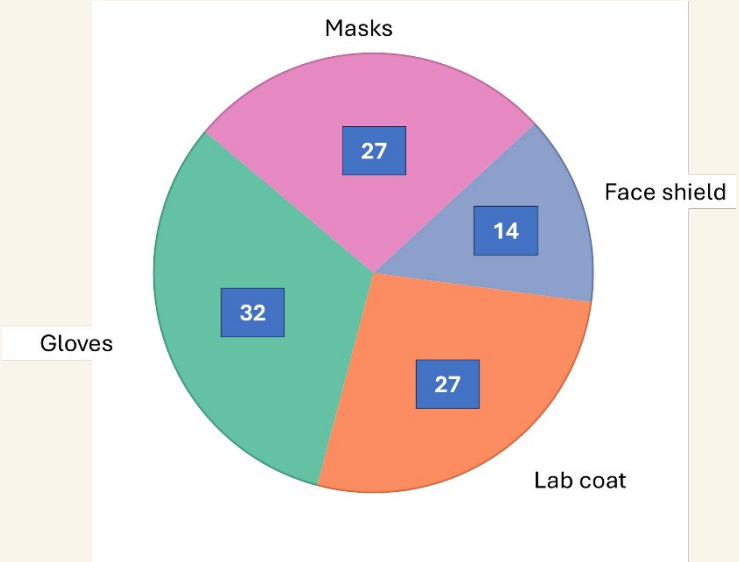
QR Code 8 Waste categories and treatment

QR Code 9 The Biosafety Officer

QR Code 10 Development of lab Safety Programme

REVIEW QUESTIONS 2

1. The pie chart shows PPE compliance in a biomedical laboratory. The data reflects the proportion of total PPE usage observed over a month:



Based on the data presented, which conclusion best reflects a possible safety concern, and how might this issue be addressed?

A. The similar percentages for gloves and masks suggest generally good compliance with frequently used PPE.

B. The lower percentage for face shields may point to a training need or a lack of awareness about their importance.

C. The equal percentages for lab coats and masks could indicate that face shields are less commonly required in this lab.

D. The lower usage rate for lab coats compared to gloves may suggest that attention to lab coat use should be improved before adding new PPE.

2. A biomedical science student places open containers of bleach and ethanol side by side on a warm benchtop. Which of the following best explains the primary safety concern in this setup?

A. The bleach and ethanol will evaporate too quickly

B. The mixture may create a flammable or toxic reaction

C. The containers are not correctly colour-coded

D. Both chemicals should be stored in glass containers only

3. A risk assessment matrix plots hazards on a grid of likelihood (rare to almost certain) and severity (insignificant to catastrophic).

Consequences / Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic
Rare	1	2	3	4	5
Unlikely	2	4	6	8	10
Possible	3	6	9	12	15
Likely	4	8	12	16	20
Almost Certain	5	10	15	20	25

Key:
- 1-4 Very Low (Green)
- 5-11 Low (Yellow)
- 12-16 Medium (Orange)
- 17-25 High (Red)

A chemical used in an experiment is ranked as "likely" and "major." According to the matrix, what would be the most appropriate action?

A. Use PPE only to reduce risk
B. Eliminate the chemical completely from the procedure
C. Reclassify the chemical to a lower risk level
D. Store the chemical in a locked cabinet after use

4. Why should PPE be considered the *last line of defence* in laboratory safety protocols?

A. PPE is only used when all other methods fail
B. PPE is more expensive than engineering controls
C. PPE protects only from minor accidents
D. PPE does not eliminate the hazard itself

5. Which of the following would be the most appropriate **first step** when designing a laboratory experiment involving live cultures?

A. Label all waste containers in advance
B. Select PPE based on previous experiments
C. Identify potential biological, chemical, and physical hazards
D. Request approval from a biosafety officer

6. A table shows average monthly waste output for four labs. Lab C produces the highest volume of infectious waste but uses the least number of yellow bags.

Laboratory	Total Waste (kg)	Infectious Waste (kg)	Yellow Bags Used (per month)	General Waste (kg)	Brown Bins Used (per month)
Lab A	120	30	40	60	10
Lab B	95	25	30	45	15

Lab C	150	50	10	80	12
Lab D	105	28	35	55	14

What is the most likely explanation for this discrepancy?

A. Lab C generates no infectious samples for disposal
B. Lab C may mix infectious waste with general rubbish
C. Lab C sends all waste types to the brown bin system
D. Lab C disposes of its waste less often than others

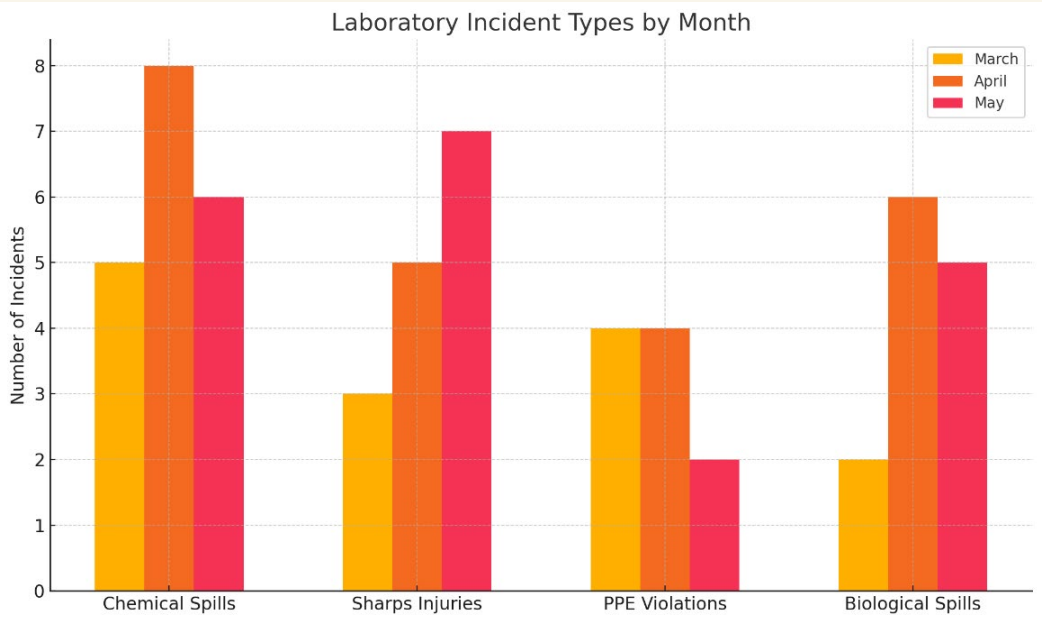
7. How do **engineering controls** differ from **administrative controls** in managing laboratory risks?

A. Engineering controls reduce risk using guidelines, while administrative controls use PPE
B. Engineering controls involve physical changes; administrative controls involve protocols and training
C. Engineering controls require less cost than administrative controls
D. Engineering controls are always more effective than all other controls

8. A student disinfects a contaminated surface using diluted bleach but immediately wipes it dry. What is the error in this procedure?

A. The bleach should not be used on that surface
B. The student failed to wear gloves while cleaning
C. The contact time was too short for effective disinfection
D. The bleach was applied without using a fume hood

9. The bar chart below shows the number of reported lab incidents in four categories over three months:



Which of the following is the most reasonable conclusion about the lab's safety practices over the three-month period?

A. Chemical spills consistently increased and should be prioritised first
B. PPE violations became the most frequent safety issue in May
C. Sharps injuries increased steadily and may reflect poor disposal practices
D. Biological spills were always the least common incident reported

10. Scenario: Identifying safety risks

You are assessing a biomedical laboratory where several unsafe practices are observed: biohazard bags are sometimes left unsealed, sharps containers are often overfilled, and personal protective equipment (PPE) is occasionally thrown into general waste bins.

a. Identify and explain three short-term risks these practices pose to laboratory staff and the environment.
b. Describe two long-term risks these practices may pose to the surrounding community.
c. Give two examples from biomedical science to support your analysis.

11.

a. Explain why PPE is considered the least effective safety measure in the hierarchy of controls.
b. Present a well-reasoned scientific argument supporting the need for higher control methods such as elimination or engineering controls.
c. Provide two examples from laboratory settings to support your argument.

12.

a. Explain why a risk assessment must be completed before starting an experiment.
b. Describe two components of risk assessment and explain how they contribute to safety.
c. Support your answer with evidence from planning or waste management practices.

13. Scenario: Planning weaknesses and biosafety standards

A team begins an experiment with iodine solution, but has not set up disposal containers in advance. They intend to label waste containers only after the experiment is done.

a. Identify and explain two weaknesses in this method.
b. Describe two possible consequences of this poor planning.
c. Suggest three improvements based on biosafety planning standards.

14. Scenario: Analysing a laboratory audit report

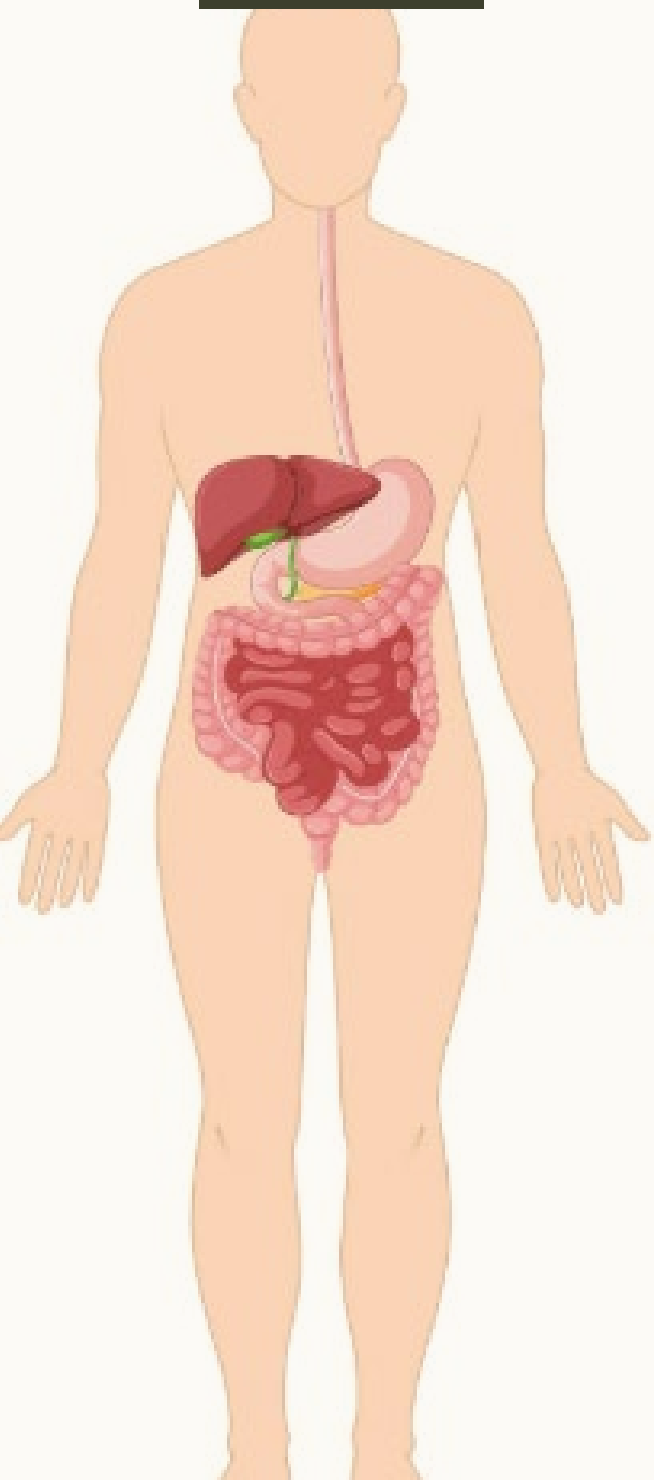
A laboratory audit report shows:

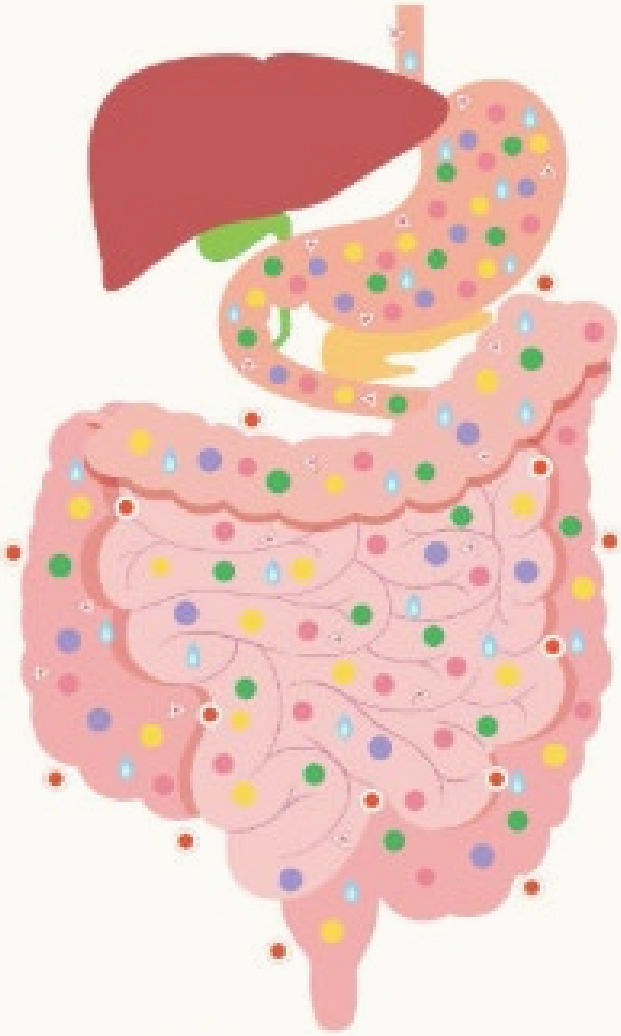
- 3 incidents of unsealed biohazard bags

- 2 overfilled sharps containers
- 4 observations of missing PPE during chemical handling
  a. Draw two conclusions about the lab's biosafety culture based on these findings.
  b. Identify two possible causes or systemic issues leading to these problems.
  c. Recommend three specific actions to improve the laboratory's biosafety practices.

SECTION 3

DIGESTION, ENERGY PRODUCTION & USE





Protein

Fats

Carbohydrates

Vitamins / minerals

Water

Enzymes

HUMAN BODY SYSTEM

Anatomy and Physiology

INTRODUCTION

The human body is a complex system made up of many parts that work together to keep us alive and functioning. Every time you eat, breathe, or move, different systems such as the digestive, respiratory, circulatory, muscular, and nervous systems work together to break down food, transport oxygen, and generate energy. In this section, you will explore how these systems are linked. You will learn how enzymes break down nutrients, how oxygen and food molecules reach your cells, and how this energy powers movement and supports life.

What you learned in Year 1 and Year 2 will help you understand this topic better. In Year 1, you studied the structure and function of body systems. In Year 2, you explored how systems communicate through signals and hormones. This section builds on both by showing how the body produces and uses energy. It helps you apply earlier knowledge to real-life functions such as exercise and recovery.

KEY IDEAS

- Cells need energy to carry out life processes. This energy comes from breaking down food and turning it into a usable form called ATP (Adenosine triphosphate) through respiration.
- Digestion starts with enzymes that break food into smaller molecules. These molecules are then absorbed into the bloodstream and carried to cells throughout the body.
- If one system fails, the others are affected too. A problem in digestion or breathing can reduce energy supply and affect the entire body's performance.
- Muscles need energy to contract and move. This energy comes from ATP, which is made in the cells using nutrients and oxygen transported by the blood.
- When oxygen is available, cells use it to produce energy through aerobic respiration. Without enough oxygen, cells switch to anaerobic respiration, which produces less energy and more waste.
- Your body systems work together to keep you alive. The digestive system breaks down food, the respiratory system brings in oxygen, and the circulatory system delivers both to cells.

WHAT ARE ENZYMES?

Introduction to Enzymes: Nature's Helpers in Digestion

Enzymes are special proteins that help your body's chemical reactions happen faster. They are called biological catalysts. They speed things up without being used up themselves because they are not part of the reaction. Without enzymes, processes like digestion, breathing, and thinking would be too slow to keep you alive. Imagine eating a meal and having to wait hours or even days for your body to get energy from it. Enzymes help break food down quickly so your cells can use the nutrients for energy, growth, and repair.

How Enzymes Work: The Key and Lock Analogy

Figure 3.1 shows how **enzymes** work using the **lock and key model**.

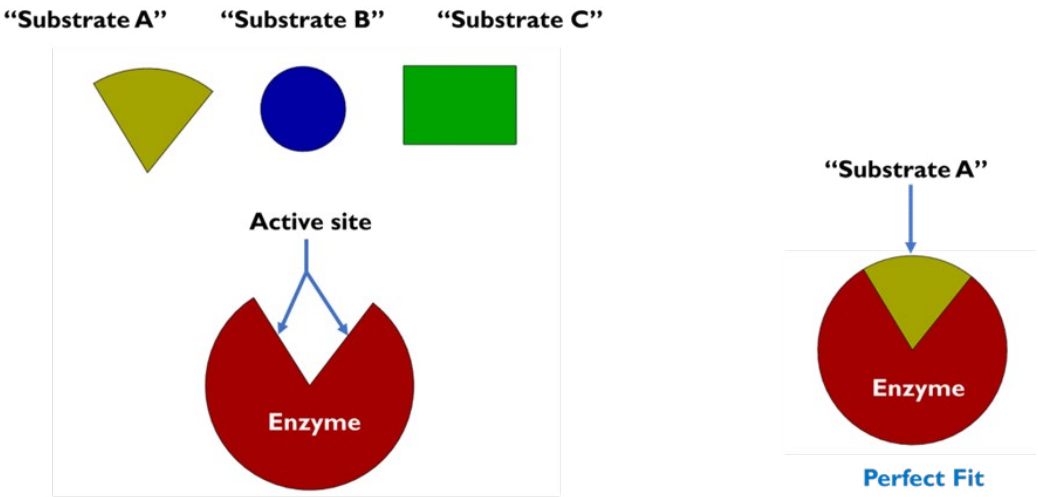


Figure 3.1 Enzyme (showing active site) and substrate

1. The enzyme (red shape) has a special area called the active site.
2. Only one shape (the yellow piece) fits perfectly into the active site. This is like how a key fits into a lock.
3. The other shapes (blue and green) do **not** fit, so the enzyme cannot work on them.

When the correct substrate fits into the active site, the enzyme can help speed up the reaction. This is like a key turning in a lock. This specific fit is the reason enzymes only work with certain molecules. It also explains why they are so fast and accurate.

Characteristics of Enzymes

1. **Specific:** Each enzyme works with only one kind of substance.
2. **Reusable:** Enzymes are not used up. They can be used repeatedly.
3. **Efficient:** Enzymes make reactions happen much faster.
4. **Sensitive:** Enzymes only work well at the right temperature and pH.

Factors That Affect Enzyme Activity

1. **Temperature** – Enzymes in the body work best at 37°C. If it is too cold, they work slowly. If it is too hot, they can be damaged (this is called denaturing) and stop working. That is why high fevers can be dangerous.
2. **pH level**: Enzymes need the right acidity (optimum pH) to work well.
   a. Pepsin (in the stomach) works best in acidic conditions (pH 1.5–2.0).
   b. Trypsin (in the small intestine) works best in alkaline conditions (pH 7.5–8.5).
3. **Substrate concentration**: More substrate usually means faster reactions, but only up to a certain point.
4. **Enzyme concentration**: More enzymes can speed up the reaction, but only if there is enough substrate.
5. **Inhibitors**: These are chemicals that can block enzymes and stop them from working.

How Enzymes Help in Digestion

Digestion is how the body breaks down food into smaller components that it can absorb and use. It happens in two main steps:

Mechanical digestion

This is physical. For example, chewing breaks food into smaller pieces.

Chemical digestion

This uses enzymes to break food into small molecules like sugars, amino acids, and fatty acids.

Figure 3.2 shows where enzymes work in the body to help digest food.

1. **Mouth**
   a. Enzyme: Amylase
   b. What it does: Starts breaking down carbohydrates (like bread and rice) into sugars.
2. **Stomach**
   a. Enzyme: Protease (called pepsin in the stomach)
   b. What it does: Breaks down proteins (like meat and eggs) into amino acids.
3. **Small Intestine**

   Enzymes
   a. Amylase – continues breaking down carbohydrates.
   b. Proteases – finish breaking down proteins.
   c. Lipases – break down fats (like oils and butter) into fatty acids and glycerol.

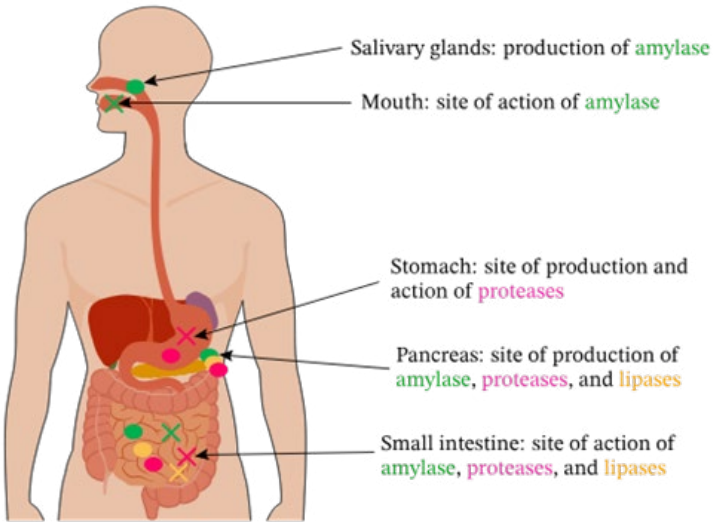


Figure 3.2: Human digestive system

Activity 3.1 Say or Sign What Enzymes Do

Objective: Explain what enzymes are and how they help with digestion. You can speak or use sign language.

Materials needed

1. A list of questions (on paper or written down)
2. A mirror or a phone to record yourself

Procedure

3. Look at the questions
   a. What are enzymes?
   b. Why does food need to be broken down?
   c. What happens if the body does not have enzymes?
4. Think about your answers.
5. Practise your answers in the mirror or record a video of yourself.
6. Try to keep your answers short and clear. For example:
   a. "Enzymes are helpers that break food into smaller parts."
   b. "We break down food to get energy and nutrients."
7. If you can, show your answer to a teacher or classmate by speaking or signing.

Activity 3.2 Enzyme – Substrate Matching Cards

Objective: Learn which enzymes work on which types of food.

Materials needed

1. Small paper cards
2. On some cards, write names of enzymes (e.g. amylase, protease, lipase)

3. On the other cards, write food types (called substrates) like starch, protein, and fat

Procedure

4. Shuffle all the cards and lay them out face up.
5. Match each enzyme card to the correct food type card. For example: Match amylase with starch
6. Write a reason for each match. For example: "Amylase breaks down starch."
7. Check your answers using your class notes or textbook.
8. Draw a simple picture to show one correct enzyme working on its substrate.

ENZYMES IN ACTION

Enzymes in Digestion and the Foods They Break Down

Let us begin with a picture that shows how the body digests different types of food. **Figure 3.3** is an infographic that shows:

1. the **type of food** (carbohydrates, proteins, or fats)
2. the **enzyme** that breaks each food down (like amylase, protease, or lipase)
3. the **final product** of digestion (like sugars, amino acids, or fatty acids)

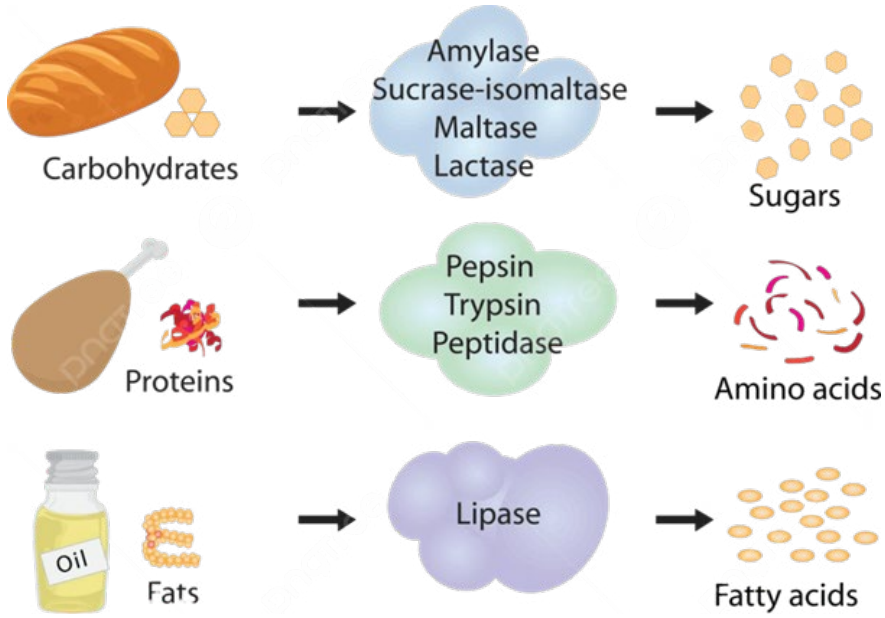


Figure 3.3: What enzymes do to food

Here are a few examples based on **Figure 3.3**

1. Amylase acts on carbohydrates like starch and breaks them into glucose, a simple sugar.
2. Pepsin and trypsin break proteins into amino acids.
3. Lipase digests fats (lipids) into fatty acids and glycerol.

These end products, which are glucose, amino acids, and fatty acids, are small enough to be absorbed into the bloodstream through the walls of the small intestine. Without enzymes, large food molecules would just pass through the body unused.

How Enzymes Are So Specific

Have you ever tried using a key that did not fit a lock? That is what happens when an enzyme meets the wrong food molecule. Enzymes are very picky. They only act on one specific type of nutrient. This is called *enzyme specificity*.

This concept is illustrated in **Figure 3.4**, where you can see how only the right substrate fits perfectly into the enzyme's active site.

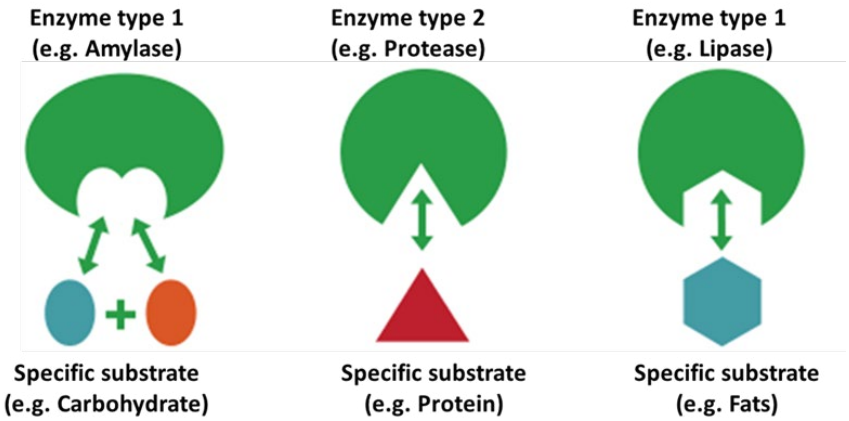


Figure 3.4: Illustration of enzyme specificity based on active site fit.

Let us look at three major enzymes

1. **Amylase**
   a. Targets carbohydrates like starch.
   b. Works in the mouth (salivary amylase) and small intestine (pancreatic amylase).
   c. Breaks starch chains into smaller two-unit sugars called Maltose.
2. **Protease** (e.g., pepsin and trypsin)
   a. Targets proteins.
   b. Works in the stomach (pepsin) and small intestine (trypsin).
   c. Breaks proteins into amino acids.
      i. *Pepsin* catalyse the conversion of proteins to peptides.
      ii. *Trypsin* break the peptides into even smaller bits in the intestines.
      iii. *Peptidases* in the walls of the small intestine break the remaining bonds to create free amino acids.
3. **Lipase**
   a. Targets fats.
   b. Works in the small intestine.
   c. Needs bile to first break fats into droplets (emulsification).
   d. Breaks fats into fatty acids and glycerol.

This specific match between enzyme and substrate keeps the digestion process efficient and well-organised.

What Happens If the Body Lacks Enzymes?

Sometimes, the body does not make enough of a certain enzyme. This can cause digestion problems and make a person feel uncomfortable or unwell. Here are some common examples:

1. **Lactase Deficiency (Lactose Intolerance)**
   a. The body does not make enough lactase.
   b. Lactase is the enzyme that breaks down lactose (the sugar in milk).
   c. Without it, people have trouble digesting dairy.
   d. This causes bloating, gas, and diarrhoea after eating or drinking milk products.
2. **Pancreatic Enzyme Deficiency**
   a. The pancreas does not make enough enzymes to digest food.
   b. Can happen in diseases like cystic fibrosis or chronic pancreatitis.
   c. This causes:
      i. Fatty stools (oily or smelly poo)
      ii. Weight loss
      iii. Vitamin deficiency (A, D, E, and K)
3. **Sucrase – Isomaltase Deficiency**
   a. The body does not make enough sucrase or isomaltase.
   b. These enzymes help break down sugars like sucrose (table sugar) and isomaltose (from starch).
   c. Without them, people feel bloated or get diarrhoea after eating sugary foods.

Activity 3.3 Enzymes at Work

Objective: Use speech or sign language to name enzymes and explain what they do.

Materials needed

1. Your class notes or textbook
2. Flashcards or a chart with enzyme names
3. A mirror or phone camera to practise

Procedure

1. Pick three enzymes – for example
   a. Amylase
   b. Protease
   c. Lipase

2. For each one, say or sign
   a. What food it breaks down
   b. What small product it makes
3. Practise explaining like this:
   a. "Amylase breaks down starch into sugar (glucose)."
   b. "Protease breaks down protein into amino acids."
   c. "Lipase breaks down fat into fatty acids and glycerol."
4. Record yourself or practise in front of a mirror.
5. Reflection
   a. Which enzyme was the easiest to remember?
   b. Why was it easier for you?

THE RESPIRATORY SYSTEM – DELIVERING OXYGEN

What Is the Respiratory System and Why Is It Important?

Every time you breathe in, your body takes in oxygen (a gas your cells need to survive). When you breathe out, your body gets rid of carbon dioxide (a waste gas produced during energy production). This constant exchange is made possible by your **respiratory system (Figure 3.5).**

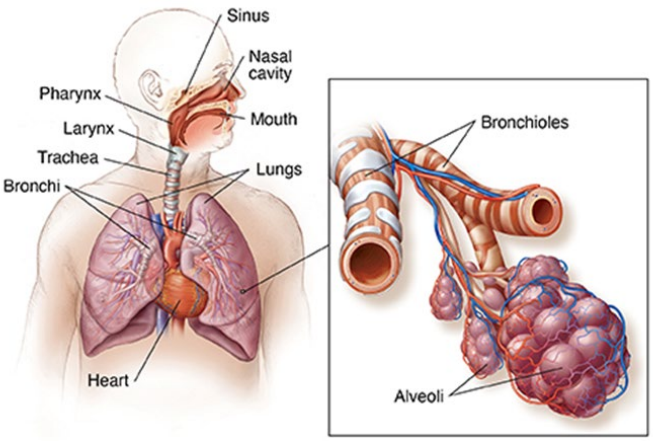


Figure 3.5: The respiratory system

The respiratory system (**Figure 3.5**) is made of special parts that work together to help you breathe in oxygen and breathe out carbon dioxide.

Main parts and what they do

1. Nasal cavity & sinuses – Warm, moisten, and clean the air you breathe in.

2. Pharynx – A passage that carries both air and food.
3. Larynx (voice box) – Has your vocal cords and sends air into the windpipe.
4. Trachea (windpipe) – A tube that carries air down into your lungs.
5. Bronchi & bronchioles – Small air tubes inside your lungs that spread air around.
6. Alveoli – Tiny air sacs where oxygen enters the blood and carbon dioxide leaves.

How Breathing Works

Breathing has two main steps

1. Inhalation – breathing in
2. Exhalation – breathing out

These steps happen when the diaphragm and the chest move. They help pull air into the lungs and push it out again. (See **Figure 3.6** for a picture)

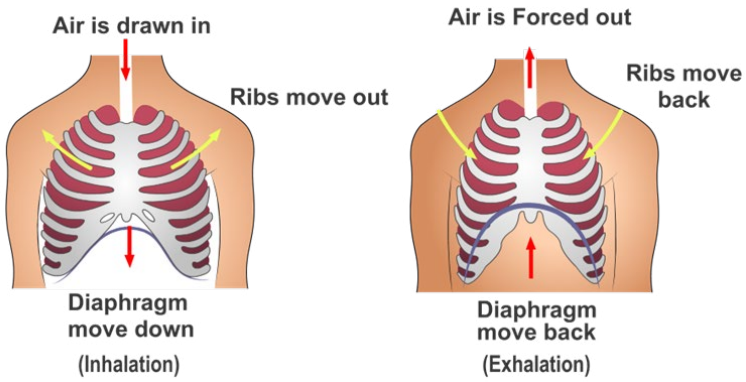


Figure 3.6: Comparison of Inhalation and Exhalation.

Inhalation (Breathing In)

1. The diaphragm moves down and flattens.
2. The chest gets bigger and creates more space.
3. Air pressure inside the lungs becomes lower than outside.
4. Air rushes in to fill the lungs.

Exhalation (Breathing Out)

1. The diaphragm moves up and relaxes.
2. The chest gets smaller, and space reduces.
3. Air pressure inside the lungs becomes higher than outside.
4. Air is pushed out of the lungs.

This in-and-out movement of air is called **ventilation**. It allows **gas exchange** to take place in the lungs.

How Does Oxygen Enter the Bloodstream?

Oxygen does not stay in your lungs. It must enter your blood so it can travel around your body. This happens in the **alveoli**, which are small air sacs at the end of the bronchioles (see Figure 3.7). The alveoli allow oxygen to move into the blood and carbon dioxide to move out.

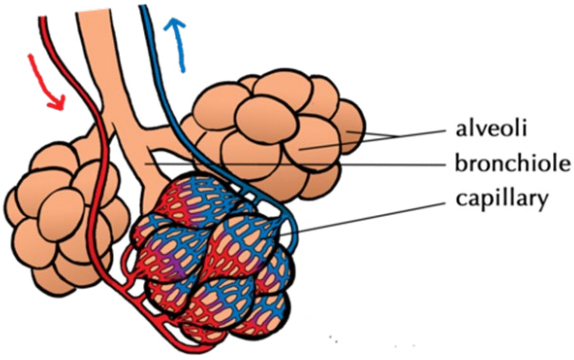


Figure 3.7 Structure of an alveolus and surrounding capillaries

Why are the alveoli good at gas exchange?

1. The walls of the alveoli are very thin. This helps gases pass through easily.
2. The inside of the alveoli is moist. This helps oxygen dissolve before it moves into the blood.
3. Tiny blood vessels called capillaries surround the alveoli. These bring blood that needs oxygen and must get rid of carbon dioxide.
4. There are millions of alveoli in the lungs. This gives a very large surface area for gas exchange, about the size of half a tennis court.

The Role of Diffusion In Gaseous Exchange

Gas exchange happens by diffusion. This means particles move from where there is more to where there is less. There is more oxygen in the alveoli than in the blood. So, oxygen moves into the blood. There is more carbon dioxide in the blood than in the alveoli. So, carbon dioxide moves into the alveoli and is breathed out.

How Oxygen is Carried in the Blood

Once oxygen enters the blood, it is picked up by a special protein called haemoglobin, found in red blood cells. Oxygen binds to an iron ion, which sits at the centre of a heme group. The heme group is a complex ring structure that acts as a socket for the iron, and together they allow the haemoglobin protein to transport oxygen. Each haemoglobin complex has four heme groups.

Figure 3.8 shows how this protein helps to carry oxygen throughout the body.

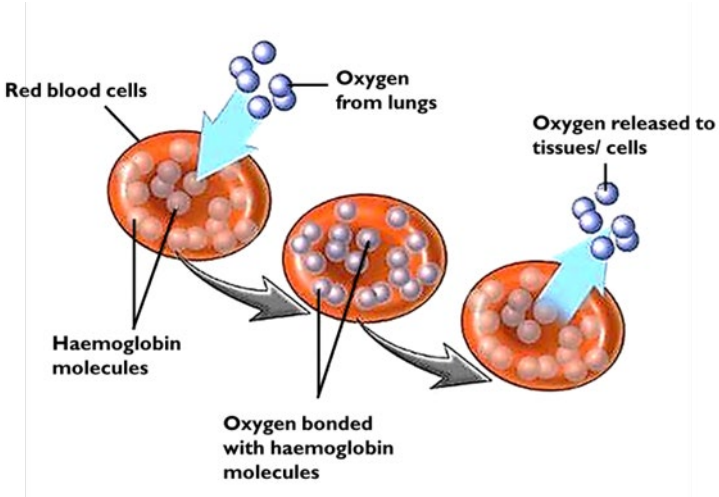


Figure 3.8: Haemoglobin as a means of oxygen transport

Each molecule of haemoglobin can carry up to four oxygen molecules, making transport very efficient. Without it, only a small amount would dissolve in the blood, which would not be enough to support normal body function. Oxygen is needed to produce energy in every cell. When the body does not get enough, such as during exercise or illness, you may feel tired or short of breath.

Understanding how the respiratory system works helps us see why breathing is so important for life. It also reminds us to protect our lungs by avoiding smoking, pollution, and harmful chemicals.

Activity 3.4 Oxygen in Action

Objective: To describe two ways the respiratory system helps the body.

Materials needed

1. A picture or model of lungs (or an online image)
2. Mirror or phone camera

Procedure

1. Look at the picture or model of the lungs.
2. Say or sign two things the lungs do. *For example: "Lungs bring in oxygen" and "They remove carbon dioxide."*
3. Practise saying or signing in front of a mirror.
4. Record yourself and watch it to check.
5. Write or draw your two points on a small poster.

THE CIRCULATORY NETWORK – DISTRIBUTING ESSENTIALS

Introduction: What is the Circulatory Network?

The circulatory system, also called the cardiovascular system, is like a delivery system inside your body. It moves oxygen, nutrients, water, hormones, and waste to and from the body's cells. Without it, the body would not work properly. Cells would not get what they need, and waste would pile up.

This system has three main parts:

1. The heart: a strong muscle that pumps blood
2. The blood vessels: the tubes through which the blood flows
3. The blood: the liquid that carries oxygen, food, and waste

All these parts work together to connect every part of the body.

How the Heart Keeps Blood Moving

The heart (see **Figure 3.8**) is a muscular organ about the size of your fist. It has four spaces called chambers:

1. Two top chambers called atria (right and left)
2. Two bottom chambers called ventricles (right and left)

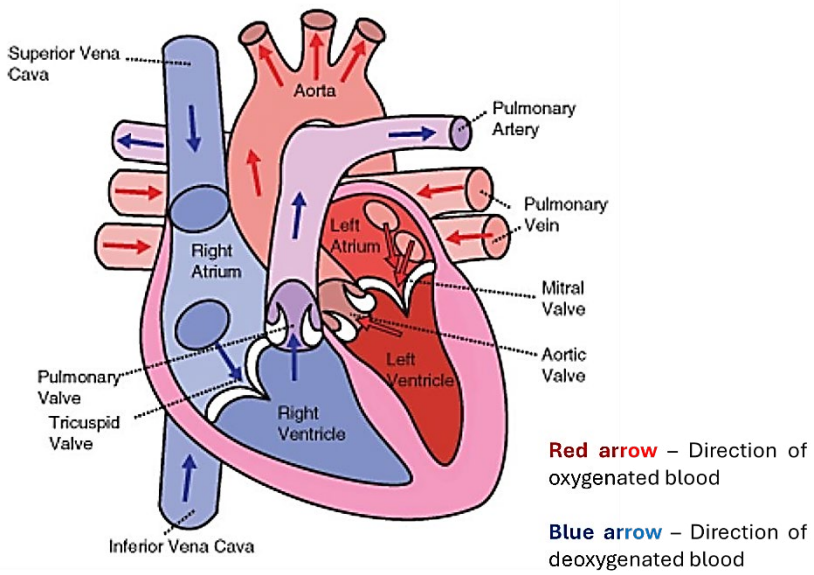


Figure 3.9: The Heart

Here is how blood moves through the heart (see **Figure 3.9**)

1. Blood low in oxygen (deoxygenated blood) from the body enters the **right atrium**.
2. It is pumped into the **right ventricle**.

3. The right ventricle pumps the blood to the **lungs** through the **pulmonary artery**. In the lungs, carbon dioxide is removed, and oxygen is added (oxygenated)
4. Blood with oxygen (oxygenated blood) comes back to the heart via the **pulmonary vein** into the **left atrium**.
5. It then goes to the **left ventricle**.
6. The left ventricle pumps the oxygen-rich blood to the rest of the body through a large blood vessel called the **aorta**.

This blood flow is divided into two parts:

1. Pulmonary circulation: heart to lungs to heart
2. Systemic circulation: heart to body to heart

See **Figure 3.10** to understand how both types of circulation work.

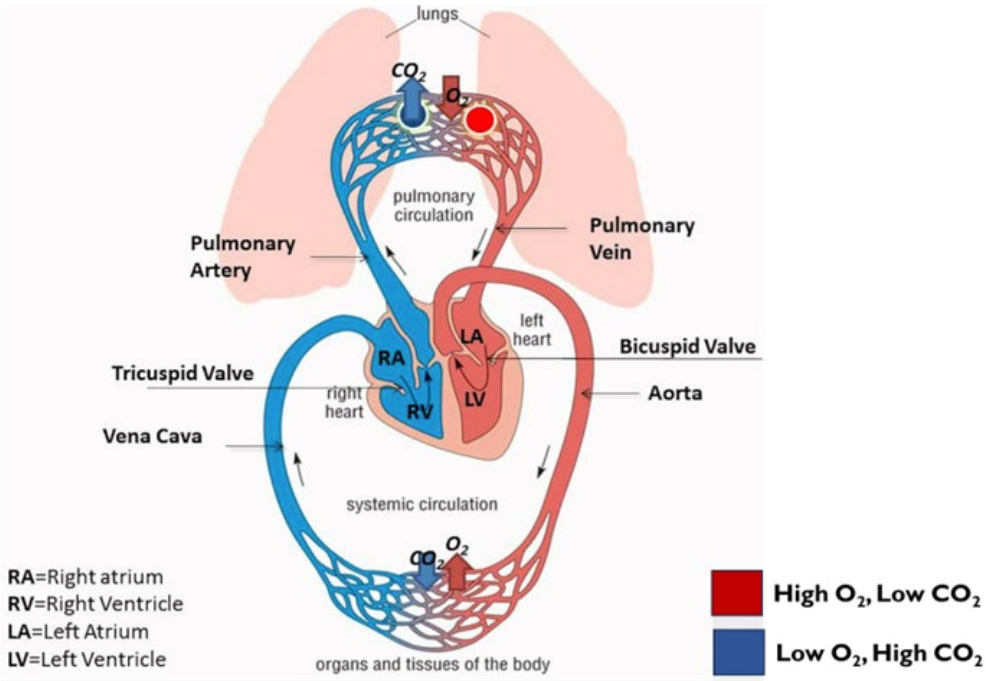


Figure 3.10: Pulmonary and Systemic Circulation

Blood Vessels: The Highways of the Body

Blood vessels are like roads that move blood around the body. There are three main types of blood vessels.

Arteries

Carry blood with oxygen away from the heart. Have thick walls to handle strong pressure.

Example: the aorta

Special case: the pulmonary artery carries blood without oxygen to the lungs

Veins

Carry blood without oxygen back to the heart. Veins have valves that stop the blood from flowing backwards

Special case: the pulmonary vein carries blood with oxygen from the lungs to the heart

Capillaries

Very small blood vessels that connect arteries and veins. They have thin walls (just one cell thick). Allow oxygen, nutrients, and waste to pass between the blood and body cells. This process is called diffusion

See Figure 3.11 for how these substances move across the capillary walls.

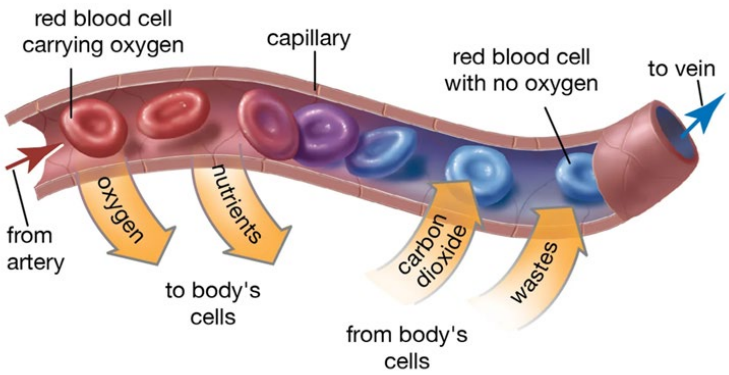


Figure 3.11: Capillary exchange showing the movement of substances

The Cardiovascular System as a Transport Network

Imagine your body as a busy city. The cardiovascular system works like a delivery service. It brings important things to your cells and carries away waste.

What Does it Transport?

1. **Oxygen and Carbon Dioxide**
   a. Oxygen enters the lungs when you breathe in
   b. It moves into the blood and attaches to haemoglobin in red blood cells
   c. This oxygen-rich blood goes to the heart
   d. The heart pumps it to the rest of the body
   e. Cells use oxygen to make energy and produce carbon dioxide as waste
   f. Carbon dioxide returns to the lungs through the pulmonary artery and is breathed out
2. **Nutrients**
   a. After digestion, nutrients are absorbed in the small intestine
   b. Water-based nutrients like glucose, amino acids, and minerals enter the hepatic portal vein and travel to the liver

c. From the liver, they move into the hepatic vein, then into the heart, and finally around the body

d. Fat-based nutrients like fatty acids and vitamins A, D, E, and K enter lymph vessels first. These then join the bloodstream near the heart

3. **Water**

Water is mostly absorbed in the small intestine, with some absorbed in the large intestine. It enters the blood through capillaries. It becomes part of blood plasma, helping to carry materials and control body temperature

Activity 3.5 Track the Flow

Objective: To draw a diagram that shows how food, water, and oxygen enter the body and travel through the bloodstream.

Materials needed

1. A short video or animation about the digestive, respiratory, and circulatory systems
2. Drawing paper
3. Colour pencils or crayons

Procedure

1. Watch the video carefully.
   a. Focus on how the body takes in food, water, and oxygen.
   b. Notice how these substances move into the bloodstream and travel around the body.
2. Draw a simple body outline on your paper.
3. Add the following parts inside the body
   a. The intestines to show where food is absorbed
   b. The lungs to show where oxygen enters
   c. The heart to show how blood is pumped
4. Use arrows and colours to show the following
   a. Food going from the intestines into the blood
   b. Oxygen moving from the lungs into the blood
   c. Blood moving around the body from the heart
5. Label your diagram with easy phrases like:
   a. “Oxygen enters blood”
   b. “Digested food enters blood”
   c. “Heart pumps blood”
6. Present your diagram to your classmate or teacher.

DIGESTION AS THE FUEL SOURCE

What Happens After Digestion?

After digestion, food is broken down into small useful parts that enter the blood and travel around the body. These parts include:

1. Glucose
2. Amino acids
3. Fatty acids and glycerol

These are like fuel for the body. They give energy and help with movement, growth, warmth, and staying alive.

Glucose: Quick Energy

Glucose is a simple sugar and the main source of energy for the body. It comes from carbohydrates like rice or bread. After digestion, glucose enters the blood. It moves into the cells and is used in a process called cellular respiration to make energy. The energy is stored as **ATP** which stands for adenosine triphosphate.

Glucose can also:

1. be stored in the liver and muscles as glycogen
2. be turned into fat if there is extra glucose

Fatty Acids and Glycerol: Long-Lasting Fuel

These come from fats and provide energy over a longer time. They:

1. are broken down slowly to make lots of ATP
2. are used during long activities like walking, sleeping, or when you have not eaten
3. are stored in fat tissues as energy
4. can be changed into glucose by the liver when needed

Amino Acids: Building Blocks and Extra Energy

Amino acids are mainly used to

1. build and repair body tissues
2. help make enzymes and hormones

In times of need, like during illness or hard exercise, they can also

1. Be turned into glucose
2. Be used to give energy

The body tries to keep amino acids for growth and repair, not for energy, unless it is really needed.

Activity 3.6 What Fuels My Heart?

Objective: To explain how digested food (glucose, fatty acids, and amino acids) gives energy for the heart to work.

Materials needed

1. Worksheet or notebook
2. Pen or pencil

Procedure

1. Think about the three main food parts that enter the blood after digestion:
   a. Glucose
   b. Fatty acids
   c. Amino acids
2. Draw or write how each one gives energy to the body.
3. Show how this energy helps the heart to keep beating.
4. Share your work with your teacher or a classmate for feedback.

THE POWERHOUSE WITHIN – CELLULAR RESPIRATION

What Is Cellular Respiration?

Cellular respiration is the way cells get energy from food. It mostly happens in small parts of the cell called **mitochondria**. These are often called the powerhouses of the cell. The energy made is stored in a form called **ATP**. Cells use ATP to do many jobs in the body.

There are two main types of cellular respiration:

1. Aerobic respiration – needs oxygen
2. Anaerobic respiration – happens without oxygen

Aerobic Respiration

This is the best way the body makes energy.

Equation: Glucose + Oxygen → Carbon dioxide + Water + Energy (ATP)

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

This reaction happens inside the **mitochondria** and it

1. makes a large amount of ATP
2. gives off carbon dioxide and water as waste
3. uses glucose from food and oxygen from the air we breathe

Anaerobic Respiration

This happens when there is not enough oxygen. For example, during hard exercise.

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

$C_6H_{12}O_6 \rightarrow 2C_3H_6O_3 + \text{Energy}$

It happens in the **cytoplasm** of the cell, and it:

1. works faster but makes less ATP
2. produces lactic acid, which can cause tired muscles or cramps

Figure 3.12 shows both aerobic and anaerobic respiration.

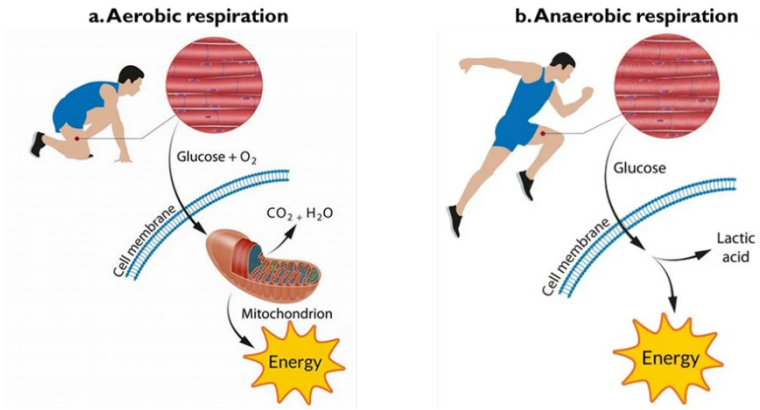


Figure 3.12: Aerobic and anaerobic respiration

Activity 3.7 My Pulse and My Energy

Objective: Measuring Your Pulse and Understanding Energy Use

Materials needed

1. A timer or watch
2. A notebook
3. A pen or pencil

Procedure

1. Sit quietly for 5 minutes.
2. Use your fingers to feel your pulse on your wrist or neck.
3. Count the number of beats in 60 seconds. Write it in your notebook.
4. Do a simple exercise like jogging on the spot for 1 minute.
5. Count your pulse again for 60 seconds. Write this number down too.
6. Talk to your teacher or classmate about which type of respiration your body likely used during the exercise: aerobic or anaerobic. Explain your answer.

ENERGY ON DEMAND

What Does the Body Use Energy For?

The energy made in cellular respiration (as ATP) is used for everything the body does.

Here are some examples

1. **Muscle Movement**

   ATP helps muscles to

   a. contract and relax
   b. do all physical actions like walking, writing, lifting, and breathing
   c. keep the heart beating and the lungs working

   Without ATP, muscles cannot move.

2. **Organ Function**

   ATP gives power to the

   a. brain to send signals and help us think and process information.
   b. kidneys to clean the blood, balance electrolytes and control water balance.
   c. liver to make useful chemicals, metabolise nutrients, and remove harmful substances

   If there is no ATP, organs cannot do their jobs.

3. **Temperature Control**

   ATP helps the body make heat during respiration. This keeps the body warm during cold weather through actions like *shivering*, where muscles move quickly to make heat

4. **Transport in Cells**

   ATP helps cells to:

   a. Uptake nutrients like glucose and minerals
   b. Push out waste products
   c. Send messages through nerve signals across the body

ATP is the energy used for every small action in the body.

From digestion to respiration, the body uses food to make energy. This energy, from glucose, fatty acids, and amino acids, is changed into ATP by cellular respiration. Whether you are running or sitting still, your body is always using ATP to keep all cells and organs working. Knowing how digestion and cellular respiration work together shows why it is important to eat well, exercise often, and breathe properly to stay strong and full of energy.

Activity 3.8 ATP in Action – A Day in My Life

Objective: To reflect on how your body uses energy throughout the day.

Materials needed

1. Notebook
2. Pen or pencil

Procedure

3. Think about a normal school day.
4. Make a timeline from morning to evening (e.g., wake up, walk to school, write notes, eat lunch).
5. Next to each event, write how ATP is helping (e.g., "ATP gave me energy to carry my books").
6. At the end, circle one activity that needed the most energy and explain why.
7. Present your timeline to a teacher or classmate.

ROLE OF MUSCULOSKELETAL SYSTEM IN ENERGY GENERATION AND USE

The Musculoskeletal System: Moving the Body and Fuelling Activity

The musculoskeletal system (see Figure 3.13) is the body's engine for all movement. It helps you blink, smile, walk, and run. It is made up of two parts that work together

1. The muscular system
2. The skeletal system

Together, they support your body, help you move, and protect your organs.

The Skeletal System – The Body's Framework

The adult human body has *206 bones*. These bones do many important jobs:

1. Structural Support – They give your body shape and help it stand upright.
2. Protection – Bones like the skull and ribs keep the brain, heart, and lungs safe.
3. Movement – Muscles pull on bones to create movement.
4. Mineral Storage – Bones store minerals like calcium and phosphorus.
5. Blood cell production – Inside bones, bone marrow makes red blood cells, white blood cells, and platelets.

The Muscular System – The Body's Motor

The body has *over 600 muscles*, mostly skeletal muscles. These muscles are connected to bones and help you move. They:

1. Use ATP (a type of energy) to do their work
2. Contract when the brain sends signals through nerves
3. Can stretch and go back to their normal shape

Figure 3.13 shows how the muscular and skeletal systems work together to move and protect the body.

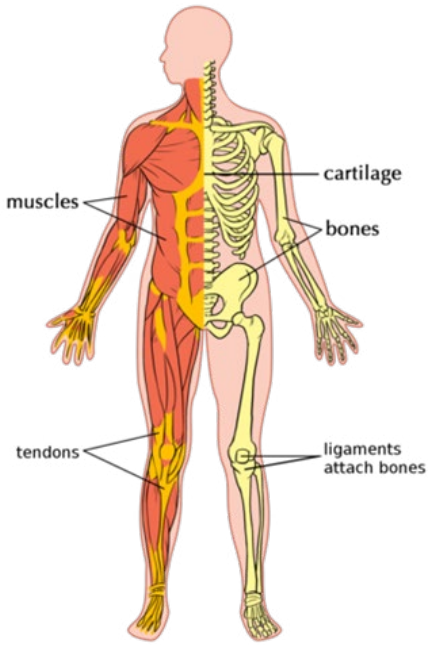


Figure 3.13: The musculoskeletal system

How Do Muscles Use Energy to Move the Body?

Skeletal muscle fibres (see Figure 3.14) are made up of small bundles called **myofibrils**. These myofibrils contain **sarcomeres**, which are the parts that help the muscle contract. Inside each sarcomere are two types of protein threads:

1. **Myosin**
2. **Actin**

When a muscle contracts, **myosin** and **actin** slide past each other. This sliding makes the muscle shorter and pulls on the bone to create movement.

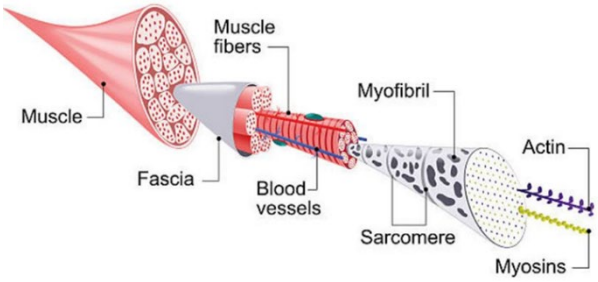


Figure 3.14: Hierarchical Structure of Skeletal Muscle Tissue

How Muscles Contract

The process needs ATP, which is the energy used by cells. Here is how it works:

1. A signal from the brain travels through a nerve to the muscle.
2. Calcium ions are released inside the muscle cell.
3. Myosin attaches to actin to form a link.
4. ATP helps myosin pull the actin inward, creating force.
5. Another ATP is needed to release and reset the myosin.
6. When the brain stops sending signals, the calcium is taken away, and the muscle relaxes. This also needs ATP.

Working in Pairs: Antagonistic Muscles

Muscles do not work alone. They always work in **pairs**. When one muscle contracts, the other relaxes. These are called **antagonistic muscles**.

For example (see Figure 3.15)

1. The **biceps** contract to bend the arm.
2. The **triceps** contract to straighten the arm.

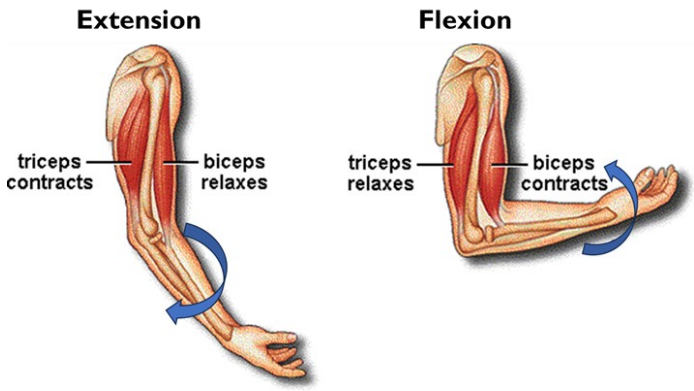


Figure 3.15: Antagonistic muscle pair (biceps and triceps)

How the Brain Controls Movement

The nervous system controls how and when muscles move. It does this by sending messages through special cells called neurons. The motor cortex in the brain plans the movement. It sends the message down the spinal cord and through motor neurons to the muscles. **Figure 3.16** shows how the brain and muscles are connected. It highlights the motor cortex, spinal cord, motor neurons, and the neuromuscular junction (the place where the nerve meets the muscle).

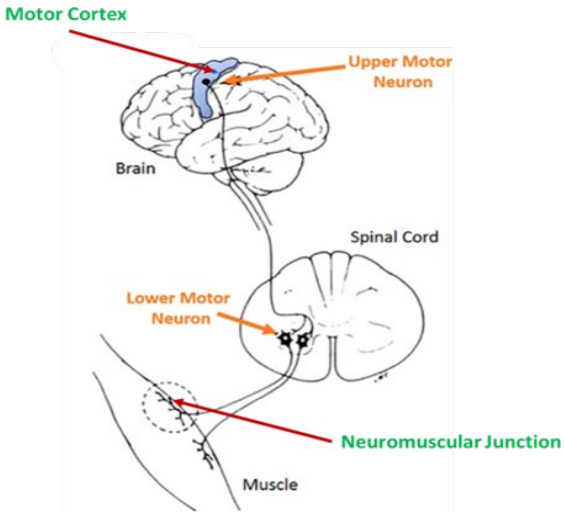


Figure 3.16: Nerve pathway from brain to muscle.

Key Steps of Muscle Control

1. The motor cortex in the brain decides what movement to make.
2. The message travels through motor neurons to the muscle.
3. At the neuromuscular junction, the nerve message tells the muscle to contract.

How the Body Controls Movement Strength

The nervous system changes how strong a movement is by:

1. using more motor units when more force is needed
2. sending messages more often for stronger contractions
3. making motor units work together at the same time

How Reflexes Help Protect the Body

The nervous system does more than control movement. It also protects the body using reflexes. Reflexes are fast and automatic actions. They happen without thinking. They are like safety tools built into the body to help react quickly to danger or sudden changes.

How Reflexes Work

Inside each skeletal muscle are sensors called muscle spindles. These sensors watch the length of the muscle.

If a muscle is suddenly stretched, like *when you step into a hole or when a doctor taps below your knee,* the muscle spindle quickly senses the stretch. It sends a message to the spinal cord. The spinal cord then sends a message back to the muscle, telling it to contract. This protects the muscle and joint from injury.

Example: The Knee Jerk Reflex

When a doctor taps just below your kneecap, your thigh muscle (called the quadriceps) is stretched slightly. The muscle spindle notices this and sends a quick signal. The muscle contracts, and your lower leg kicks forward. This happens in less than one second. It shows how the nervous system can protect you even before you know what is happening.

Activity 3.9 Muscles Need Energy to Move

Objective: To learn how bones and muscles work together using energy from food.

Materials needed

1. Paper
2. Pencil or pen
3. Cardboard or thick paper
4. String or rubber band
5. Scissors
6. Glue or tape
7. Picture of bones and muscles (if you have one)

Procedure

1. Look at a picture of the musculoskeletal system, like Figure 3.14. This shows how bones and muscles are connected.
2. Cut two strips of cardboard or thick paper. These will be your bones.
3. Use a string or rubber band as your muscle. Attach the ends of the string to the two cardboard strips using glue or tape.
4. Gently pull the string and watch the two cardboard bones move. This shows how muscles pull on bones to cause movement.
5. Explain what your model shows. Point out:
   a. Which parts are the bones
   b. Which part is the muscle
   c. How pulling the string shows muscle action
6. Say or sign that muscles need energy from food to move. This energy is stored in a form called ATP.
7. Draw a simple diagram showing how movement begins in the brain, travels through the nerves, and reaches the muscles.

JOINTS – THE MOVERS AND SHAKERS

What are joints?

Joints are the places where two or more bones meet. They allow the body to move and stay stable at the same time. Without joints, the skeleton would be stiff and unable to move. Joints help us do everyday activities. For example, bending your elbow to eat, turning your head to look behind you, or gripping a pen with your fingers. All these actions happen because of joints.

Joints work like levers or hinges. They guide how bones move and stop them from moving too far. Joints also help absorb shock and protect the body during actions like running, jumping, or lifting things. They spread out the impact on bones and help protect organs inside the body.

Joints are supported by different parts, including

1. Ligaments: hold bones together and stop them from moving too much
2. Cartilage: cushions the ends of bones
3. Synovial fluid: keeps the joint smooth and reduces friction

Types of Joints

Joints can be grouped into three main types based on their structure and how much they move:

1. Fibrous joints
2. Cartilaginous joints
3. Synovial joints.

Fibrous Joints

These joints do not move. The bones are tightly joined by strong tissue. There is no space between them. Their main job is protection.

Example: The joints in the skull (Figure 3.17). These joints lock the skull bones in place to protect the brain. They do not move after early childhood.

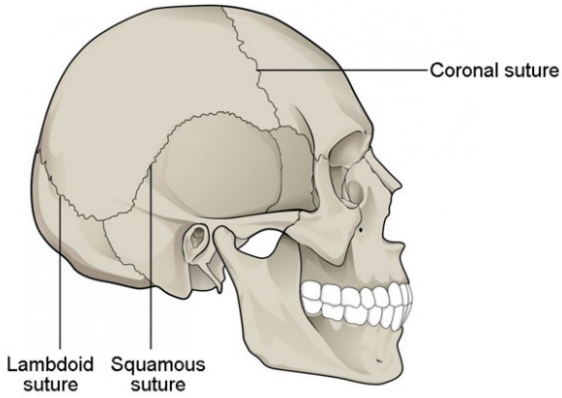


Figure 3.17: Fibrous joint of the Skull

Cartilaginous Joints

These joints allow only a small amount of movement. The bones are joined by cartilage, which is firm but slightly flexible. These joints help with shock absorption.

Example: The joints between the bones in the spine (vertebrae) (Figure 3.18). The cartilage discs between the vertebrae let the spine bend and twist a little, while keeping it strong and steady.

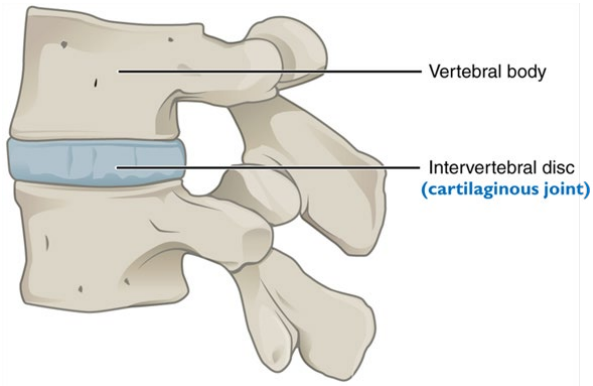


Figure 3.18 Cartilaginous joint between vertebrae

Synovial Joints

These are the most common and flexible joints. They allow different types of movement like bending, stretching, and turning. These joints have a space filled with fluid that helps the bones move smoothly.

Important Parts of a Synovial Joint

1. Articular cartilage: reduces friction
2. Joint capsule: protects the joint
3. Synovial fluid: keeps the joint moving smoothly
4. Ligaments: keep bones in place
5. Menisci (in some joints): absorb shock
6. Bursae: reduce rubbing between bones and soft tissues

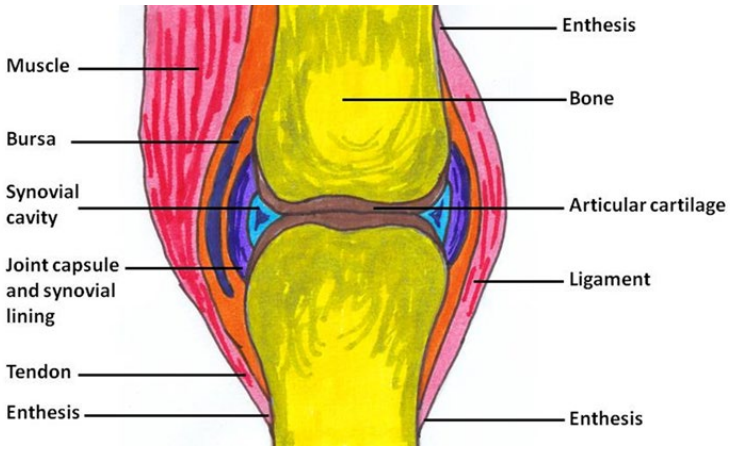


Figure 3.19: A Synovial Joint.

Types of Synovial Joints

1. **Hinge Joint:** Moves in one direction, like a door hinge.
   Examples: Elbow, knee, fingers, and toes.
   Helps with: Bending, straightening, gripping, and balance.
2. **Ball and Socket Joint:** Moves in many directions and can rotate.
   Examples: Shoulder and hip joints.
   Helps with: Throwing, kicking, dancing, or climbing.
3. **Pivot Joint:** Allows rotation around one axis.
   Examples: Neck (between the atlas and axis bones), and in the elbow (between radius and ulna).
   Helps with: Turning the head side to side or turning the palm up or down.
4. **Gliding Joint:** Let's bones slide over each other in small movements.
   Examples: Wrists, ankles, and small joints in the spine.
   Helps with: Balance, twisting, and small movements during walking or stretching.

Activity 3.10 My Body, My Joints

Objective: To show how joints help your body to move.

Materials needed

1. Mirror (if available)
2. Notebook
3. Pen or pencil

Procedure

1. Stand up and do five simple movements. For example
   a. Squat down
   b. Stretch your arm forward
   c. Turn your head left and right
   d. Raise your arm
   e. Twist your upper body
2. After each movement, write the name of the joint you used. For example, squatting uses the **knee joint**.
3. Write or sign what kind of movement the joint allowed. For example, the elbow allows bending and straightening.
4. Draw a simple picture of yourself doing each movement. Label the joint you used in the picture.
5. Show your notebook to your teacher or a classmate. Explain your work.

Activity 3.11 Energy from My Lunch

Objective: To understand how the body uses food to make energy through different body systems.

Materials needed

1. Notebook and pen or pencil
2. Drawing paper
3. Coloured pencils or markers

Procedure

1. Think about a lunch you have eaten. For example: rice and beans, or kenkey and fish.
2. Write down the main nutrients in that meal. These can be carbohydrates, proteins, and fats.
3. Draw a simple flow chart to show how each part of the food is broken down in the digestive system.
4. Draw or label how glucose and oxygen travel in the blood to the muscles.
5. Use words or sign language to explain how energy is made in the cells, and how the nervous system helps the muscles use that energy.
6. In your notebook, write two short sentences about why your body needs all the systems to work together to make energy.

EXTENDED READING

QR Code 11 Enzymes as biological catalysts

QR Code 12 Digestive Enzymes

QR Code 13 Digestive System Process

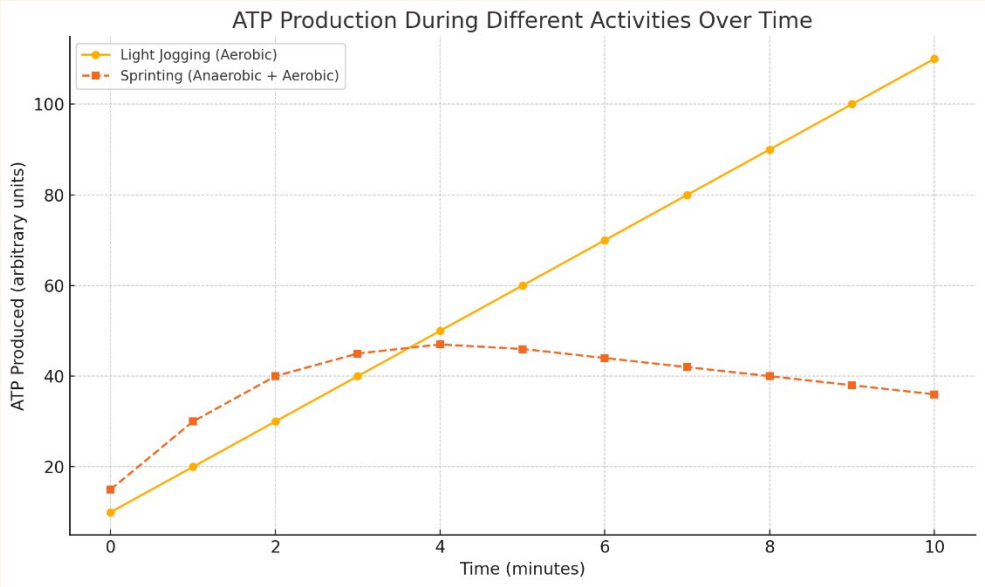
QR Code 14 Cellular respiration

QR Code 15 Types of joints and movement

QR Code 16 Nervous System and Movement

REVIEW QUESTIONS 3

1. The graph below shows the amount of ATP produced over 10 minutes during two different activities: light jogging and sprinting.



a. Analyse the trends in ATP production for both activities.

b. Explain why the levels differ using your knowledge of aerobic and anaerobic respiration.

c. Describe how the circulatory, respiratory, and muscular systems respond in each activity.

d. Predict what would happen to muscle function and fatigue levels if the activity continued for 30 minutes.

e. Suggest training or recovery strategies that could help maintain energy output during prolonged exercise.

2. Your task is to analyse how different types of nutrients contribute to energy production and represent this information in a pie chart. Use the following estimated contributions to total energy use in a typical balanced diet:

- Carbohydrates: 55%
- Fats: 30%
- Proteins: 15%

a. Create a labelled pie chart showing these proportions. You may use coloured sections for each nutrient group.

b. Below your pie chart, explain the role of each nutrient in energy production.

   i. Which nutrient is used first?

   ii. Which one provides the most energy per gram?

iii. Which one is used for repair when energy is low?

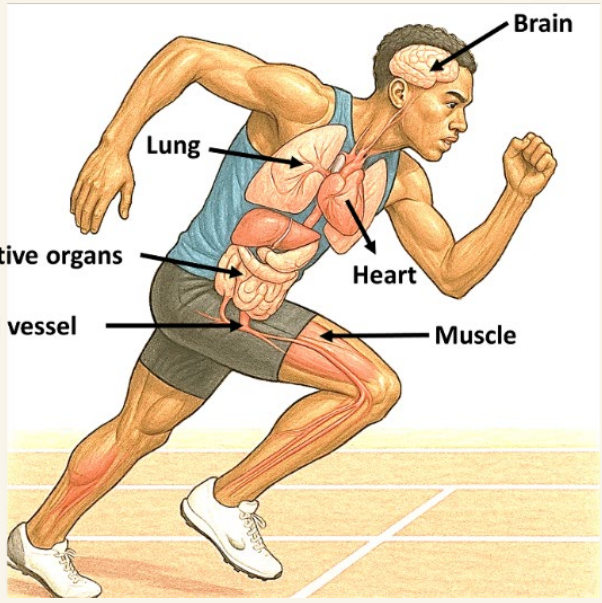
c. Apply your understanding by describing how these contributions might change in the body of:

i. Someone who runs for a long time

ii. A person recovering from surgery

d. Use speech or sign to explain your pie chart and your conclusions to a classmate or teacher.

3. You are given an image showing a person sprinting on a track. The image includes labels for the lungs, heart, muscle, blood vessels, brain, and digestive organs.



*Study the image **carefully**, then respond to the following tasks:*

a. Identify and describe what each labelled organ is doing during the sprint.

b. Explain how the respiratory, circulatory, muscular, and nervous systems are working together to support the sprint.

c. Analyse how oxygen and glucose are delivered and used by muscle cells to produce ATP.

d. Evaluate what would happen if the oxygen supply was reduced during the sprint (e.g. due to asthma or fatigue).

e. Propose two real-life strategies (e.g. training, diet, or medical support) that could help improve performance and energy use.

f. Use talk or sign to explain your findings to a peer or teacher, then write a short summary in your notebook.

4. A student athlete complains of constant fatigue and digestive issues. Doctors discover that the student has low levels of pancreatic enzymes and mild anaemia.

a. Explain how both enzyme deficiency and poor oxygen transport could lead to tiredness.
b. Describe what body systems are affected and how.
c. Suggest two medical or lifestyle interventions.

5. Choose a health condition (e.g., asthma, enzyme deficiency, or joint damage).

a. Create a concept map showing how that condition disrupts the normal function of at least three body systems.
b. Explain how the dysfunction in one system affects the others, using scientific language.

6. You are asked to write a brief training guide for junior athletes explaining:

a. How food becomes energy at the cellular level
b. How oxygen and nutrients are delivered to muscles during physical activity
c. What happens when oxygen is limited
d. How the nervous and muscular systems coordinate rapid movement
e. Support your report with labelled diagrams and real-life examples.

7. Your team is to analyse exercise-related data and explain how energy production is influenced by changes in oxygen availability and body system function. You are given the following data table showing **oxygen uptake** and **estimated ATP production** in two students during 10 minutes of continuous cycling:

Time (minutes)	Oxygen Uptake - Student A (ml/min)	Oxygen Uptake - Student B (ml/min)	Estimated ATP - Student A (units)	Estimated ATP - Student B (units)
0	200	200	10	10
2	800	600	40	30
4	1200	800	60	45
6	1400	900	75	52
8	1600	1000	90	58
10	1800	1100	100	60

a. Compare the oxygen uptake of Student A and Student B. What patterns do you observe over time?
b. Analyse the relationship between oxygen uptake and ATP production in both students.
c. Explain how differences in the respiratory and circulatory systems might account for the difference in ATP output.

d. Evaluate how these differences could affect performance and fatigue levels if the exercise continued for 30 minutes.

e. Propose realistic interventions (e.g. training, breathing techniques, dietary support) to help Student B improve ATP production and oxygen use.

f. Use talk or sign language to present your conclusions to a peer.

g. Write a summary in your notebook using clear scientific terms.

SECTION 4

DISEASES AND DISORDERS

HUMAN BODY SYSTEM

Diseases and Disorders

INTRODUCTION

Welcome to Year 3 of your biomedical science journey! This year, we will explore the vital roles of lipids and cholesterol in maintaining heart health and understanding the risks associated with heart disease. Building on the foundational knowledge you gained in Years 1 and 2, we will delve deeper into how these components influence overall health. In Year 1, you learned about the significance of biomedical science in addressing diseases and disorders, focusing on symptoms that guide diagnosis and treatment. Year 2 expanded your understanding of human body systems and their interconnections, particularly the impact of nervous and endocrine system disorders on health.

Now, in Year 3, we will investigate the types of lipids, the transport of cholesterol in the blood, and the roles of HDL and LDL. We will also examine how these lipoproteins affect heart disease risk and the importance of angiograms in diagnosis. Through engaging discussions and activities, you will deepen your understanding of cardiovascular health and learn to make informed choices for promoting heart wellness.

KEY IDEAS

- Angiograms are tests that take pictures of blood vessels. They help biomedical scientists find blockages and check the health of the heart.
- Cholesterol has important functions, such as helping to keep cell membranes flexible and serving as a building block for hormones and bile.
- Cholesterol moves through the bloodstream with help from lipoproteins, mainly HDL (good cholesterol) and LDL (bad cholesterol), which affect heart health differently.
- High levels of LDL can lead to plaque buildup in arteries, which increases the risk of heart disease. In contrast, higher levels of HDL can help remove excess cholesterol and lower that risk.
- Important risk factors for heart disease include poor diet, lack of exercise, smoking, and family history, all of which can affect heart health.
- There are three main types of lipids: triglycerides, phospholipids, and steroids. Each type has important roles, like storing energy, making up cell membranes, and producing hormones.

LIPIDS AS A DIVERSE GROUP OF MOLECULES

Let us embark on an exciting journey into the world of lipids! These remarkable molecules are not just simple fats; they are hydrophobic or nonpolar compounds that play vital roles in our bodies. Composed primarily of hydrocarbons, lipids serve essential functions ranging from energy storage to hormone signalling.

Exploration of the Different Types of Lipids and Their Unique Properties

Lipids are unique in that they are insoluble in water, making them hydrophobic, yet they dissolve in organic solvents. This property allows them to perform a variety of critical functions. The primary forms of lipids are triglycerides, phospholipids, and steroids (See ***Figure 4.1***).

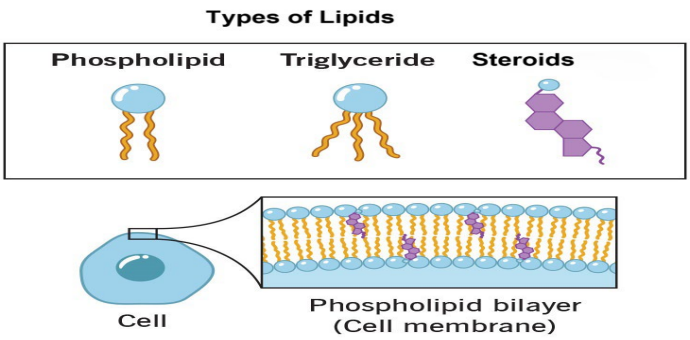


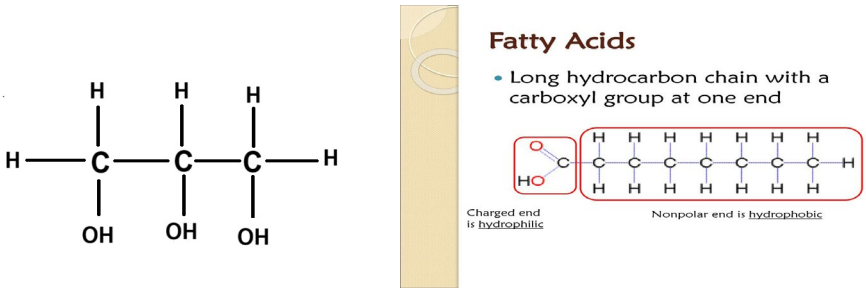
Figure 4.1: Types of lipids (Cleveland, 2022)

To understand lipids better, let us delve into their structure

Structure of Lipids

These fascinating molecules are made up of carbon, hydrogen, and oxygen, but they are hydrophobic compared to other biomolecules such as proteins and carbohydrates. Unlike polysaccharides and proteins, lipids do not form polymers because they lack repeating monomeric units. Instead, they are primarily constructed from two key components: glycerol and fatty acids.

Glycerol consists of *three* carbon atoms; each bonded to a hydroxyl (OH) group and hydrogen atoms. See ***Figure 4.2 (a)***. For instance, triglycerides have one glycerol backbone attached to three fatty acid chains, as shown in ***Figure 4.4***.



(a) **(b)**

Figure 4.2: Structure of glycerol (a) and fatty acid (b)

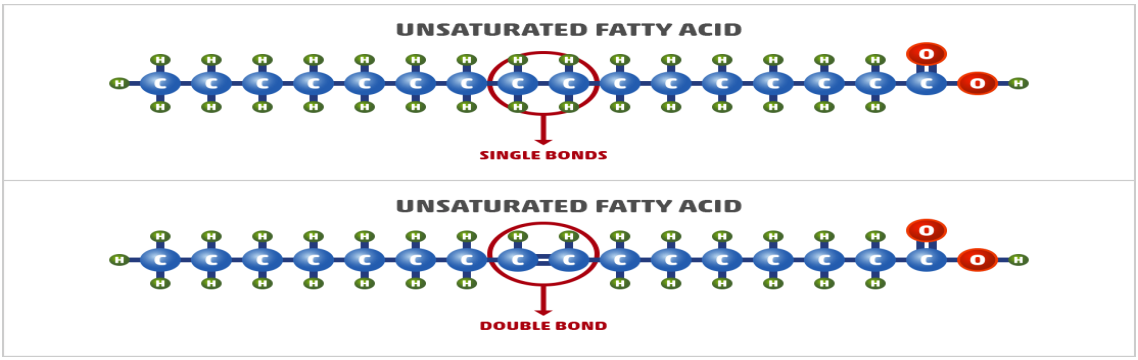
Fatty acids are intriguing molecules with an acid group (-COOH) at one end and a hydrocarbon chain (C-H), usually denoted by the letter 'R' (R-group) as shown in ***Figure***

***4.2** (b)*. The acid group is called carboxylic acid. Fatty acids can be classified into two categories viz saturated and unsaturated fatty acids.

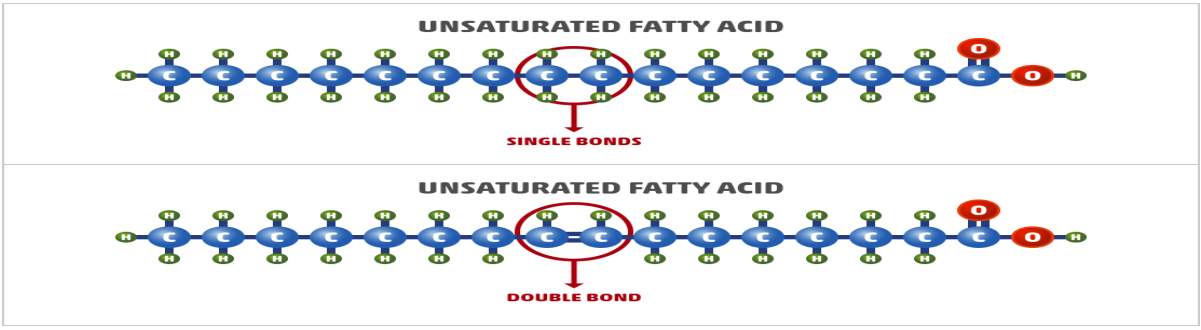
Did you know?

Hydrocarbons are not just in fuel, but they are also in the fats and oils you eat! Your body breaks down these hydrocarbon chains in fatty acids to release energy, just like a car engine burns fuel to run! Hydrocarbons consist of carbon and hydrogen atoms.

1. **Saturated fatty acids** have all their carbon atoms fully bonded with hydrogen. This means they have only single (C-C) bonds and no double bonds in their chain. They are typically solid at room temperature and come mostly from animal sources (except for coconut and palm oil). Other examples include cheese, butter, lard (animal fat).



2. **Unsaturated fatty acids** contain one or more double (C=C) bonds. For example, monounsaturated fatty acids have one double bond and are found in avocados and olive oil, while polyunsaturated fatty acids have two or more double bonds, such as omega-3s, are abundant in fishlike salmon and mackerel. These unsaturated fats, often liquid at room temperature, are recognised for their health benefits, including improved cholesterol levels.



Now, let us categorise lipids to appreciate their diversity and functionality!

Classification of Lipids

Lipids can be classified based on structure or function, providing insight into their roles in our bodies.

Simple Lipids

Simple lipids are made from fatty acids, which are long chains of carbon atoms with a carboxylic acid group (-COOH) at one end. See ***Figure 4.2 (b)***. They are the main components of triglycerides. Depending on the alcohols they contain, simple lipids can be classified as fats, oils, or waxes. At room temperature, fats are solid, while oils are liquid.

Triglycerides are the most common type of simple lipids found in our bodies and in food. Over 95% of dietary lipids are triglycerides. You can see concentrated fats in butter, vegetable oil, and meat, but they are also hidden in foods like pastries, milk, cheese, and fried foods. Natural sources include avocados, palm fruits, and nuts. A triglyceride is made of glycerol and three fatty acids. Glycerol serves as the backbone, with three fatty acids attached as shown in ***Figures 4.3*** and ***4.4***.

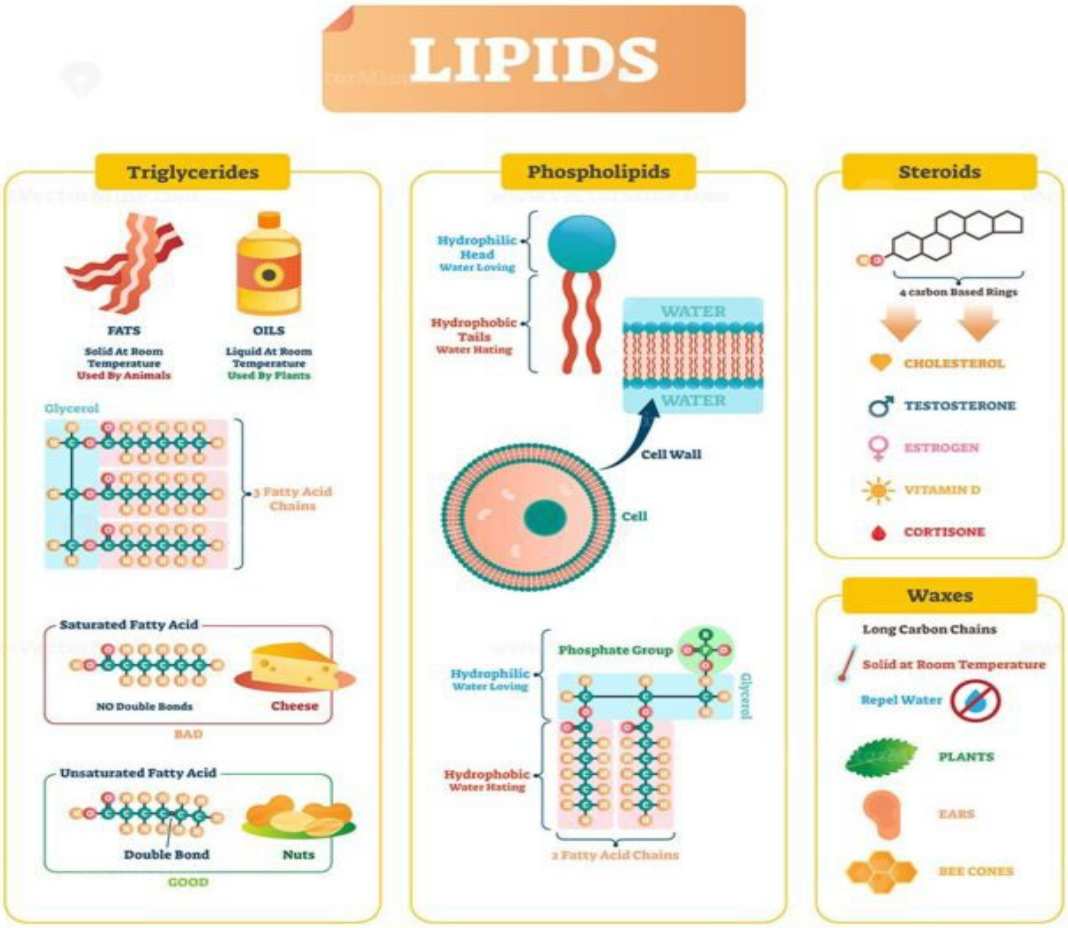


Figure 4.3: Structure of lipids

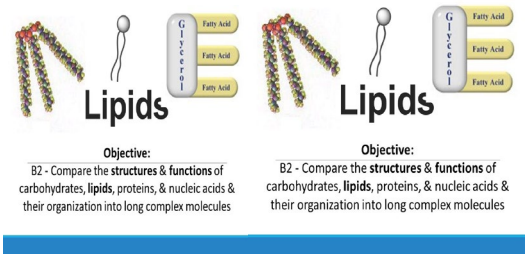


Figure 4.4: Simple Lipid - Triglyceride

Complex/Compound Lipids

These lipids contain additional chemical groups beyond fatty acids and alcohols, such as phosphates (in phospholipids) or sugars (in glycolipids).

1. **Phospholipids**

   These consist of two fatty acids, a glycerol backbone, and a phosphate group. They play essential roles in the body, even though they only make up about 2% of dietary lipids. The body can produce phospholipids, so they do not need to be consumed. Every cell has a membrane made mostly of a double layer of phospholipids, known as the phospholipid bilayer.

   The hydrophilic (water-attracting) heads face outward, while the hydrophobic (water-repelling) tails point inward, forming a flexible barrier. This structure allows the membrane to control what enters and exits the cell. Small molecules like oxygen can pass through easily, while larger or charged molecules need special channels. Phospholipids help protect the cell and transport substances.

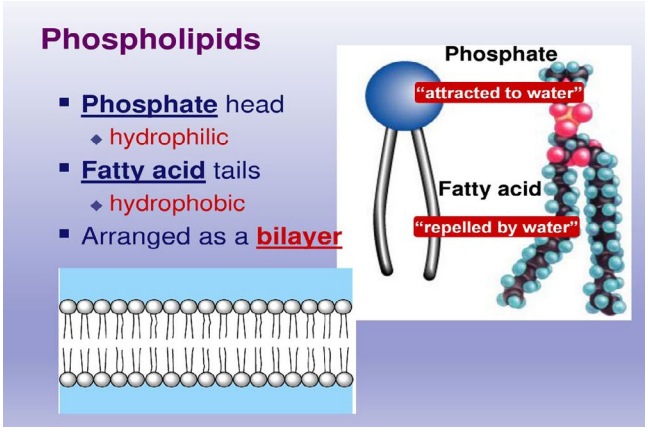


Figure 4.5: Complex Lipid - Phospholipid

2. **Lipoproteins**

   These are lipids attached to proteins, forming spherical complexes that transport water-insoluble lipids like triglycerides and cholesterol through the bloodstream. Examples include HDL (high-density lipoprotein) and LDL (low-density lipoprotein).

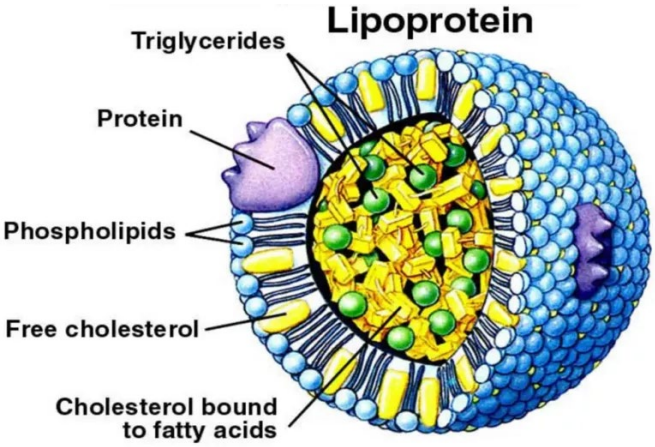


Figure 4.6: Structure of Lipoprotein

Derived Lipids

These are molecules formed from simple or compound lipids during digestion or metabolism. They still have lipid characteristics and are used in biochemical reactions to produce substances like steroids and bile.

Steroids: These have a different structure compared to triglycerides and phospholipids. Most steroids, including cholesterol, do not contain fatty acids. Instead, they consist of interlinked carbon rings (four cyclohexane rings and one cyclopentane ring) with side chains. Cholesterol is important for heart health, as it can contribute to artery blockages (atherosclerosis). However, it also helps maintain cell membrane structure and flexibility by fitting between phospholipids, ensuring the membrane remains adaptable.

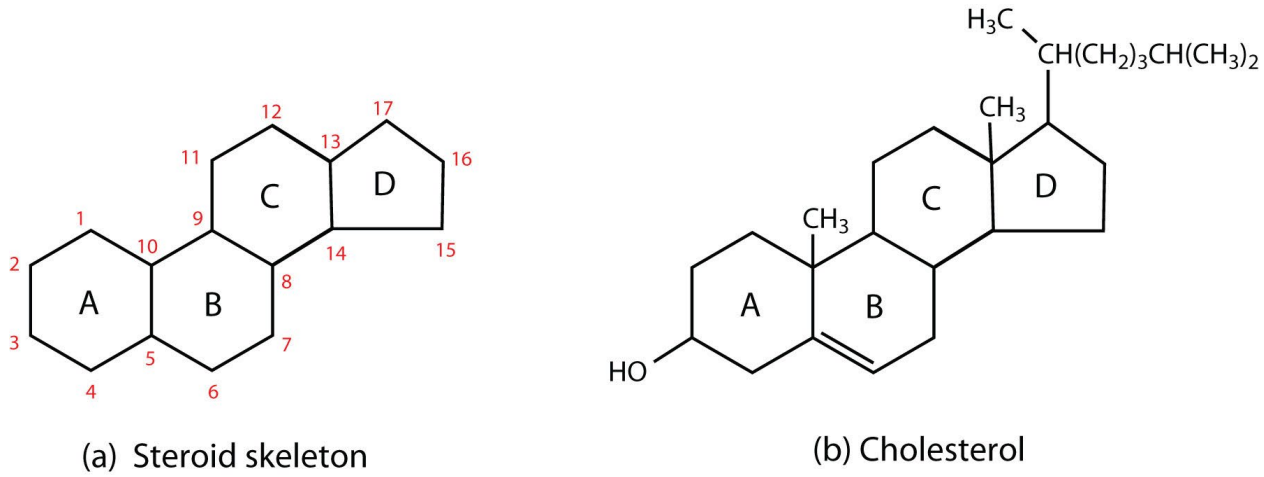


Figure 4.7: The steroid skeleton and the structure of cholesterol

Let us explore the important properties that define lipids

Properties of Lipids

Lipids exhibit several key characteristics that make them essential for biological functions:

1. **Physical States**: They can exist as either liquids or non-crystalline solids at room temperature—think of the difference between olive oil (or coconut oil) and butter!
2. **Sensory Characteristics:** Pure fats and oils are colourless, odourless, and tasteless, yet they pack a powerful energy punch.
3. **Energy Density:** These molecules are energy-rich, yielding more than twice the energy per gram compared to carbohydrates or proteins.
4. **Solubility:** While they are insoluble in water, lipids easily dissolve in organic solvents like alcohol and chloroform.
5. **Charge:** Lipids carry no ionic charge, which contributes to their unique behaviour in biological systems.
6. **Saturated Fats:** These fats, which are rich in saturated fatty acids, are found in foods like beef, cheese, and palm oil.

7. **Unsaturated Fats:** High in unsaturated fatty acids, these healthier fats are abundant in avocados, nuts, and fatty fish.

Finally, let us dive into the multifunctional roles of lipids that keep our bodies thriving.

Functions of Lipids

Lipids are not just energy reserves; they are integral to numerous biological processes:

1. **Energy Storage and Supply:** Triglycerides, stored in adipose tissue, serve as a ready source of energy when needed. Hormones signal fat cells to release these stored fats for energy production.
2. **Structural Framework of Cells**: Phospholipids and cholesterol maintain the structural integrity of cell membranes, allowing for selective permeability and cellular communication.
3. **Insulation and Protection**: Fat layers beneath the skin provide thermal insulation and cushion vital organs, protecting them from damage.
4. **Hormone and Vitamin Production:** Cholesterol is essential for synthesising steroid hormones and transporting fat-soluble vitamins (A, D, E, and K), crucial for various bodily functions.
5. **Cell Signalling and Communication**: Some lipids act as signalling molecules, helping the body respond to changes in the internal and external environment.
6. Immune System Support: Omega-3 and omega-6 fatty acids are involved in producing eicosanoids, which play a role in inflammation and immune responses.

Activity 4.1 Lipid Detective Summary

Objective: Recap the definition and significance of lipids.

Materials needed

1. Notebook or sheet of paper
2. Pen

Procedure

1. Get a notebook or some sheets of paper. Title the first page “Lipid Detective.”
2. Write a clear, simple definition of lipids in your own words, focusing on their unique properties.
3. Next, write down definitions for important terms related to lipids:
   a. Hydrophobic
   b. Amphiphilic
   c. Fatty acids
   d. Glycerol backbone
4. Create a bullet-point list of at least three key roles lipids play in the human body, such as energy storage.

5. Draw a simple structure of any lipid molecule.

Activity 4.2 Lipid Classification

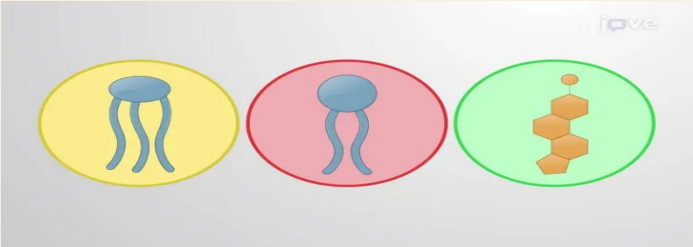
Objective: To classify different types of lipids and understand their characteristics.

Materials needed

1. Paper
2. Markers or pens

Procedure

1. Draw three columns on a sheet of paper and label them "Triglycerides," "Phospholipids," and "Steroids."
2. Research or recall key characteristics and examples of each lipid type.
3. Write the characteristics and examples in the appropriate columns.
4. Draw each structure in the correct column.



5. Note the structural differences between the types of lipids.
6. Present your findings to a family member or peer. Ask for feedback.

EXPLORATION OF CHOLESTEROL, ITS ROLES AND TRANSPORT IN THE BODY

Cholesterol

Cholesterol is a derived lipid molecule essential for various functions in the body. It is a type of fat molecule that is important for several functions in the body. It helps make essential substances like vitamin D, bile acids, and sex hormones (such as progesterone, testosterone, and oestrogen). Although your liver can produce cholesterol, you can also get it from the food you eat.

Roles of Cholesterol in the Body

1. Regulation of Membrane Fluidity: cholesterol helps keep cell membranes stable. At high temperatures, it makes membranes less fluid, preventing them from becoming too loose. At low temperatures, it stops membranes from getting too stiff, ensuring they remain flexible.

2. Integrity and Stability: it supports the overall strength and stability of cell membranes, helping them act as barriers that control what enters and exits the cell.
3. Precursor for Bile Acids: the liver converts cholesterol into bile acids, which are essential for digesting and absorbing dietary fats and fat-soluble vitamins (A, D, E, K). Bile acids help break down fats into smaller, more manageable pieces.
4. Precursor for Vitamin D Absorption: cholesterol is involved in making vitamin D when your skin is exposed to sunlight. This vitamin is crucial for absorbing calcium, which is necessary for strong bones and a healthy immune system.
5. Precursor for Steroid Hormones: cholesterol is the starting material for making steroid hormones, which are important for various body functions. For example,
   a. sex hormones such as oestrogen, testosterone and progesterone are key for reproduction and sexual characteristics. See ***Figure 4.3***.
   b. adrenocortical hormones like cortisol helps manage stress and metabolism while aldosterone controls blood pressure and fluid balance.

Transportation of Cholesterol

Cholesterol is hydrophobic so it does not mix with water, making its transport in the bloodstream challenging. To address this, the body packages cholesterol into *lipoproteins*, which are specialised protein-lipid complexes. These lipoproteins serve as transport vehicles, carrying cholesterol and other fats, such as triglycerides. Without lipoproteins, cholesterol would remain un-transported in the blood. Additionally, lipoproteins have a spherical structure that enhances their effectiveness in lipid transport.

Lipoprotein Structure

1. Hydrophobic Core: Contains fats, including cholesterol and triglycerides.
2. Hydrophilic Outer Shell: Made up of water-friendly components like phospholipids and proteins (apolipoproteins) that help stabilize the lipoproteins and signal to cells.

This structure allows lipoproteins to transport cholesterol and other fats throughout the body. (Scan **QR code 1** to watch a video on cholesterol transport or surf online for videos).

Types of Lipoproteins

1. **Low-Density Lipoproteins (LDL)**

   Carry cholesterol from the liver to cells. Known as “bad cholesterol,” high levels of LDL can lead to plaque buildup in arteries, increasing the risk of heart disease. About 70% of cholesterol in the blood comes from LDL.

2. **High-Density Lipoproteins (HDL)**

   Pick up excess cholesterol from tissues and return it to the liver for removal. HDL is referred to as "good cholesterol" because higher levels are linked to a lower risk of heart disease. It helps reduce plaque buildup.

3. **Very Low-Density Lipoproteins (VLDL)**

   Made by the liver, VLDL transports triglycerides to tissues for energy or storage. Like LDL, high levels of VLDL can also contribute to plaque buildup, raising the risk of heart disease and stroke.

The Role and Transportation of Triglycerides in the Body

Triglycerides are energy-rich fats that are transported in the body by lipoproteins. They cannot move freely in the bloodstream, so they rely on lipoproteins for transport. The primary lipoprotein involved in this process is very low-density lipoprotein (VLDL), which carries triglycerides from the liver to various tissues.

Triglycerides are the body's most efficient form of energy storage. They are stored in adipose (fat) tissue and can be broken down when energy is needed. During times of fasting, exercise, or when food intake is low, hormones signal fat cells to release fatty acids from triglycerides. These fatty acids are then used by cells to produce ATP (adenosine triphosphate), the energy currency of the cell.

Triglycerides provide more than double the energy per gram compared to carbohydrates or proteins, making them a vital energy reserve. Aside energy storage, triglycerides help maintain body temperature and protect vital organs. The fat stored under the skin acts as insulation, reducing heat loss, while the fat surrounding internal organs cushions them from shocks.

Therefore, the transport of triglycerides by lipoproteins is essential not only for energy distribution but also for physical protection and temperature regulation in the body.

Activity 4.3 Cholesterol & Triglycerides - Teach & Share!

Objective: Understand the roles of cholesterol and triglycerides in the body and how they are transported.

Materials needed

1. Notebook and pen/pencil
2. (Option 1 - Online) Smartphone or camera for recording, social media account
3. (Option 2 - Offline) Family member or friend

Procedure

1. Read (or listen to information) about cholesterol, triglycerides, and lipoproteins (LDL, HDL, VLDL) in a textbook or other resource. Focus on their roles and how LDL, HDL, and VLDL transport them.
2. Select your sharing method
   a. (Option 1 - Online: Skit/Video) Create a short skit or video explaining cholesterol and triglycerides.
   b. (Option 2 - Offline: Teach a friend) Prepare a short lesson to teach a family member or friend about cholesterol and triglycerides.
3. Create & Share (Online) / Teach (Offline)
   a. (Online) Record your skit/video. Share it on social media to educate others. Use relevant hashtags (e.g., #cholesterol, #triglycerides, #healthyeating).
   b. (Offline) Teach your family member or friend what you've learned. Answer their questions.
4. In your notebook, write a few sentences about what you learned from teaching others (online or offline). What was easy to explain? What was challenging?

Activity 4.4 Cholesterol Reflection

Objective: Reflect on your understanding of cholesterol.

Materials needed

1. Pen
2. notebook

Procedure

1. Take a moment to think about cholesterol. Reflect on the following points in your mind or jot them down.
   a. What cholesterol is.
   b. Name two types of cholesterol and their roles.
   c. Which cholesterol type is considered to be "good"? Explain why
   d. Describe actions you can take to lower LDL levels.
2. Considering what you have learned about cholesterol, prepare a write-up on HDL and LDL, focusing on their differences and functions.
3. Present your write-up to your peers or family for comments.

THE CONNECTION BETWEEN LIPOPROTEIN LEVELS AND HEART DISEASE RISK

The Role of LDL in Heart Disease Risk

LDL (low-density lipoprotein) is primarily responsible for transporting cholesterol from the liver to various tissues in the body. It can lead to plaque accumulation in blood vessels, increasing the risk of coronary artery disease, heart attacks, and strokes. Once inside cells, LDL particles are broken down, releasing cholesterol for cellular use. The LDL receptors then return to the cell surface to collect more cholesterol.

When LDL levels are high, or when LDL receptors are dysfunctional—due to genetics or lifestyle—excess LDL can accumulate. This excess LDL may oxidize and contribute to fatty plaque formation within arterial walls, thereby narrowing arteries and reducing blood flow. This condition, known as atherosclerosis, can significantly increase the risk of heart attacks and strokes. (Scan **QR Code 2** for an illustration).

The Role of HDL in Heart Disease

HDL (high-density lipoprotein) plays a crucial role in reverse cholesterol transport (RCT). This process involves collecting excess cholesterol from tissues and arteries and transporting it back to the liver for excretion or reuse. An enzyme associated with HDL converts free cholesterol into hydrophobic esters, which move into the core of the HDL particle, causing it to mature.

Mature HDL particles then return cholesterol to the liver, where it can be converted into bile acids and eventually excreted from the body (Scan **QR Code 3** for video illustration).

High levels of HDL are beneficial because they indicate the efficient removal of excess cholesterol, including that from arterial plaques, which reduces the risk of atherosclerosis.

How LDL and HDL Levels Contribute to Atherosclerosis

The balance between HDL and LDL levels in the blood significantly influences heart disease risk. While both lipoproteins transport cholesterol, they have opposite effects on cardiovascular health. A high LDL level coupled with a low HDL level leads to cholesterol accumulation in arteries, with minimal removal. This imbalance accelerates plaque formation and increases inflammation in arterial walls, raising cardiovascular disease risk.

Even seemingly healthy individuals can experience silent plaque buildup, which may go unnoticed for years before resulting in serious health events. Hence, the need to know your cholesterol levels. This can be done through a test called a lipid profile. See ***Figure 4.8*** for cholesterol ranges for adults, termed as the lipid profile. A **lipid profile** is a blood test that checks the levels of different types of fats in your blood. They are called lipids, and they help the body in many ways, but too much of some types can be harmful.

The Lipid Profile Test Measures Four Main Things

1. Total Cholesterol: This is the overall amount of cholesterol (fat) in your blood. Your body needs some, but too much can block blood vessels.
2. LDL: This is called "bad cholesterol." It can build up in blood vessels and cause heart problems.
3. HDL: This is known as "good cholesterol." It helps remove extra fat from your blood and protects your heart.
4. Triglycerides: These are another kind of fat from the food you eat. Too much can also increase your risk of heart disease.

Imagine your arteries as a busy highway

1. ***LDL*** *acts like a flood of heavy trucks loaded with cholesterol, which can clog lanes and deposit excess cholesterol on artery walls. This accumulation forms sticky plaques, narrowing the arteries and making it harder for blood to flow freely. (See walls* ***Figure 4.9****).*
2. ***HDL****, on the other hand, functions like a dedicated maintenance crew, constantly patrolling to clean up cholesterol debris and transport it away to the liver for disposal.*

When HDL levels are low, there are not enough cleanup crews to handle the debris caused by excess LDL traffic. This dangerous scenario—too many LDL trucks spilling cargo and too few HDL vehicles cleaning up—triggers inflammation and narrows arterial passages. If plaques rupture, they can cause blood clots that block arteries, leading to heart attacks or strokes. Thus, high LDL levels contribute to congestion while low HDL levels fail to clear it, creating conditions for dangerous plaque buildup.

Total Cholesterol Level	Risk
Less than **200mg/dL**	Desirable
200-239 mg/dL	Borderline High
240mg/dL and above	High

LDL (Bad) Cholesterol Level	Risk
Less than **100mg/dL**	Ideal
100-129mg/dL	Near ideal/above ideal
130-159 mg/dL	Borderline High
160-189 mg/dL	High
190 mg/dL and above	Very High

HDL (Good) Cholesterol Level	Risk
Less than **40 mg/dL**	High risk for heart disease
40—59 mg/dL	Good
60 mg/dL and higher	Preventive against heart disease

Figure 4.8: Cholesterol ranges (mg/dL) for Adult Lipid Profile

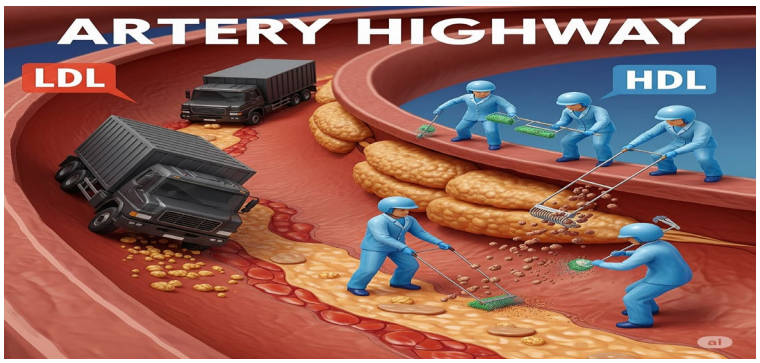


Figure 4.9: Cholesterol Transport; LDL and HDL Dynamics

Activity 4.5 Understanding Cholesterol Levels

Objective: Learn how LDL and HDL cholesterol levels affect heart health and understand the importance of maintaining healthy levels.

Materials needed

1. Notebook and pen/pencil
2. Health booklet or textbook (if available)
3. Paper for notes

Procedure

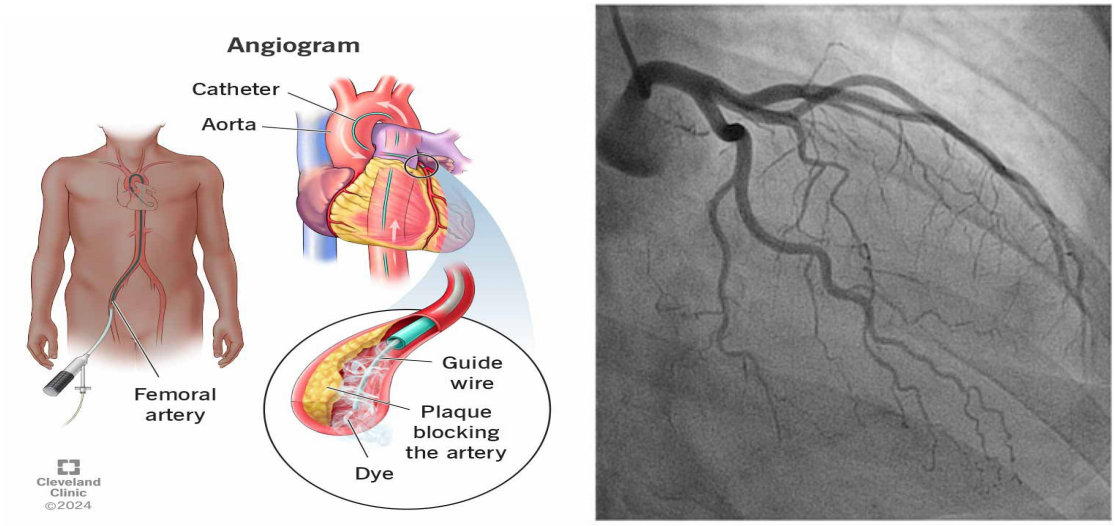
1. Reflect on what you know about LDL (bad cholesterol) and HDL (good cholesterol). Consider the following key points:
   a. The role you think LDL and HDL play in heart health.
   b. How they might affect the risk of heart disease and stroke.
2. If you have access to a health resource, the internet or a textbook, read about how LDL and HDL are measured and their normal levels.
   a. Take notes on key points you find important.
   b. Write down why it is important to keep LDL low and HDL high.
3. List three specific actions you can take to manage your cholesterol levels; for example, limit sugary snacks and fried foods.
4. Share what you have learned as well as your goals with a family member or friend. Ask for their support.

ANGIOGRAMS AND HEART DISEASE RISK FACTORS

Angiograms as a Diagnostic Tool for Visualising Blood Vessels

A coronary angiogram (AN-jee-o-gram) is a procedure that uses X-ray imaging and a dye to study the heart and blood vessels, especially arteries and veins. It is an important tool for finding blockages or narrow spots in blood vessels, particularly those that supply the heart, brain, or arms and legs. During an angiogram, a special dye is injected into your blood through a thin tube called a catheter. This dye helps to make the blood vessels visible on X-ray images, allowing biomedical scientists to see areas where blood flow might be blocked or reduced due to plaque buildup or blood clots.

Angiograms are commonly used to diagnose problems like coronary artery disease, strokes, and peripheral artery disease. The information from an angiogram helps doctors decide on the best treatments, which could include lifestyle changes, medication, or surgeries like angioplasty or bypass surgery. Angiograms are considered one of the most accurate ways to see inside arteries, especially when diagnosing heart diseases.



(a) (b)

Figure 4.10: Angiogram showing plaque in an artery (a). The image (b)shows an angiogram of the heart's blood vessels, focusing on the coronary arteries in black and white. The dark spot in the angiogram (b) represents an area of reduced blood flow or a blockage in one of the coronary arteries.

How the Procedure is Done

1. *Preparation day: The patient will be admitted to the hospital the day before the angiogram. It is important to refrain from eating or drinking anything for about 6 hours before the procedure.*
2. *Inserting the Catheter: A thin tube, known as a catheter, is inserted into a blood vessel, usually at the groin or wrist.*
3. *Guided by X-ray: Cardiologists use real-time X-ray imaging to carefully manoeuvre the catheter up to the arteries that supply blood to your heart.*
4. *Dye Injection: A special dye is then injected through the catheter. This dye makes your blood vessels visible on the X-ray images.*
5. *Capturing Images: X-ray images (angiograms) are taken to show the dye flowing through the blood vessels. This helps the doctors identify any blockages, narrow areas, or unusual shapes.*
6. *Identifying Issues: Any problems, such as plaque buildup or narrowing, will show up as areas where the dye flow is reduced or absent.*
7. *Assessing Blockages: Cardiologists can measure how narrow any blocked arteries are to understand the severity of the issue.*

The Role of Angiograms In Diagnosing Heart Diseases Includes The Following

1. Gold Standard Test: They are the most reliable method for diagnosing coronary artery disease (CAD), which involves plaque buildup in the heart's arteries.
2. Visualising Blockages: angiograms provide clear images of where blockages are located, their severity, and how many exist.

3. Confirming Symptoms: If a patient experiences symptoms like chest pain or has abnormal test results, angiograms help confirm whether CAD is present.
4. Mapping the Arteries: They offer a complete view of the coronary artery system, pinpointing the exact locations and severity of any problems.
5. Planning Treatment Approaches: 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. Diagnosing Other Heart Issues: Angiograms can also identify causes of heart attacks and other heart-related complications.

Some Risk Factors Associated with Heart Disease

Heart disease is influenced by a range of risk factors, many of which can be managed or changed. Here is a deeper look at these factors and how they can be reduced.

1. **High Blood Pressure (Hypertension)**
   a. Occurs when the force of blood against the artery walls is consistently too high. This condition often has no symptoms, which is why it is called the "silent killer."
   b. Impact: Over time, hypertension can damage the arteries, making them stiff and narrow. This increases the risk of plaque buildup (atherosclerosis) and can lead to heart attacks or strokes.

   Management: Regular monitoring, a balanced diet low in sodium, maintaining a healthy weight, and physical activity can help control blood pressure.

2. **Family History**
   a. Genetic factors: a strong family history of heart disease means that close relatives like parents or siblings have experienced heart-related issues at a young age.
   b. Increased risk: if heart problems occurred before age 55 for men or 65 for women in your family, your risk may be higher due to shared genetic traits.

   Awareness: Knowing your family history encourages proactive health management, including lifestyle changes and regular check-ups.

3. **Unhealthy Diet**
   a. Saturated Fats: found in red meat, full-fat dairy, and processed foods, these fats can raise "bad" LDL cholesterol levels, promoting plaque formation.
   b. Excess Sodium: High salt intake can elevate blood pressure and lead to fluid retention, increasing the workload on the heart.
   c. Added Sugars: Consuming too much sugar can result in weight gain and higher triglyceride levels, both of which raise heart disease risk.

   Health Choices: a diet rich in fruits, vegetables, whole grains, lean proteins, and healthy fats (like those found in fish and nuts) supports heart health.

4. **Sedentary Lifestyle**

   A sedentary lifestyle is characterised by insufficient physical activity, often due to prolonged sitting or inactivity. Risks Associated with Inactivity:

   a. Obesity: lack of exercise can lead to significant weight gain, which is a key risk factor for heart disease.
   b. Cholesterol Levels: Physical activity helps raise HDL (good) cholesterol while lowering LDL (bad) cholesterol and triglycerides.
   c. Insulin Sensitivity: Regular exercise improves the body's ability to use insulin, reducing the risk of type 2 diabetes.

   Recommendations: Aim for at least 150 minutes of moderate-intensity exercise per week, such as walking, swimming, or cycling.

5. **Smoking (Tobacco Use)**

   Smoking introduces harmful chemicals into the bloodstream that damage blood vessels and contribute to plaque buildup.

   a. Risks: smoking lowers HDL cholesterol, increases blood pressure, and makes blood more likely to clot, all of which elevate the risk of heart disease.
   b. Second-hand Smoke: even being around smokers can increase your risk of heart disease.

   Quitting: stopping smoking significantly reduces the risk of heart disease and improves overall health.

6. **Diabetes and Insulin Resistance**

   a. Link to Heart Disease: diabetes can damage blood vessels and nerves that control the heart. Having diabetes increases the risk of heart disease significantly.
   b. Insulin Resistance: This condition occurs when the body doesn't use insulin effectively, often leading to type 2 diabetes and higher blood sugar levels, which can further damage blood vessels.

   Control Measures: maintaining a healthy diet, regular exercise, and monitoring blood sugar levels are crucial for prevention.

Understanding these risk factors is crucial for making informed choices about heart health. By adopting a healthy lifestyle and working with healthcare professionals, individuals can significantly reduce their risk of heart disease and improve their overall well-being.

Activity 4.6 Investigating Heart Health and Cholesterol

Objective: Identify blocked blood vessels using sample angiogram images and understand the risk factors for heart disease, including lifestyle, genetics, and lipid imbalances.

Materials needed

1. Sample angiogram images (printed or available in a health booklet)
2. Notebook and pen/pencil
3. Chart paper or a blank sheet for notes

Procedure

1. Review what an angiogram is and its role in identifying blocked blood vessels.
2. Study a sample angiogram image and do the following.
   a. Note any visible blockages and consider what they might indicate about heart health.
   b. Identify any areas that look blocked and think about how this could relate to heart disease.
3. Write down the common risk factors for heart disease, such as smoking. Give a brief explanation of why you think each increases the risk of heart disease. Consider questions like:
   a. "How does high LDL cholesterol contribute to blocked arteries?"
   b. "Why is a sedentary lifestyle a risk factor?"
4. Reflect on how genetics and lifestyle choices interact to influence heart health. Write down your thoughts on:
   a. how someone with a family history of heart disease still lead a heart-healthy life?
   b. one risk factor you can control and an action you can take to improve your heart health.
5. Educate someone on what you learned about heart health and cholesterol. Consider how they can apply this knowledge to their lifestyle.

Activity 4.7 How Diseases Affect the Body System

Objective: Learn how different diseases affect different body systems, understand the role of cholesterol in heart health, and recognise symptoms of bacterial and viral infections

Materials needed

1. 1 sheet of A4 paper
2. 1 pen or pencil
3. 1 printed match-up chart (or write it by hand—see below)

Procedure

1. On a paper, create a 3-column chart titled.

Body System	Disease/Disorder	Clue or Symptom
Nervous		Shaking hands, memory loss
Endocrine		Weight loss, bulging eyes
Immune		Fever, swollen glands

Cardiovascular		High LDL, blocked vessels
Reproductive		Painful urination, discharge
Digestive		Vomiting, diarrhoea

2. On a second sheet (or back of the first), list these disorders/diseases randomly:
   a. Diabetes
   b. HIV
   c. Stroke
   d. Gonorrhoea
   e. Hyperthyroidism
   f. Heart disease
   g. Food poisoning
3. Read the clues in the third column of the chart.
4. Match each disease from the list to the correct body system and clue.
5. After matching, draw a simple heart or star emoji next to any disease you think is affected by cholesterol levels (e.g., heart disease).
6. Put a "V" for viral and a "B" for bacterial infection next to diseases like HIV, Gonorrhoea, and Food Poisoning.
7. Reflect on how cholesterol (HDL and LDL) plays a role in cardiovascular health
   a. Distinguish between viral and bacterial infections
   b. Explain why early diagnosis based on symptoms is important

EXTENDED READING

QR Code 1 Cholesterol transport

QR Code 2 LDL and HDL

QR Code 3 Reverse cholesterol transport

REVIEW QUESTIONS 4

Multiple Choice Questions

Instructions: Read or listen to each scenario or prompt carefully. Choose the best answer.

1. During coronary angiography, a contrast dye is injected into the bloodstream. What is the primary function of this dye?

A. It dissolves cholesterol deposits in blood vessels, as shown on X-ray
B. It enhances the visibility of blood vessels under X-ray imaging
C. It restores blood pressure by widening blood vessels during an X-ray
D. It stimulates muscular activity in blood vessels to assist in X-ray

2. Fatima replaces fried meats with salmon, avocado, and oats. How might her cholesterol levels respond?

A. LDL may decrease, and HDL may increase
B. LDL may rise while HDL drops gradually over time
C. No changes may occur in lipid concentration levels
D. Triglycerides may rise while fat digestion slows down

3. A student with a family history of heart disease can lower their risk by changing their lifestyle. These include

A. depending solely on energy drinks for a nutrition boost.
B. eating more red meat and butter-based meals for protein.
C. limiting saturated fat and increasing fibre intake.
D. not exercising to reduce heart strain from exertion.

4. When plaque inside an artery ruptures, the most likely result is

A. a clot forms and may block the vessel entirely.
B. artery expands and flushes out plaque to other tissues.
C. heart slows to prevent high pressure and oxygen loss.
D. red blood cells transport more nutrients to tissues.

5. HDL is often called “good cholesterol” for this reason, it

A. breaks down complex proteins in the liver cells.
B. carries large fats to the stomach wall for absorption.
C. raises sugar levels in the blood rapidly after meals.
D. removes cholesterol from arteries efficiently.

6. In a classroom test, cholesterol does not dissolve in water. How does this explain cholesterol transport in blood?

A. Cholesterol binds with glucose for delivery across tissues
B. Cholesterol is hydrophobic and needs transport help
C. Lipoproteins assist in hormone secretion during digestion
D. Lipoproteins transport small water molecules for balance

7. VLDL differs from LDL and HDL by transporting which substance in the blood?

A. Bile salts involved in fat breakdown and emulsification
B. Cholesterol molecules to the kidneys for excretion
C. Oxygen from lungs to the tissues and organs
D. Triglycerides from liver to tissues for storage

8. A meal high in saturated fats poses the greatest danger because it

A. Increases LDL levels and promotes plaque buildup
B. Prevents protein digestion in the stomach lining
C. Slows blood circulation in major arteries temporarily
D. Stimulates sugar absorption in the liver for energy

9. Someone with high LDL and low HDL wants to reduce heart disease risk. Which strategy would be **most** effective?

A. Avoid drinking water and walk less frequently outdoors
B. Exercise regularly and eat unsaturated fats daily
C. Replace fish with fried meats in every weekly meal plan
D. Skip breakfast and reduce total food intake per day

10. Phospholipids form part of the cell membrane because they

A. allow water to pass directly through the cell membrane.
B. bond tightly to blood proteins and form stable rings.
C. contain both water-loving and water-fearing ends.
D. regulate calcium movement between tissues and blood.

11. A student compares the structure of triglycerides and phospholipids. How can the structure of phospholipids explain their function in membranes?

A. Carry nitrogen across fluid compartments in cells
B. Contain only long chains of sugars and water
C. Lack flexible molecules for lipid interactions
D. They contain polar heads and nonpolar tails

12. HDL and LDL influence heart health. Their interaction affects cholesterol as

A. both balance oxygen levels across blood vessels in the body
B. HDL stores fats while LDL extracts them from tissues
C. LDL adds cholesterol to arteries, HDL removes it
D. they regulate sugar breakdown in liver cells during fasting

13. Kwame receives a blood test showing LDL = 180 mg/dL and HDL = 35 mg/dL. Without any lifestyle changes, this profile is **most** likely to

A. lead to arterial plaque buildup and eventual heart disease.
B. maintain normal blood flow even with partial artery obstruction.
C. prevent fat buildup and reduce chance of cardiovascular disease.
D. stop glucose production despite elevated risk of coronary blockage.

14. An angiogram shows a partially blocked artery. Which process **most** likely explains this?

A. Absorption of dietary calcium in small intestines
B. Breakage of red blood cells in heart vessels
C. Expansion of heart valves under pressure
D. LDL cholesterol accumulation forming plaque

15. LDL and HDL transport cholesterol in different ways. Their roles can be summarised as

A. Both digest fats inside muscle and brain tissues effectively
B. HDL transports triglycerides, LDL carries proteins away
C. LDL moves cholesterol to cells; HDL returns it to the liver
D. LDL stores fat in the liver, HDL moves glucose to cells

Short Answer Questions

1. A 17-year-old SHS 3 student goes for a health screening. Her results show high LDL and low HDL levels. Explain how this combination increases her risk of heart disease.
2. Describe how the structure of a phospholipid enables it to form the bilayer of a cell membrane.
3. A nutritionist advises a teenager in Ghana to reduce fried food consumption and increase exercise. Explain how this advice helps improve cholesterol levels in the body.
4. After reviewing an angiogram, a biomedical scientist notes multiple narrowed arteries. Explain how such narrowing affects oxygen delivery to the heart and how this could lead to a heart attack.
5. Analyse why lipids are considered more efficient long-term energy stores than carbohydrates.

Essay Type Questions

6. Analyse the table carefully and answer the questions that follow.

Table: Comparison of Lipid Types

Lipid Type	Structure	Function	Source
Triglycerides	Glycerol + 3 Fatty Acids	Energy Storage	Butter, Palm Oil
Phospholipids	Glycerol + 2 Fatty Acids + Phosphate	Cell Membrane Structure	Body-made, Egg Yolk
Steroids	4 Carbon Rings	Hormone Production	Cholesterol, Steroid Hormones

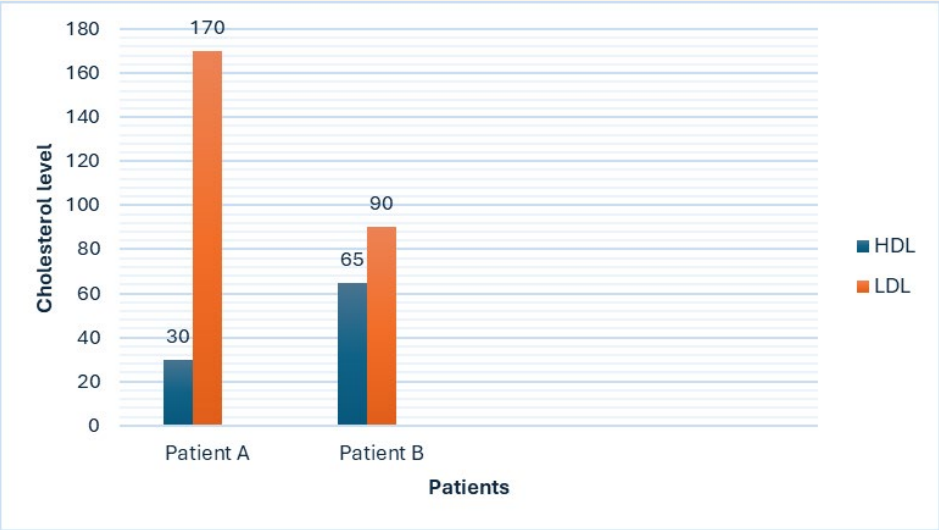
Questions

a. Construct a Venn diagram comparing triglycerides and phospholipids in terms of structure and function.

b. A teenage boy eats mostly fried chicken and margarine with little fish or vegetables. Which type of lipid is he overconsuming, and what long-term health effect might this cause?

c. Based on the chart, design a one-day Ghanaian meal plan that includes all three lipid types in healthy proportions.

7. Study the bar chart below carefully. It shows the cholesterol levels of two patients — Patient A and Patient B. The chart compares their levels of LDL (bad cholesterol) and HDL (good cholesterol). Use the information from the chart to answer the questions that follow.



a. If Patient A were to undergo a lifestyle intervention program including dietary changes and daily physical activity, what specific shifts in the HDL and LDL bars would indicate a reduced cardiovascular risk profile? Explain how these shifts reflect physiological improvement.

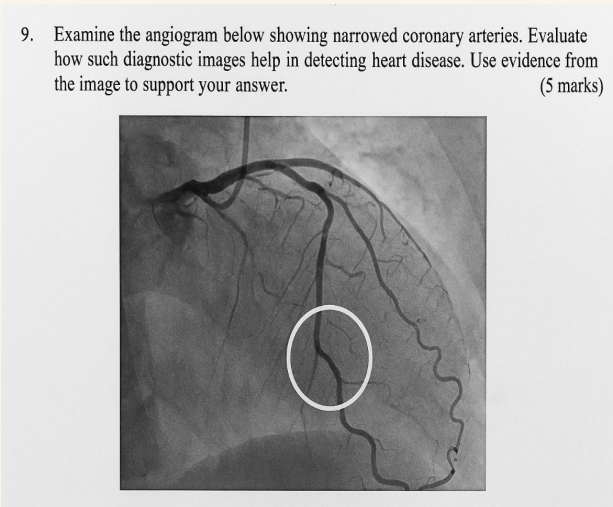
a. Suppose Patient B starts consuming a high-saturated-fat diet for 6 months. Predict how the HDL and LDL levels might change.

b. Recommend a personalised lifestyle plan for both patients using evidence from the graph. Support your plan with clinical reasoning, including how altering HDL and LDL levels directly impacts cardiovascular health.

8. Analyse how cholesterol is transported in the blood by HDL and LDL. What roles do each of these lipoproteins play in maintaining cardiovascular health?

9. Compare and contrast the different types of lipids found in the human body (e.g. triglycerides, phospholipids, sterols). How do their structures relate to their functions?

10. Examine the angiogram below showing narrowed coronary arteries. Evaluate how such diagnostic images help in detecting heart disease. Use evidence from the image to support your answer.


9. Examine the angiogram below showing narrowed coronary arteries. Evaluate how such diagnostic images help in detecting heart disease. Use evidence from the image to support your answer. (5 marks)

11. Evaluate how the concentrations of HDL and LDL influence the development and progression of heart disease. Support your response with scientific reasoning.

12. Case Study: Kwame, a 45-year-old man, has a family history of heart disease. His recent blood test shows high LDL (170 mg/dL) and low HDL (30 mg/dL).

a. Analyse the significance of Kwame's lipid profile and explain the health risks he may face.

b. Justify two specific lifestyle changes Kwame should adopt to improve his lipid profile and reduce his risk of heart disease. (2 marks)

13. Case Study: Fatima, a 50-year-old woman, has very high triglyceride levels of 200 mg/dL and normal HDL levels.

a. Discuss how high triglyceride levels can affect her cardiovascular health.

b. Suggest two dietary changes that could help her manage her triglyceride levels.

SECTION 5

MEDICAL DIAGNOSTIC & THERAPEUTIC DEVICES

BIOMEDICAL INTERVENTION

Diagnostic Devices

INTRODUCTION

Medical devices help people stay healthy and safe. Some are simple, like thermometers. Others are complex, like **insulin pumps**. These tools support doctors, nurses, and patients in caring for health. Each device must be planned, built, tested, and checked to make sure it works well and is safe to use. In this section, you will learn how medical devices are made and improved. You will explore design thinking, safe disassembly and reassembly, writing clear user instructions, getting approval from health agencies, and promoting devices through marketing.

In Year One, you studied local health problems, lab-acquired infections, and medical interventions. You also listed diagnostic tools, discussed how to fix them, and explored ways to solve health problems in Ghana. In Year Two, you explored careers in biomedical science, proper use of PPE, and how technology is used in healthcare. You also studied biosafety cabinets and how diagnostic devices work. These topics prepare you to understand medical devices better.

KEY IDEAS

- **Biomedical engineers** design and build machines that solve health problems. They work with doctors and scientists to make healthcare better.
- **Design thinking** helps create medical devices. It focuses on healthcare problems. It leads to safe, useful, and practical designs.
- **Disassembly and assembly** show how a device works inside. They help explain how parts fit and work together. This also teaches safety and careful handling.
- **Marketing** shows the value of a device. It explains the benefits, builds trust, and gets support. It links new ideas to healthcare needs.
- **Operating manuals** must be easy to read. They need clear steps, safety warnings, and labelled diagrams. This helps users operate devices safely.
- **Regulatory processes** protect users. Devices must be tested, approved, and checked regularly. The rules depend on how risky the device is.

THE ROLE OF BIOMEDICAL ENGINEERS IN BUILDING A HEALTHIER FUTURE

Biomedical Engineers

Who are Biomedical Engineers?

Biomedical engineers are problem solvers in the world of healthcare. They use science and engineering to create smart solutions that make life better for patients. From simple tools to high-technology machines, their inventions help doctors, nurses, and other health professionals do their jobs more safely and efficiently. Their work brings science and care together in powerful ways.

These engineers design devices that can do amazing things, such as help detect diseases, support surgeries, and speed up recovery. Whether it is a heart monitor, an artificial limb, or a scanning machine, biomedical engineers are behind the scenes making sure these tools work properly and are safe to use. Thanks to their work, hospitals can offer better treatment, faster results, and improved care for patients.

Biomedical engineers do not work alone. They often team up with biomedical scientists. These scientists understand how the human body functions, how illnesses affect it, and how treatments should work. By combining their knowledge, they design devices that are safe, reliable, and ready to be used every day in real hospital settings. This kind of teamwork helps save lives and makes healthcare smarter and more effective.

Biomedical engineers use science and engineering to solve problems in healthcare and improve the lives of patients. Their work helps make treatments safer, faster, and more effective. They apply their knowledge to design useful tools and machines that support doctors, nurses, and other healthcare professionals in their daily work.

These engineers create many different types of medical devices. Some help doctors find out what is wrong with a patient, while others help treat diseases or support recovery. Their designs can range from simple tools to complex machines used in hospitals and clinics. By developing and improving these devices, biomedical engineers play a key role in making healthcare better for everyone.

Biomedical engineers often work closely with biomedical scientists. These scientists understand how the body works, how diseases affect it, and how treatments should help. Together, they design medical devices that are safe, reliable, and useful for everyday use in hospitals and clinics. This teamwork helps doctors provide better care and can even save lives. Biomedical engineers help fix health problems. They use science and engineering to make life better for patients. They also create tools and machines that support doctors, nurses, and other healthcare workers.

Biomedical engineers design and build many kinds of medical devices. These help in finding diseases, treating health problems, and helping patients recover more quickly. Their work makes healthcare safer, faster, and more effective. For example, a biomedical engineer might create a machine that takes pictures inside the body, such as an ultrasound

or MRI scanner. They might also design a device that gives the right amount of medicine at the right time to help a patient heal safely.

Biomedical engineers often work closely with biomedical scientists. These scientists understand how the body works, how diseases affect it, and how treatments should help. Together, they design medical devices that are safe, reliable, and useful for everyday use in hospitals and clinics. This teamwork helps doctors provide better care and saves lives.

What Do Biomedical Engineers Do?

Biomedical engineers contribute to many exciting areas. Let us explore them one by one.

Bioinstrumentation

This area of biomedical engineering focuses on designing tools that can measure signals from the human body. These signals include heart rate, breathing, brain activity, and muscle movement. Biomedical engineers in bioinstrumentation create devices that collect these signals and turn them into useful information. Doctors and nurses can then use this information to check a patient's health and make quick decisions.

For example, a device can be made to watch a patient's heartbeat all the time. If the heartbeat becomes too fast, too slow, or stops, the device sends a warning signal to the medical team. This helps doctors act quickly and can save lives. (See ***Figure 5.1*** for an example of such a device.)

Figure 5.1: Device for recording heartbeats using electrodes to detect biological signals

Clinical Engineering

Clinical engineers are biomedical engineers who work in hospitals and clinics. Their main job is to make sure that all medical equipment is working properly, safely, and accurately. They help doctors and nurses by checking, fixing, and maintaining the machines used to care for patients. They also help choose the right equipment for the hospital and teach staff how to use it safely. Their work helps keep patients safe and supports better healthcare every day.

For example, a clinical engineer may check a blood test machine to make sure it gives accurate results. If the machine shows wrong numbers, it could lead to wrong treatment. That is why the work of clinical engineers is very important. (See ***Figure 5.2*** for an example of medical equipment checked by a clinical engineer.)

Figure 5.2: Medical equipment opened for maintenance and repair.

Biomechanics

This is the study of how the body moves and how its parts work together during movement. It looks at how bones, muscles, and joints help us walk, run, jump, lift, and do everyday tasks (see ***Figure 5.3***).

Biomedical engineers in this area study how the human body moves. They measure body movements, test how much force joints and muscles can handle, and look at how people move in different situations. This helps them learn what normal movement looks like and how to spot problems. They also help doctors and therapists understand movement issues, such as walking problems after an injury or changes in movement caused by disease. Their work helps improve physical therapy, injury prevention, and movement support.

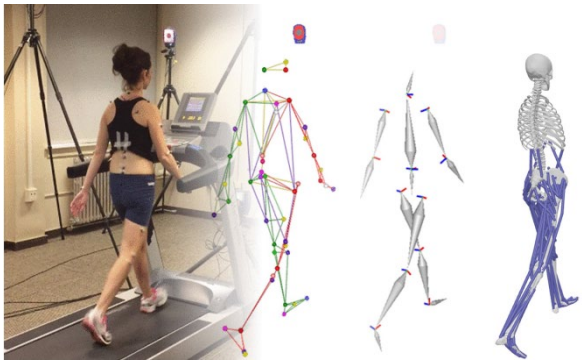


Figure 5.3: Studying body movements.

Medical Imaging

Medical Imaging uses special machines to take pictures of the inside of the body. These pictures help doctors see bones, organs, and tissues without doing surgery (see ***Figure 5.4***). Common machines include X-rays, CT scanners, and MRI scanners. Biomedical engineers play an important role in this area. They help design, improve, and maintain medical imaging machines. They also work to make the images clearer and more detailed, so doctors can see problems more easily.

For example, a biomedical engineer might improve an MRI machine so it shows better images of a tumour. This helps doctors find the exact location and size of the tumour and plan the right treatment.

Biomedical engineers also make sure the machines are safe to use and give the right amount of energy, so patients are not harmed. Their work helps doctors make fast and accurate decisions to care for patients.

Figure 5.4: Medical imaging devices.

Biomaterials and Tissue Engineering

This is the area of biomedical engineering that focuses on creating safe materials to be used inside the body. These materials can replace or support damaged body parts, such as skin, bones, or heart valves (see ***Figure 5.5***). Biomedical engineers play an important role in this area. They design and test materials that the body will accept without harm. These materials must be strong, safe, and able to work well inside the body for a long time.

For example, a biomedical engineer might create artificial skin to help patients with serious burns. This skin protects the wound and helps the body heal more quickly.

Figure 5.5: Biomaterials and Tissue Engineering Products.

Rehabilitation Engineering

This area of biomedical engineering focuses on helping people move again after an illness, injury, or disability (see ***Figure 5.6***). When a person loses the ability to walk, lift objects, or use a part of their body, they may need support to regain that movement. Biomedical engineers design special tools and machines that make daily life easier. These include walking aids, wheelchairs, artificial arms or legs, and devices that help people hear or see better.

Example: An engineer designs an artificial arm for someone who lost their arm. This new arm can open and close using sensors. It helps the person eat, write, and hold objects again. The goal is to help people live more independently and feel confident in what they can do.

Figure 5.6: Prosthetic limb to make movement easier.

Neural Engineering

Biomedical engineers in this area study how the brain and nerves work. They explore how signals travel from the brain to the rest of the body. This helps them understand how we move, feel, see, hear, and think (see ***Figure 5.7***). When the brain or nerves are damaged by illness or injury, people may lose some abilities, like moving their arms or speaking. Neural engineers create special systems and devices to help restore these functions.

Example: An engineer designs a robotic arm that moves when the user thinks about the action. Sensors pick up brain signals and send them to the robotic arm. This allows the person to control the arm with their mind.

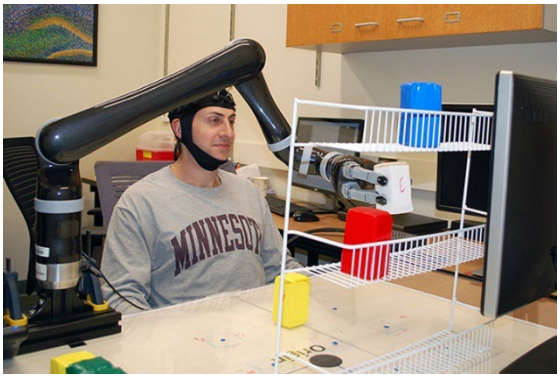


Figure 5.7: Controlling a robotic arm with thought.

Systems Physiology

Biomedical engineers use computers to build models of the human body. These models help show how different body parts and systems work together, such as how the heart, lungs, and blood vessels keep us alive (see ***Figure 5.8***). By using these models, engineers can study how the body reacts to illness, injury, or treatment. They do not need to test on real people at first. Instead, they can test ideas safely using the computer.

Example: An engineer creates a computer model of the heart. This model helps them see how heart disease affects blood flow. It also shows how a new treatment or medicine could improve the patient's condition.

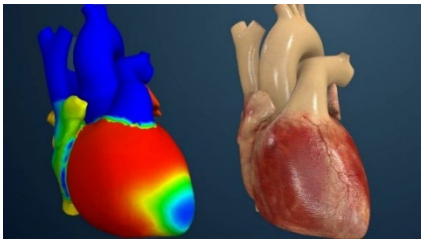


Figure 5.8: Computer model of the human heart.

Bioinformatics and Computational Biology

This area of biomedical engineering focuses on using computers to study information from living things, such as cells, genes, and proteins (see ***Figure 5.9***). This is called *bioinformatics*. Biomedical engineers in this field collect and study large amounts of data. They use this data to understand how the body works and how diseases affect it. They also look at how people may respond differently to the same medicine.

Example: An engineer studies a person's genetic information using a computer. This helps doctors choose the medicine that will work best for that person. It can also help avoid side effects.

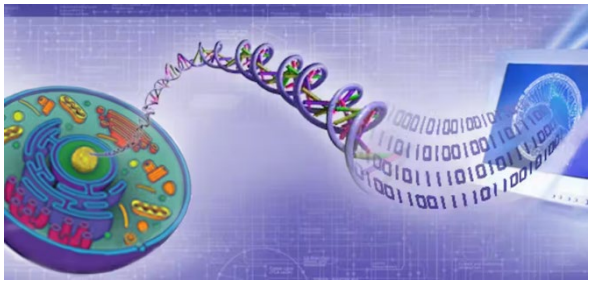


Figure 5.9: Studying a Person's Genetic Information.

Biomedical Engineers and the Medical Device Lifecycle

The journey of a medical device can be shown as a cycle (see ***Figure 5.10***), with each step playing an important role in making sure the device is safe, useful, and ready for hospital use. This cycle helps us understand how biomedical engineers are involved at every stage, from identifying a health problem to designing, testing, building, and maintaining the device once it is in use.

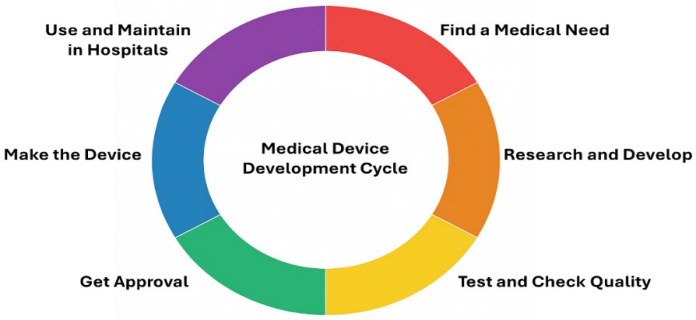


Figure 5.10: Medical Device Lifecycle

A detailed explanation of each stage in the medical device lifecycle is provided below.

1. **Identifying a Medical Need**

   Everything begins with a real-life problem. Biomedical engineers speak with doctors, nurses, and patients to learn about challenges in healthcare. They ask questions, observe how things are done, and listen carefully to understand what is missing. This helps them find out what kind of device could make care safer, easier, or faster. Once they understand the problem, they begin thinking of ways to solve it.

   Example: A hospital finds it hard to monitor patients closely during surgery. The existing tools are slow or not very clear. Biomedical engineers talk to the surgical team and decide to design a new device that gives quicker and more accurate information during surgery. This helps doctors make better decisions and keep the patient safe.

2. **Research and Development**

   After finding the problem, biomedical engineers begin to think of ways to solve it. This stage is called research and development.

   Engineers study the problem carefully and look for new materials that are safe for the human body. They also use computer software to design the shape and parts of the device. Sometimes, they build simple models or early versions, called prototypes, to test how the device works.

   Example: Engineers are asked to design a pacemaker. A pacemaker is a small device that helps the heart beat properly. First, the engineers study how the heart works. Then, they choose safe materials that will not harm the body. They use computer tools to plan the size and shape of the pacemaker. After that, they build a prototype of the pacemaker.

3. **Testing and Quality Checks**

   Before any medical device can be used by patients or healthcare workers, it must go through careful testing. Biomedical engineers are responsible for making sure the device is safe, reliable, and works the way it is supposed to. They test the device in many different situations to see how well it performs. For example, they check if it still works properly in hot or cold temperatures, under pressure, or in dusty or wet environments. They also test how long the device will last if it is used every day.

   During testing, biomedical engineers look closely for any problems or weak points. If something does not work well, they return to the design stage and make improvements. Then they test the device again. This cycle may happen many times until the device is strong, safe, and ready for real-life use. Biomedical engineers also make sure the device meets safety standards set by national and international health organisations. These standards help protect patients and ensure the device performs as expected in hospitals and clinics.

4. **Regulatory Approval**

   After testing and improving the device, biomedical engineers must make sure it meets the rules set by health authorities. This stage is called regulatory approval.

Regulatory affairs engineers are responsible for this part of the process. They carefully collect and organise all the information about the device, including how it was made, how it works, and all the safety and test results. This is called documentation. These documents must show that the device is safe for patients, works properly, and meets high-quality standards.

In Ghana, these engineers send the documents to national health agencies like the Food and Drugs Authority (FDA) or the Ghana Standards Authority (GSA). These agencies carefully check the documents and may ask questions or request more testing. The device can only be approved if it passes all the rules.

Without this approval, the medical device cannot be sold, used in hospitals, or given to patients. This step is very important because it protects people from unsafe or faulty devices. Biomedical engineers work hard to make sure everything is done correctly so that doctors and patients can trust the device.

5. **Manufacturing the Device**

   Once the medical device is approved by health authorities, it is ready to be made in large numbers. This step is called manufacturing. Biomedical engineers help plan how to build the device in a factory. They choose the right machines, tools, and materials to make sure the device is made safely and correctly every time. Biomedical engineers also make sure that the factory is clean and meets health and safety rules. For example, some devices must be made in special clean rooms with filtered air to prevent germs or dust from getting into the product. Biomedical engineers work closely with factory workers to train them and to solve any problems during production.

   Example: A factory needs to produce thousands of surgical masks each day. Biomedical engineers design a clean and organised production line where workers wear protective clothing. The surgical masks are made, checked for quality, and safely packed to protect both patients and healthcare workers.

6. **Using and Maintaining the Device in Hospitals**

   After a medical device is made and sent to the hospital, it needs to be set up correctly before it can be used. Clinical engineers are the ones who install the device and make sure it works well. They also teach doctors, nurses, and other hospital staff how to use the device safely. This is important because some medical machines are very advanced and must be used properly to help patients. Clinical engineers also check the device from time to time. They make sure it is clean, safe, and still working correctly. If the device breaks down or is not working right, they repair it as soon as possible.

   Example: A dialysis machine helps clean a patient's blood when their kidneys do not work well. A clinical engineer checks the machine every week to make sure it is safe and working properly. If something is wrong, they fix it quickly so that patients can keep getting the care they need.

Activity 5.1 Is the Medical Device Working Well?

Objective: Learn how biomedical engineers check if a medical device is safe to use.

Materials needed

1. A medical device (for example, a thermometer or weighing scale)
2. Paper
3. Pencil

Procedure

1. Choose a health device that you can safely see or touch.

   Precaution: Make sure the device is not plugged in or connected to electricity while you inspect it.

2. Look closely at the device.

   Precaution: Do not press any buttons unless a teacher or adult says it is safe. Handle it gently to avoid damage.

3. Think about what can make it stop working.

   For example: low battery, loose parts, or broken screen.

4. Write or sign three safety or function checks a biomedical engineer might do.

   For example: “Check if the screen turns on”, “Check if the buttons work”, or “Check for cracks or damage”.

5. Say or sign why each check matters. Explain how the check helps keep patients safe or makes sure the device gives correct results.
6. Share your findings with a classmate or teacher. You can show the device, explain your checks, or use signs or pictures to describe what you learned.

Activity 5.2 Imagining a New Health Device

Objective: To think like a biomedical engineer and design a new device to solve a health problem.

Materials needed

1. Drawing paper
2. Pencil
3. Crayons or coloured pencils (optional)

Procedure

1. Think of a health problem that some people may face.

Examples: Difficulty walking, hearing loss, weak eyesight, or trouble breathing. Precaution: Be respectful when talking or thinking about people with health problems. Focus on helping, not making fun.

2. Imagine a health device that could help solve the problem.

   Precaution: Make sure your idea is safe and helpful for people of all ages.

3. Draw your device on paper and label its parts.

   Precaution: Do not copy real devices exactly. Use your own ideas and think about safety and ease of use.

4. Say or sign what your device does and how it helps people.

   Example: "It helps people walk better," or "It gives medicine safely."

5. Share your idea with a classmate, teacher, or group. Explain how your device works and say which part of biomedical engineering it belongs to (like medical imaging, biomechanics, or biomaterials).

DESIGN THINKING FOR MEDICAL DEVICES

What is Design Thinking?

Design thinking is a way of solving problems that starts with people (see ***Figure 5.11***). It is called a *human-centred approach*. This means engineers begin by understanding what real people, such as patients, nurses, or doctors, need in their daily lives.

Instead of quickly building a machine, biomedical engineers observe, listen, and learn from people who use or are affected by medical devices.

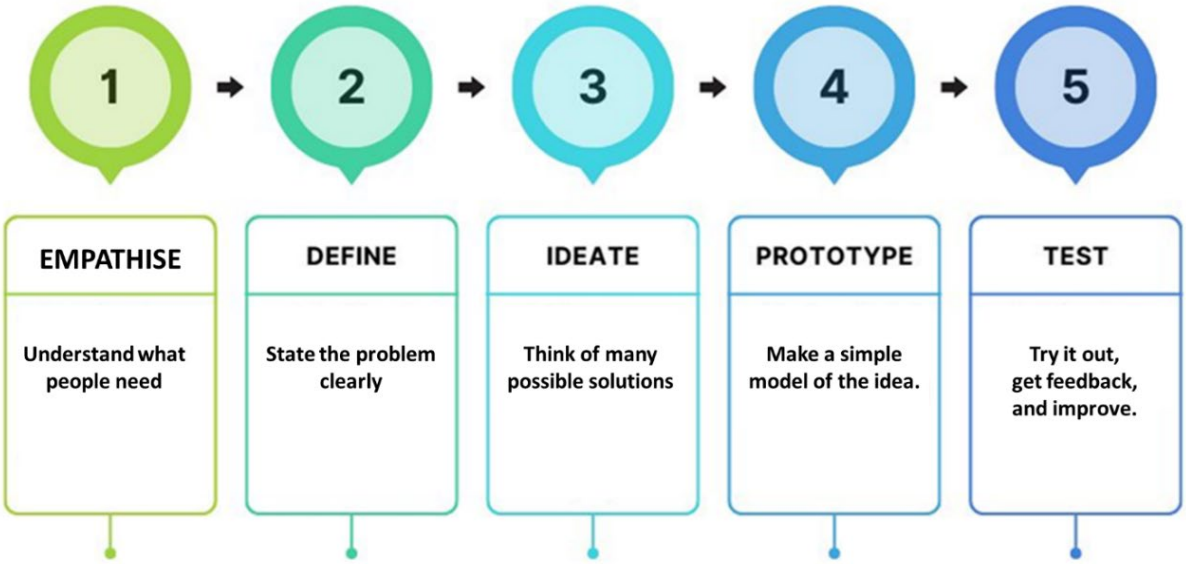


Figure 5.11: Design Thinking for Medical Devices

Why is it Important in Healthcare?

In biomedical engineering, design thinking helps to create tools that are safe, easy to use, and suitable for real use. For example, imagine building a walking frame. Instead of just focusing on technical features like the weight and dimensions of the walking frame, engineers first study how older people use walking aids. They ask questions like:

1. Is it too heavy?
2. Is it difficult to fold?
3. Is it strong?

This helps make sure the final product works well in real life.

The Five Steps of Design Thinking

Let us explore the five simple but powerful steps in design thinking (see ***Figure 5.11***) using a walking aid as an example.

1. **Empathise**

   This means to understand the people who face the problem. Engineers go out to meet them, watch what they do, and listen to their experiences.

   Example: Engineers visit a hospital and watch how older patients use walking frames. They hear people say things like, "This is too heavy," or "I cannot lift it over the step." This step helps engineers understand real life problems from the user's point of view.

2. **Define**

   After learning from the users, the engineers write down a clear problem they want to solve.

   Example: From the hospital visit, they write this: "Older patients struggle to use standard walking frames because they are too heavy and hard to move."

   This step keeps the team focused on the right problem.

3. **Ideate**

   Now it is time to think of different ideas. The team meets and shares many possible solutions. No idea is too strange at this point. Example: Some of their ideas may include:

   a. a walking frame that can fold
   b. a frame made from light plastic
   c. a frame with wheels that can be locked

   This stage allows for creativity and fresh thinking.

4. **Prototype**

   Next, engineers choose the most useful idea and build a simple model of it. This is called a prototype. It is a basic version that helps test the idea.

   Example: They create a walking frame using plastic pipes, foam, and tape. It is not perfect, but it gives users something to try.

   This step allows users to try it and give feedback.

5. **Test**

   The last step is to let real users try the model. Their opinions and feedback help improve it.

   Example: A patient tries the new frame and says, "It is light and easy to carry, but I cannot fold it when I travel." The engineers use this comment to make changes and improve the folding part.

   This step may be repeated until the final version is ready.

Activity 5.3 My Device Sketch Plan

Objective: To design a simple diagnostic medical device idea on paper.

Materials needed

1. Drawing paper
2. Pencil or pen
3. Ruler
4. Eraser

Procedure

1. Choose one health problem. Example: checking temperature or heart rate.
2. Draw a simple design of a medical device that can help solve the health problem.
3. Label each part of the device.
4. Explain what each part does.
5. Write a short explanation of how the device works.
6. Show your drawing and explanation to your teacher or a classmate.

Activity 5.4 Mini Prototype with Paper

Objective: To create a basic model of a health device using simple materials.

Materials needed

1. Paper or cardboard
2. Scissors
3. Glue or tape
4. Markers or pens

Procedure

1. Choose one medical device to make a model. Example: a thermometer.
2. Cut paper or cardboard into parts.
3. Shape the parts as needed.

4. Use glue or tape to join the parts.
5. Draw buttons, screens, or labels.
6. Show your model to others.
7. Explain how it works with words or sign language.

Activity 5.5 Take it Apart, Learn its Heart

Objective: To explore how a basic biomedical device is built and how its parts work.

Materials Needed

1. One used or non-working diagnostic device (e.g., digital thermometer)
2. A clean table or flat surface
3. Notebook and pencil
4. A small screwdriver or flat plastic tool (e.g., the edge of a spoon)

Procedure

1. Place the device on a clean table.
2. Ask your teacher or an experienced person for guidance before opening.
3. If the device has screws, use a small screwdriver to open it.
4. If the device has no screws, use a flat plastic tool to lift the cover slowly.
5. Look carefully at the parts inside.
6. Draw the inside of the device in your notebook.
7. Label at least two parts in your drawing.
8. Say or sign what each part might do.
9. Put all parts back in the correct place.
10. Close the device.
11. Say or sign one thing you learned about the device.

MARKETING FOR MEDICAL DEVICES

Medical Device Marketing

What is medical device marketing?

Marketing is not just about selling a product. In biomedical engineering, marketing plays a much bigger role. It helps show how a medical device can solve real health problems. It acts as a bridge between innovation and the real world, connecting ideas from the lab with the needs of patients, nurses, doctors, and hospitals (see ***Figure 5.12***).

Marketing helps explain how a device works, who it helps, and why it matters. It also helps secure funding to make the device a reality. Investors are more likely to support a new medical device if they understand its value. That is exactly what good marketing shows.

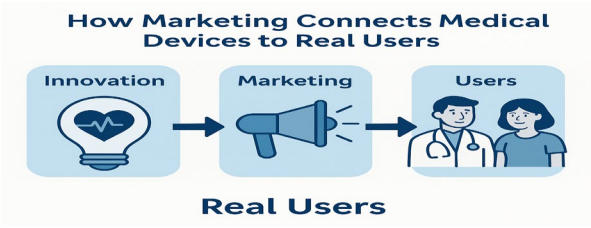


Figure 5.12: How marketing connects Innovations (such as medical devices) to real users

Why Marketing Matters in Medical Device Development

Marketing supports the entire journey of a medical device, from early ideas to full use in healthcare settings. Here are five key reasons why marketing is essential:

1. **It Attracts Investors**

   Before a medical device can be built and tested, companies often need money to support development. Marketing explains the value of the device in a way that helps attract financial support.

   Example: A company develops a new hearing aid that provides clearer sound, especially in noisy environments. Marketing shows how it improves daily life for people with hearing loss. This makes it easier to gain the trust of investors who want to support products that solve real problems.

2. **It Helps Understand Users' Needs**

   Marketing teams often begin by asking patients, doctors, and nurses what they need from a device. This feedback helps engineers design tools that are truly helpful.

   Example: When designing artificial limbs, user feedback may show that comfort and ease of movement are top priorities. This pushes engineers to improve materials and adjust the design to suit everyday use.

3. **It Builds Trust and Awareness**

   Healthcare workers and patients must trust that a device is safe, effective, and easy to use. Marketing spreads this message through training, education, and demonstrations.

   Example: If a new portable defibrillator is introduced, marketing might include training sessions for ambulance staff. These demonstrations build confidence and ensure proper use in emergencies.

4. **It Helps the Device Stand Out**

   Many medical devices already exist. Marketing helps show what makes a new device better than others. It may focus on cost, speed, design, or results.

   Example: A new wound dressing that heals cuts faster than traditional ones will need marketing to explain this benefit. When people understand the advantage, they are

more likely to try and adopt the device.

5. **It Supports Use After Launch**

   Marketing does not stop after the device is released. It continues to support users by training them, sharing updates, and encouraging adoption.

   Example: When a new insulin pump is launched, marketing teams may run workshops to train both nurses and patients. These sessions make sure the device is used correctly and help people feel more comfortable with the technology.

Marketing is more than advertising. It is a powerful tool that helps turn great ideas into real-life medical solutions. It ensures the right people know about a device, trust it, and know how to use it. In biomedical engineering, marketing helps bring devices to life and into the hands of those who need them most.

Creating a Marketing Plan for a Medical Device

A marketing plan is a simple guide that shows how a medical device can succeed in the real world. It explains why the device is important, who will use it, and how people will find out about it. A good marketing plan also helps attract investors and ensures the device reaches the people who need it most.

Below are six easy steps for creating a strong marketing plan, with examples to guide your understanding.

1. **Define the device and its benefits**

   Start by clearly explaining what your device is and the health problem it helps to solve. Think about how the device improves patient care or makes a healthcare task easier.

   Example: A portable blood pressure monitor helps people check their blood pressure at home. This makes it easier for patients with hypertension to monitor their health regularly and reduces their need to visit a clinic.

2. **Analyse the target market**

   Next, think about who will use the device and where they are located. Are they doctors, nurses, patients, or health workers in remote areas? This step helps make sure the device meets real needs (See ***Figure 5.13***).

   Example: A low-cost malaria test kit may be most useful in rural areas of Ghana. The main users would be healthcare workers in community clinics and non-governmental organisations (NGOs) that work to improve public health.

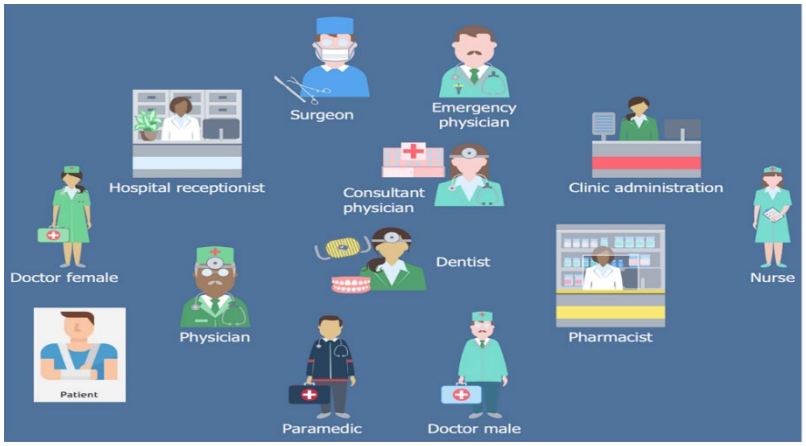


Figure 5.13: Target market for a new medical device

3. **Research competitors**

   Look at devices that already exist and are solving the same problem. What do they do well? What do they lack? Then explain how your device is better or different.

   Example: Many asthma inhalers do not track how many doses have been used. Your new smart inhaler could include a mobile app that sends reminders to help users take their medicine on time. This would be especially helpful for children or elderly patients.

4. **Plan pricing and funding**

   Decide how much money it will take to make your device. Think about materials, testing, packaging, and promotion. Also explain how you plan to get the money, such as through investors or donations.

   Example: If it costs GH₵120 to make one community health monitor, making 500 units will cost GH₵60,000. You will also need extra funding to test the device, print posters, and train users.

5. **Plan marketing strategies**

   Now explain how you will spread the word about your device. Think about who you want to reach and how you can reach them using available tools like posters, radio, or social media.

   Example: A health app for pregnant women could be shared at antenatal clinics. Midwives could show patients how to use the app. In rural areas without internet, posters and radio messages could explain how it helps mothers track their health.

6. **Set goals and timelines**

   Create a timeline that shows what you plan to achieve and when (See ***Figure 5.14***). Setting clear goals helps keep the project on track and shows progress to funders or teachers.

   Example timeline

   a. Month 3: Finish early testing of the device

   b. Month 6: Receive approval from health authorities

c. Month 12: Distribute 2,000 units and collect feedback from at least 50 users

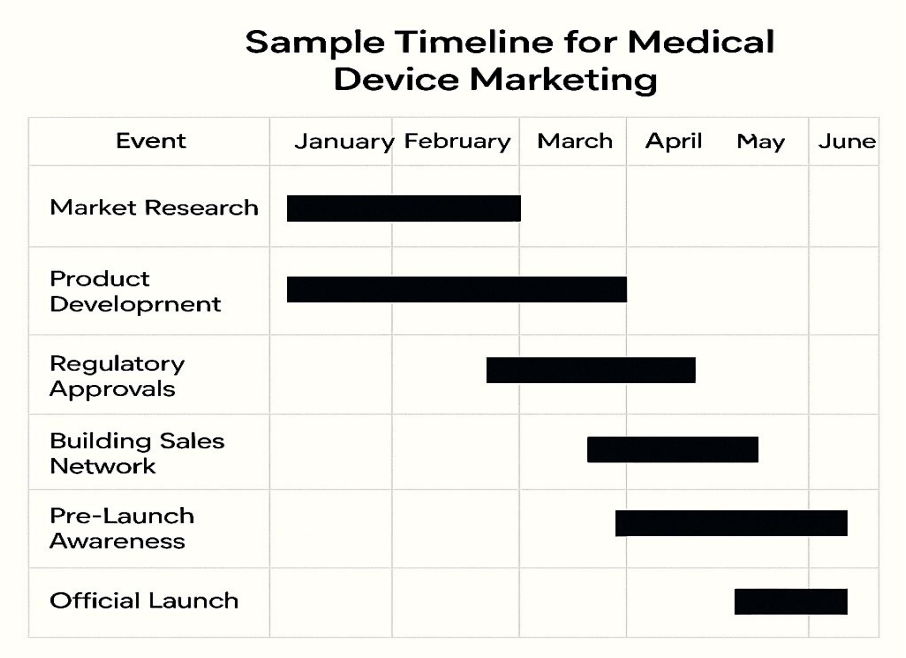


Figure 5.14: Sample timeline for medical device marketing

Activity 5.6 Pitching a Common Therapeutic Device

Objective: To prepare and practise a short pitch that explains the usefulness of a therapeutic device.

Materials needed

1. Notebook or plain paper
2. Pen or pencil
3. A phone (optional, for recording or timing)
4. A medical device. This can be a real/drawn picture of the device.

Procedure

1. Choose one therapeutic device you know or have seen

   (E.g., digital thermometer, blood pressure monitor, or glucose meter).

2. Write down the following details about the device:
   a. The health condition it helps manage
   b. The type of people who often use it
   c. One or two things that make it helpful in homes or clinics
3. Use the information to create a short pitch that explains why the device is useful and important in daily life.
4. Practise your pitch aloud or sign it using sign language.
5. If possible, record your pitch using your phone and review it.

6. Share your pitch in class or send a summary to your teacher.

Activity 5.7 Who Needs This Device?

Objective: To find out who uses a health device and how it helps them feel better or stay healthy.

Materials needed

1. Notebook or plain paper
2. Pen or pencil
3. A simple sketch or picture of a medical device

Procedure

1. Select one therapeutic device you know of (e.g. malaria test kit, digital thermometer, or insulin pen).
2. Draw the device in your notebook.
3. Under the drawing, list at least three types of users (e.g. schoolchildren, pregnant women, elderly people, or rural health workers).
4. Next to each user, write a sentence explaining how the device helps them.

   Example: "Pregnant women use malaria test kits to detect malaria early and stay healthy."
5. Practise explaining your list aloud or in sign language in front of a mirror.
6. Present your work to your classmate or teacher.

UNDERSTANDING DISASSEMBLY AND ASSEMBLY OF MEDICAL DEVICES

Disassembly and Assembly

What is Disassembly and Assembly?

In biomedical engineering, it is important to understand how therapeutic devices are built and how their parts work together. Disassembling (taking apart) and assembling (putting back together) these devices helps us see how design, safety, ease of use, and performance are all connected. By looking closely at each part, we can learn how the mechanical, electrical, and user-friendly features of a device work together.

Safe Disassembly of Therapeutic Devices

Therapeutic devices like digital thermometers, nebulisers (used to deliver medicine as mist into the lungs), and digital blood pressure monitors are great for learning because they are compact, safe, and often used in healthcare settings (see ***Figure 5.15***).

Figure 5.15: Disassembling a digital blood pressure monitor

Steps for Safe Disassembly

1. Read the manual: Start with the device's user guide to learn how to open it safely.
2. Power off and unplug: Always switch off and unplug the device before opening.
3. Wear protective gear: Use gloves or eye protection to stay safe.
4. Use a clean workspace: Work on a tidy, well-lit surface.
5. Label and take notes: Write down or take pictures as you remove each part.
6. Use the right tools: Don't force anything open. Use gentle tools like screwdrivers.
7. Disassemble in the right order: Start from the outside (e.g., covers) and move inward.
8. Handle parts carefully: Especially electronics like sensors and circuit boards.
9. Store parts safely: Use trays or containers to keep removed parts organised.
10. Dispose of waste correctly: If a part is dirty or used once, dispose of it safely.

What You Learn During Disassembly

Here are four important parts you will often see

1. **Power source**

   This could be

   a. Batteries

   b. Rechargeable batteries

   c. Plug-in cords

   Why it matters: The power system shows how energy is delivered and kept safe with things like fuses or protective cases.

2. **Delivery mechanism**

   This is how the device provides treatment.

   a. In a nebuliser, it is the compressor, tubing, and mask.

   b. In a hot water bottle, it's the rubber body and stopper.

   Why it matters: It shows how the device actually helps the patient.

3. **Control panel**

   These are the buttons and displays you use to operate the device.

   a. On/off buttons
   b. LED lights
   c. Dials or settings

   Why it matters: A clear, simple layout makes the device easier and safer to use.

4. **Labelled parts**

   When you disassemble, label parts like:

   a. Circuit boards
   b. Wires
   c. Sensors
   d. Tubing

   Why it matters: Labelling helps you remember where each part goes when you put it back together.

Reassembly of Therapeutic Devices

Reassembly is just as important as disassembly. If you do not put parts back correctly, the device might stop working or even become unsafe. ***Figure 5.16*** shows a student reassembling a digital thermometer, checking connections and using a screwdriver carefully.

Figure 5.16: Reassembling a digital thermometer

Steps for Safe Reassembly

1. Check all parts: Make sure you have everything and clean the parts if needed.
2. Wear protective gear: Gloves and clean hands help prevent damage or infection.
3. Use the official guide: Follow the instructions from the manufacturer.
4. Use the correct tools: Avoid damage by using clean and proper tools.
5. Follow the correct order: Start from the inside parts and build outwards.
6. Tighten properly: Don't force screws or bolts too tightly.
7. Check alignment: Moving parts and wires must be correctly placed.

8. Final inspection: Look for loose screws, dirt, or gaps.
9. Test the device: Turn it on (if safe) and check if it works.
10. Write it down: Record what you did and any problems you saw.

Why Proper Reassembly Is Important

1. **Ensures Patient Safety**

   Example: If the cuff tube on a blood pressure monitor is loose, the reading might be wrong. This can lead to wrong treatment.

2. **Keeps the Device Working**

   Example: A misaligned nebuliser cup won't create mist. Reassembly ensures correct function.

3. **Protects the Parts**

   Example: A leaking hot water bottle could burn someone. Assembly protects seals and connectors.

4. **Helps Troubleshooting**

   If a properly reassembled device still doesn't work, you know it's a real fault—not just a mistake in reassembly.

5. **Meets Safety Standards**

   Healthcare devices must pass checks. A loose part inside a thermometer might cause it to fail.

Disassembling and assembling therapeutic devices teaches you how they work and why each part matters. It also builds skills used by biomedical engineers to make healthcare better and safer.

Activity 5.8 How a Hot Water Bottle Helps with Pain

Objective: To find out how a hot water bottle is used to reduce body pain.

Materials needed

1. Rubber hot water bottle with a stopper
2. A clean towel or cloth
3. Cool or warm (not hot) water
4. Pen or pencil and paper

Procedure

1. Spread a clean towel on a table or bed to create a safe work area.
2. Check the hot water bottle for holes or cracks. If damaged, do not use it.
3. Gently fill the bottle halfway with warm water. Do not use hot water, as this can cause burns.

4. Carefully tighten the stopper. Make sure it is sealed well to prevent leaks.
5. Gently press the bottle to check for leaks. If it leaks, empty it and tighten the stopper again.
6. Do not place the hot water bottle directly on your skin. Wrap it in a towel to avoid burning yourself.
7. After checking, pour the water back into a container or safely dispose of it.
8. On a piece of paper, draw and label the hot water bottle. Include the main parts: the body, opening, and stopper.
9. Educate someone about how the hot water bottle helps reduce pain, for example, "It gives gentle heat to muscles" and why hot water bottles are helpful.

Activity 5.9 Learning the Blood Pressure Cuff

Objective: To describe the parts of a manual blood pressure cuff and explain what each part does.

Materials needed

1. Manual blood pressure cuff (with pump, tube, and dial)
2. A clean towel or table
3. Pen or pencil and paper

Procedure

1. Lay a clean towel on a table or bed. Place the blood pressure cuff on it.
2. Check the cuff for any visible damage. Do not continue if any parts are broken.
3. Look at the main parts of the device:
   a. Arm band (goes around the upper arm)
   b. Rubber pump bulb (used to fill air)
   c. Air tube (joins the parts)
   d. Pressure dial (shows pressure numbers)
4. Do not test the device on your arm or anyone else, as incorrect use can cause discomfort or give false readings.
5. Gently touch the parts and learn how they are connected.
6. Carefully remove the air tube from the bulb and reconnect it. Do not pull or twist it roughly to avoid damage.
7. On a sheet of paper, draw and label the four parts of the blood pressure device.
8. Say or sign what each part does. For example, "The bulb pumps air," or "The dial shows pressure."
9. Write one sentence about why checking blood pressure is important in staying healthy.

DEVELOPING AN OPERATING MANUAL

Why Are Operating Manuals Important?

An operating manual is like a step-by-step guidebook that explains how to use a medical or therapeutic device. Think of it like the manual that comes with a new phone, TV, or bicycle. Without the manual, you may not know how to set it up, use it safely, or fix small problems.

For medical devices, the manual is even more important because it helps to:

1. Protect health: it shows users how to avoid danger and stay safe.
2. Prevent mistakes: it explains clearly how to use the device the right way.
3. Keep the device working: it teaches proper care so the device lasts longer.
4. Save time: clear steps make it faster and easier to use.

Operating manuals are written in simple, clear language so that everyone can understand them easily, from patients using devices at home to busy nurses and doctors in hospitals.

Why Should Language be Clear?

1. Many patients use devices such as blood pressure monitors, nebulisers, or thermometers at home without the direct help of a nurse or doctor. If the instructions are written in very difficult language or filled with big technical words, several problems can happen:

   a. The patient may use the device in the wrong way.

   b. The device may give wrong results that can harm the patient's health.

   c. The device may get damaged or stop working.

   Clear instructions are therefore very important because they help patients feel confident, safe, and able to take care of themselves. For example, look at these two instructions for using electrode pads:

   ❌ *Difficult:* "Insert the electrode pads in accordance with the manufacturer's specified polarity orientation."

   ✅ *Clear:* "Stick the pads to the skin as shown in the diagram. Match the red and black wires to the correct pads."

   The second one is easier to follow because it uses everyday words and also gives a picture to guide the patient.

2. For Healthcare Workers: Even experienced nurses and doctors sometimes use new or unfamiliar devices. If the manual is written in simple and clear steps, it:

   a. Helps them avoid mistakes during treatment.
   b. Saves valuable time when they are busy.
   c. Makes it easier to train other workers quickly.

   For example, a nurse may need to use a new type of thermometer. A clear manual

means the nurse can learn quickly, check temperatures correctly, and focus on caring for patients instead of struggling with instructions.

What Should an Operating Manual Include?

A good operating manual should be written in simple English so that anyone can read and follow it. It should not use too many technical words, and the steps should be explained in the right order so that users do not get confused. A useful manual should also explain not only what to do but why it is important to do it in that way.

Every operating manual should have *three* main parts:

1. Step-by-step instructions: This shows the correct way to set up, use, clean, and store the device.
2. Safety warnings and precautions: This gives rules to keep the user safe and prevent damage to the device.
3. Troubleshooting guide: This provides simple solutions to common problems that may happen when using the device.

A description of these main parts is given below. Each part has been explained in more detail so that you can understand its purpose and how it helps the user.

Step-by-Step Instructions for Use

An operating manual should guide the user through all the important actions they need to take. The instructions must be written as simple steps, in the right order, so that even someone using the device for the first time will not get confused. Each step should also explain what to do and why it matters.

Here are the main parts

1. **Setting up the device**

   Before using the device, you must prepare it properly. This ensures it works well and prevents accidents.

   a. Place the device on a stable table or surface so it does not fall or shake during use.

   b. Check that the power supply is ready. This may mean plugging it into electricity, putting in batteries, or connecting the charging cable.

   c. Look carefully at all parts of the device to make sure they are clean and not broken. If the parts are dirty or damaged, clean or repair them before use.

2. **Using the device**

   This step explains how to operate the device correctly. Following the right order prevents mistakes and helps the device give correct results or proper treatment.

   a. Place the device in the correct position. For example, if it is meant for the body, make sure it is fixed to the right area.

   b. Ensure it is properly attached or fitted before turning it on.

c. Press the power or start button to begin. Remain calm and avoid moving around while the device is working.

d. Wait until the process is complete. The device may display results, make a sound, or stop on its own when the treatment or measurement is finished.

3. **Cleaning and maintenance**

   Taking care of the device after use helps it last longer and keeps it safe for the next person.

   a. Wipe the surface with a soft cloth to remove dust or dirt.

   b. Never put the device in water unless the manual says it is safe.

   c. Do not use strong chemicals or detergents because they may damage the device.

   d. After cleaning, store the device in a safe, dry place away from water, heat, or dust.

   e. From time to time, check for cracks, loose wires, or other damage. If you see a problem, repair or replace the damaged part before using it again.

Safety Warnings and Precautions

Safety rules are very important when using any medical or electronic device. They protect you, the people around you, and the device itself. If the rules are not followed, the device may give wrong results, break down, or even harm the user.

Here are some key safety precautions

1. Always use the device exactly as instructed
   a. Every device comes with a manual that explains the right way to use it.
   b. Do not guess or create your own method. Following instructions makes sure the device works well and keeps you safe.
2. Do not apply it to injured or sensitive areas unless approved by a doctor
   a. If the device is placed on a wound, broken skin, or a very sensitive body part, it can cause pain or make the condition worse.
   b. Always check with a health professional if you are not sure.
3. Keep it away from water, steam, or high temperatures
   a. Water and electricity can cause shocks or damage the device.
   b. Heat or steam can melt parts, weaken wires, or cause the device to stop working.
   c. Store the device in a cool, dry place at all times.
4. Stop using it if you feel unwell or experience unusual pain
   a. A device should not make you feel worse.
   b. If you start feeling dizzy, weak, or in pain, stop using it immediately and tell a teacher, parent, or health worker.
5. Do not open or attempt to repair the device yourself
   a. The inside of the device may have sharp parts, wires, or electricity that can hurt you.

   b. Only trained technicians or professionals should repair it. Trying to fix it yourself may cause more damage.

6. Inspect the device regularly for cracks, loose cables, or other signs of damage
   a. A broken device is unsafe to use.
   b. Small cracks, loose wires, or bent parts can cause accidents or wrong results.
   c. Always check before use, and if damaged, stop using it until it is repaired or replaced.

Troubleshooting Common Problems

Sometimes, even when you use a device correctly, it may stop working or give the wrong results. This does not always mean the device is broken. It may just be a small problem that can be fixed easily.

Troubleshooting means finding the cause of the problem and knowing what to do. A good manual should include a troubleshooting guide. This guide lists:

1. The problem (what you see happening)
2. The possible cause (what may be wrong)
3. What to do (the solution)

Here is an example of a troubleshooting table with explanations:

Problem	Possible Cause	What to Do	Why This Helps
Device will not turn on	Power not connected or batteries empty	Check that the power cable is plugged in properly or replace the batteries	A device needs power to work. Checking the power first saves time.
Screen is dim or unclear	Low battery or dirty screen	Replace the batteries or clean the screen with a soft cloth	A weak battery or dust can make it hard to see the screen clearly.
Unusual results appear	Device not placed correctly or too much movement	Reposition the device and remain still	If the device is not positioned well, it may not measure correctly.
Device does not start	Loose connection or blocked part	Check all cables, tubes, or parts to make sure nothing is loose or blocked	A loose cable or a blocked tube can stop the device from working.
Error message shows	Incorrect use	Review the instructions in the manual and try again	Many devices show an error when used incorrectly. Reading the manual helps fix it quickly.

Activity 5.10 My Experience with a Medical Device

Objective: To reflect on past experiences with medical or therapeutic devices and describe what instructions or safety tips were followed.

Materials needed

1. Pen or pencil
2. Notebook or worksheet
3. Optional: Images of medical devices (e.g. thermometer, digital BP monitor, nebuliser)

Procedure

1. Think of a medical or therapeutic device you have seen or used before (e.g. digital thermometer, nebuliser).
2. Write down:
   a. What the device is used for.
   b. Who used it (you, a family member, a health worker).
   c. What instructions or safety advice do you remember?
3. Using either talking or sign language, explain to a partner or teacher what you wrote.
4. Discuss with your partner:
   a. Were the instructions easy or hard to follow?
   b. What would you improve if you had to write the manual?
5. Write two things you learnt from listening to someone else's experience.

Activity 5.11 Creating a Simple User Manual

Objective: To create a clear and safe operating manual for a common medical device.

Materials needed

1. Pen or pencil
2. A4 sheets or an exercise book
3. Sample device (real or pictured), such as a digital thermometer or BP monitor
4. Ruler (optional)

Procedure

1. Choose one common device you know (e.g. thermometer, nebuliser, pulse oximeter).
2. Draw or describe what the device looks like.
3. On your paper, write these headings:

a. Setting up the device
b. Using the device
c. Cleaning and maintenance
d. Safety warnings
e. Common problems and solutions

4. Under each heading, write simple instructions for the user.
5. Add simple icons or sketches to make your manual clearer.
6. Show your manual to a partner, family member, or teacher. Ask them to follow your steps and give you feedback.

ENSURING SAFETY AND EFFICACY: THE ROLE OF REGULATORY AGENCIES

Medical Device Regulations

What are medical device regulations?

Before medical devices are allowed to be used in homes, clinics, or hospitals, they must go through a process called **regulation**. Regulation is a way of checking that devices are safe and that they work properly. Without these checks, unsafe or faulty devices could reach patients and cause harm. Regulations, therefore, act as a safeguard, protecting both patients and health workers.

Why Are Devices Grouped by Risk?

Since medical devices are not all the same, they are grouped according to the level of risk they pose to users. Some devices are simple and safe, while others are complex and carry greater risks if they fail. Grouping devices by risk allows regulators to apply the right level of testing and control.

In Ghana, devices are placed into four classes

1. Class 1 (low risk): Devices like bandages and gloves. These are checked mainly for safety and correct labelling.
2. Class 2 (moderate risk): Devices such as digital thermometers. These must be tested to confirm that they work as intended.
3. Class 3 (high risk): Devices like infusion pumps and scanners. These undergo stronger safety checks and strict quality control.
4. Class 4 (highest risk): Devices such as defibrillators and heart valves. These require very strict testing and inspections before they are approved.

In the **United States**, the Food and Drug Administration (FDA) uses a three-class system:

1. Class I: Devices such as gloves and stethoscopes. These must meet basic safety and labelling rules.
2. Class II: Devices such as glucometers and powered wheelchairs. These require extra testing to prove their accuracy and reliability.
3. Class III: Devices such as pacemakers. These pose the highest risk and must pass very strict safety checks, including clinical trials, before approval.

Why Is Regulation Important?

If devices are not properly regulated, they can

1. Give results that are wrong and mislead doctors or patients
2. Cause harm or injury when used
3. Fail during treatment and put lives at risk

When devices are regulated, they are carefully tested for safety and performance. This makes people trust them and ensures that health workers can rely on them to give safe and effective care.

What Do Regulatory Agencies Do?

Regulatory agencies are government bodies that make sure medical devices are safe, reliable, and effective. They guide how devices are made, check them before they are sold, and continue to monitor them while they are being used. Their work protects patients, health workers, and the general public.

1. **Set Safety and Quality Standards**

   The first role of regulators is to make rules for how medical devices should be designed and built. These rules ensure that:

   a. The materials used are safe for people.
   b. The device performs its job correctly.
   c. The device can be cleaned properly and reused where necessary.

   Example: A thermometer must show the correct temperature, must be safe when placed on the skin, and must be easy to clean after each use.

Figure 5.17: Thermometer being tested

2. **Review Devices Before Approval**

   Before a medical device is allowed onto the market, regulators carefully review the evidence that shows it works properly. This evidence can come from laboratory tests and clinical trials.

   Example: A blood glucose meter must work reliably in both hospitals and at home for patients. The results from testing are studied before the device can be sold.

3. **Inspect Manufacturing Facilities**

   Regulatory agencies also visit the factories where medical devices are made. They check how the factory is run to make sure the products will be safe and of high quality. During these visits, they look at:

   a. Whether the factory is clean and well organised.

   b. Whether the machines used in production are working well.

   c. Whether staff are properly trained to handle materials and equipment.

   Example: At a nebuliser factory, inspectors may check if workers are wearing gloves and if tools are kept clean (see ***Figure 5.18***).

Figure 5.18: Factory inspection in progress

4. **Approve and License Devices**

   Before any medical device can be sold or used in hospitals, it must be approved and given a licence by the regulator.

   a. In Ghana, this is done by the FDA Ghana.

   b. In the United States, this is done by the FDA.

   Example: A blood pressure monitor must be approved before it can be used in clinics, and a heart implant must be licensed before doctors can place it in patients.

5. **Monitor Devices After Approval**

   Regulation does not stop once a device is approved. Agencies continue to monitor devices that are already in use. This ongoing process is called *post-market surveillance*.

They collect reports from hospitals, clinics, and manufacturers. If many people report problems, the regulator investigates.

Example: If blood bags are found to be leaking, the regulator can order updates, call for a recall of the product, or change the safety instructions.

6. **Regulate Advertising and Claims**

   Regulators also control how medical devices are advertised. Companies must be honest about what their devices can and cannot do. A company cannot claim that a device cures a disease unless it has been tested and approved.

   Examples

   a. A pulse oximeter cannot be marketed as a cure for heart disease unless there is strong proof.
   b. A device must not be described as risk free unless evidence shows it truly is.

   This protects users from being misled or given false hope.

What Are the Approval Stages?

Before a device can be sold and used, it must pass through several stages of approval.

1. **Pre-clinical Testing**

   The device is first tested in laboratories or sometimes on animal models. At this stage, regulators check the strength of the device, its accuracy, and whether the materials used are safe.

Figure 5.19: Machine testing a knee implant

2. **Clinical Trials**

   The device is then tested on people in hospital settings. This stage checks whether the device works well in real-life situations, whether there are any side effects, and whether it is safe for patients.

   Example: An insulin pump may be tested on diabetic patients in hospitals to see how well it helps control blood sugar.

3. **Regulatory Review**

   After testing, all the results are sent to the regulatory agency. The agency carefully studies the data and looks at the safety, quality, and manufacturing process.

At this point, the agency can either approve the device, ask for more tests, or reject the application if it does not meet standards.

4. **Post-Market Surveillance**

   Even after approval, the device is continuously monitored. Reports from hospitals and clinics are collected to make sure no new problems appear.

   If many people report issues, regulators can remove the device from the market, change the instructions for safe use, or order the product to be recalled.

Activity 5.12 Investigating a Medical Device Label

Objective: To identify how safety and approval information is shown on a medical device label.

Materials needed

1. A real or sample box/label of a medical device (e.g. thermometer, blood pressure monitor, glucometer)
2. Notebook or worksheet
3. Pen or pencil

Procedure

1. Look closely at the medical device label or box.
2. Find and write down the following:
   a. Name of the device
   b. Country of manufacture
   c. Manufacturer's name
   d. Safety warnings (e.g. "keep dry", "for external use only")
   e. Approval symbols (e.g. FDA Ghana logo, CE mark)
3. Check if there is an expiry date or batch number.
4. Write a short answer to this question: How does this label show that the device is safe to use?

Precaution

1. Do not open sealed or new medical products during the activity.
2. Handle any real device gently and return it after use.

Activity 5.13 Spot the False Advert!

Objective: To identify misleading statements in a medical device advertisement.

Materials needed

1. Sample printed or digital medical device advert (real or created by the teacher)
2. Notebook or worksheet
3. Pen or pencil

Procedure

1. Read the advert carefully.
2. Look for claims that sound too good to be true. For example:
   a. "This device can cure all diseases."
   b. "100% safe with no side effects!"
   c. "Works without testing or doctor advice."
3. Write down two sentences from the advert that may be false or misleading.
4. Beside each one, explain why it may be dangerous to believe it.
5. Now, answer this question in two sentences: How can the FDA or other regulatory bodies stop false adverts?

Precaution

Do not share real adverts that could confuse others unless your teacher has checked them.

Activity 5.14 Planning My Own Medical Device

Objective: To plan a simple medical device that is safe, helpful, and easy to use.

Materials needed

1. Pen or pencil
2. Notebook or plain paper
3. A sample or picture of a basic medical device (optional)
4. Ruler (optional)

Procedure

1. Think of a health problem that affects people.
2. Write one short sentence to describe it.

   Example: "People forget to take their medicine."
3. Think of a simple device that could help solve the problem.
4. Draw or describe what the device looks like.
5. Write one sentence about what the device can do.

   Example: "It gives a sound to remind the person."
6. Write the names of important parts of your device.

7. Write what each part is used for.
   a. Example: “Speaker – makes sound.”
   b. Example: “Button – turns the device on.”
8. Describe how to take it apart safely if needed.
9. Write 3 to 5 simple steps showing how to use the device.
   a. Example: “Press the start button.”
   b. “Wait for the sound.”
   c. “Take your medicine.”
10. Add 1 or 2 safety warnings.
    a. Example: “Do not use near water.”
    b. “Turn off after use.”
11. Think about how risky the device is.
12. Choose the class:
    a. Class 1 – very low risk (e.g. hot water bottle)
    b. Class 2 – low to medium risk (e.g. thermometer)
    c. Class 3 – high risk (e.g. infusion pump)
    d. Class 4 – very high risk (e.g. pacemaker)
13. Write one or two things that must be checked for safety.

    Example: “The battery must be safe. The case must be sealed properly.”
14. Write who will use the device.

    Example: “Elderly people or patients at home.”
15. Write why it is helpful.

    Example: “It reminds them to take their medicine.”
16. Write one or two short sentences to promote the device.

    Example: “This device is small and easy to use. It helps people take medicine on time.”
17. Say or sign your plan to a teacher, classmate, or family member.
    Ask: “Is the device safe, clear, and useful?”
    Make changes if needed based on their feedback.

EXTENDED READING

QR Code 1: **Who is a Biomedical engineer**

QR Code 2: **Biomedical engineer roles**

QR Code 3: **Medical device marketing**

QR Code 4: **Disassemble and assembly**

QR Code 5: **Medical device manual**

QR Code 6: **Medical device regulation**

QR Code 7: **FDA Ghana's role**

REVIEW QUESTIONS

1. You are helping to create a learning resource that introduces others to the different areas of biomedical engineering and how they help improve healthcare.

   Your task is to answer the following questions

   a. What are five different branches of biomedical engineering that you know or can find through research?
   b. What does each branch focus on? Try to explain in your own words (for example, helping people move, designing hospital machines, or solving brain problems).
   c. How does each branch make healthcare better or support the work of doctors, nurses, or patients?
   d. Can you name one real-life device or system used in hospitals or clinics that comes from each of the five branches?
   e. How do biomedical engineers work with doctors, nurses, or computer scientists to help patients?

2. You are part of a team designing medical tools at a hospital. Nurses have said the current intravenous fluid stand is too heavy and hard to move between beds. This makes their work slower and harder, especially in emergencies.

   Using the design thinking steps,

   a. explain what you would do at each step (empathise, define, ideate, prototype, test) to solve this problem.
   b. explain how these steps help you create an intravenous fluid stand that is safe, easy to use, and helpful for both nurses and patients.

3. Design a new low-cost medical device that could be used in rural clinics. Follow the five stages of the design thinking process to guide your project. Your submission should include:

   a. A short paragraph describing each stage (Empathise, Define, Ideate, Prototype, Test)
   b. Sketches or labelled diagrams of your prototype
   c. A justification of how user needs influenced your design decisions

4. You are a member of a biomedical startup team. Your group has developed a low-cost, portable blood testing device. To get funding, you need to pitch your device to a panel of healthcare investors. Create a marketing plan for your device.

   Your plan must include

   a. clear explanation of what the device does and who it helps
   b. Analysis of the target users and their needs
   c. Research on competing devices and what makes yours better
   d. Marketing strategies to reach users (posters, demos, clinics, etc.)
   e. A timeline with goals for development and promotion

5. You are working on a **digital thermometer**. After using it many times, the inside parts (especially the circuit board) have become **damaged by moisture (water or liquid).** Now, you have been asked to **improve the design** so it lasts longer and is easier to fix.

   Your task

   a. Suggest **two changes** you would make to the design to stop water from causing damage.
   b. Explain **how each change** will protect the inside parts and still allow easy opening and closing (reassembly).
   c. Describe any **possible problems or difficulties** these changes might cause (for example, higher cost, more difficult to clean, etc.).

6. You are given **two versions of a user manual** for a digital blood pressure monitor. **Manual A** uses technical terms and long sentences. **Manual B** uses plain language and diagrams.

   Task

   a. Compare the two manuals in terms of readability, safety, and user experience.
   b. Identify specific features in Manual B that make it more effective.
   c. Now, create a **hybrid version** that includes the best features of both.
   d. Write a short paragraph justifying your design decisions and how they support user safety and independence.

7. You are presenting to a hospital procurement board deciding whether to purchase a Class III infusion pump made by a new overseas manufacturer.

   Instructions

   a. Create a short presentation outlining the regulatory checks this device should pass before use.
   b. Anticipate and respond to 3 possible concerns the board may raise about safety or reliability.
   c. Conclude with a recommendation supported by evidence and regulatory guidelines.

8. A charity wants to donate a Class 3 ultrasound machine to your local hospital. However, the machine was made in a country that does not have strong safety checks, and it has not yet been approved by the Food and Drugs Authority (FDA) Ghana.

   Your task: Write a report that includes the following:

   a. List the main safety steps the machine still needs to go through before it can be used in the hospital.
   b. Explain why each step is important for keeping patients and health workers safe.
   c. Give your opinion: Should the hospital accept the machine, reject it, or only use it for testing and research? Give clear reasons for your answer.

SECTION 6

RESEARCH & DESIGN IN BIOMEDICAL SCIENCE

BIOMEDICAL INNOVATION

Research And Design In Biomedical Science

INTRODUCTION

In this section, you will build on your scientific skills by applying statistical methods to real biomedical data. You will learn how to calculate basic statistics like mean, range, and standard deviation to examine variation among participants. Go further by connecting your results to research questions and recognising limitations such as a small sample size. You will also begin to design simple biomedical experiments by exploring real-world health questions and outlining steps using the scientific method. Through these activities, develop confidence in selecting appropriate tools, analysing data, and clearly interpreting findings. In Year 1, you explored how the scientific method is used to investigate biomedical problems. In Year 2, you evaluated scientific data from popular media and peer-reviewed journals and applied statistical techniques to experimental studies. Now, bring these skills together to design, analyse, and evaluate your own biomedical investigations with critical insight.

KEY IDEAS

- A hypothesis is an educated guess that predicts what will happen, like believing that more study time will lead to better exam results.
- Conclusions based on data analysis give insights into the research question, helping to confirm or disprove the initial guess.
- Designing experiments with controls helps ensure that results are fair and trustworthy, allowing researchers to test the hypothesis accurately.
- Scientific research begins by noticing things in everyday life, like how learners study and how it affects their grades.
- Systematically gathering data and analysing it helps researchers find out if the results support or challenge the hypothesis.
- Turning observations into clear questions is important for research, such as asking how study time affects exam scores.

STATISTICAL ANALYSIS OF RESULTS

Analysis of Biomedical Research Data

In biomedical science, analysing datasets is an essential step in understanding and interpreting results from laboratory experiments, clinical studies, or public health research. It helps scientists organise, summarise, and draw conclusions from the data they collect. This data can come from patient records, surveys, diagnostic tests, or controlled trials. By applying statistical techniques such as calculating the average (mean), standard deviation, or testing hypotheses, researchers can

1. Identify trends in how diseases occur and respond to treatment
2. Examine how variables relate (e.g., medication dose and symptom improvement)
3. Predict possible health outcomes
4. Back medical innovations and policies with evidence

Understanding how to analyse biomedical data will equip you with essential skills to engage in real-world research and critically interpret results that influence health care. Questions that researchers often explore using data include: "Does this drug reduce symptoms?", "What is the average blood pressure for people aged 40–50?", or "Is lifestyle linked to disease risk?"

Also, recall that identifying variables is essential for understanding and analysing scientific studies, especially in health research. For example, when studying the effect of a medication on a disease, the **independent variable** is the medication given; it is what the researcher controls or changes. The **dependent variable** is the patient's response, such as a decrease in symptoms or improvement in health. In this context, the medication is the "cause" or "input," and the health outcome is the "effect" or "result." Understanding the relationship between these variables helps researchers and healthcare professionals determine whether a treatment is effective and make informed decisions based on data.

Calculation of Basic Statistics to Understand the Distribution of Results

Basic statistical measures help summarise and describe datasets, allowing you to better understand how the values are distributed. 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 These measures include: **Mean** (average), **Median** (middle value) **Mode** (most frequent value), **Range** (spread between the highest and lowest values) and **Standard Deviation** (how spread out the data is from the mean) These tools show us how values are centred and how much they vary.

Mean (Average)

The mean is found by adding all the values together and dividing by how many values there are. That is, ($\bar{x}$) = (.

1. Ungrouped data formula: ($\bar{x}$) =

2. Grouped data formula: ($\bar{x}$) =

   Where:

   (f) = frequency

   (x) = value of each observation

   (n) = total number of values

Example

Ungrouped data

Calculate the mean heart rates (beats per minute, bpm) of five patients: 72, 78, 65, 80, 70.

Solution

Add all the heart rates and divide by the number of patients (5)

$(\bar{x}) = = = 73$ bpm

GROUPED DATA

A group of SHS students took part in a health study that measured their resting heart rates. The results were grouped as shown below:

Heart Rate (bpm)	Students
60–64	2
65–69	4
70–74	6
75–79	3
80–84	5

a. Using the grouped data formula: Mean $(\bar{x}) =$, calculate the mean resting heart rate of the students.

b. The normal resting heart rate for teenagers is between 60 and 100 bpm. Compare your calculated average heart rate with this normal range. What does your result tell you about the heart health of the students in your group?

Solution

Step 1: Create a frequency table and find the midpoint (x) of each group's heartrate

Heart Rate (bpm)	Frequency (f)	Midpoint (x)	f x
60–64	2	62	124
65–69	4	67	268
70–74	6	72	432
75–79	3	77	231
80–84	5	82	410

Step 2: Add totals

$\Sigma f = 2 + 4 + 6 + 3 + 5 = 20$

$\Sigma fx = 124 + 268 + 432 + 231 + 410 = 1465$

Step 3: Apply the formula

Mean ($\bar{x}$) = = 1465 / 20 = 73.25 bpm

Conclusion

The average resting heart rate of the students is 73.25 beats per minute, which is within a healthy range of 60 to 80 bpm. This helps biomedical scientists monitor group heart health.

Median

The median is the middle number when the values are arranged in order. It's useful when extreme values (e.g. very high blood pressure) might affect the mean.

Steps

Order the values from smallest to largest

If the number of values is odd, the median is the middle number

If even, take the average of the two middle numbers

Example (**odd n**)

Find the median heart rate: 70, 72, 68, 74, 76, 72, 70

Arrange the data in order: 68, 70, 70, 72, 72, 74, 76 → Median = 72 bpm

Example (**even n**)

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?

Arrange the data in ordered: 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3

Average middle value = = = 4.95 mmol/L

Mode

The mode is the value that occurs most often. A dataset may have one mode, more than one, or none.

Example (no mode)

80, 85, 90, 70, 95. All appear once therefore, there is No Mode

Example (with mode)

80, 85, 90, 85, 70. Here 85 appears twice therefore, the Mode is = 85

Range

The range shows how far apart the smallest and largest values are.

Formula: Range = Maximum value - Minimum value

Example

Temperatures (in °C) of 6 patients during a fever study are: 38.2, 37.6, 39.0, 38.5, 37.9, 38.7.

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

Standard Deviation (SD)

Standard deviation shows how much the values vary from the mean. A small SD means values are close to the average; a large SD means they are 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.

Steps

1. Find the mean
2. Subtract the mean from each value
3. Square the result
4. Add them all
5. Divide by (N - 1) $SD = \sqrt{\frac{\sum (x - \bar{x})^2}{N - 1}}$
6. Take the square root

Example

A biomedical science learner measured the resting respiratory rates (in breaths per minute, bpm) of 5 patients: 16, 18, 17, 20, 19. Calculate the standard deviation.

Step 1: Find the mean (x represents each resting respiratory rate measured)

Mean =

Step 2: Subtract the mean from each respiratory rate and square the result for each value

Value (x)	(x -) = x - 18	$(x-)^2 = (x-18)^2$
16	-2	4
18	0	0
17	-1	1
20	2	4
19	1	1
		$)^2 = 10$

Step 3: Divide by n−1 = =

Step 4: Take the square root = = 1.58 bpm

This tells us most values are close to the mean. A larger SD would mean values are more varied.

Uses of Central Tendency and Dispersion Measures

In biomedical science, we often collect numerical data such as blood pressure, heart rate, body temperature, or glucose levels. To understand these numbers better, we use basic statistical tools such as mean, median, mode, range, and standard deviation. These help us describe how the values are spread out and spot common patterns or trends in the data.

Mean (Average)

The mean shows the central value of a group of numbers. But it can be affected by very high or very low values (called outliers).

Example: If most heart rates in a group are between 68 and 75 beats per minute, but one person has a rate of 110 bpm, the mean may not truly reflect the group.

Median (Middle Value)

The median is the middle number when the data is arranged in order. If there are two middle numbers, you take their average. The median is helpful when there are outliers.

Example: If most glucose levels are around 5.0 mmol/L, but one person has 15.0 mmol/L, the median gives a better picture than the mean.

Mode (Most Frequent Value)

The mode is the number that shows up most often. It is useful when you want to know what is most common.

Example: If blood group O+ is recorded more than any other group in a clinic, then O+ is the mode. Unlike the mean, the mode is not influenced by extreme values

Range (Difference Between Highest and Lowest)

The range tells you how spread out the values are.

Example: If respiratory rates range from 12 to 24 breaths per minute, the range is 12. This gives a quick idea of variation, but it only looks at the two extremes.

Standard Deviation (Spread Around the Mean)

This tells us how closely the values are grouped around the mean. A small standard deviation means the numbers are close together while a large standard deviation means the numbers are more spread out.

Example: If the average systolic blood pressure is 120 mmHg with a standard deviation of 2 mmHg, most readings fall between 118 and 122 mmHg that is mmHg. This shows that the results are consistent.

Interpreting Results with Basic Statistics

For example, if the mean (average) respiratory rate among patients is 18 breaths per minute with a standard deviation of 1.58, this suggests that most patients had similar breathing rates, with only slight variation.

If the median and mode are also close to the mean, it indicates that the data is symmetrical and there are no extreme values (outliers) influencing the results.

In the context of an experiment that aims to assess whether a treatment helps to stabilise respiratory rate, a low standard deviation and a narrow range would suggest that the treatment may be effective in producing consistent outcomes across patients.

However, it is important to note that the sample size in this case was small only five patients. This limits the reliability and generalisability of the findings. A small sample may not accurately represent the wider population and can be affected easily by individual differences. Additionally, because this was a simple observational study, other factors such as age, physical activity, or underlying health conditions may not have been controlled, and could have influenced the results.

To improve the strength of future studies, researchers should consider using a larger and more diverse sample and applying a controlled experimental design. This would lead to more reliable evidence and allow for more confident conclusions.

Data Visualisation

Visual tools are very important in biomedical research. They help to make complex data easier to understand, highlight patterns, and clearly communicate research findings. Instead of just looking at raw numbers, visual tools allow researchers to gain insights and make better decisions. Choosing the right type of chart depends on the kind of data and what message you want to communicate. A well-chosen visual makes the data clearer, helps to point out important **findings**, and supports faster and more accurate interpretation. This is useful not only for researchers but also for the public.

Some commonly used visual tools in biomedical science

Pie Charts

Pie charts are used to show proportions or percentages of a whole. Each slice represents a category's share of the total. Pie charts are most effective when comparing a few categories (usually 2 to 5). If too many slices are added, the chart becomes confusing.

In biomedical research, pie charts are useful for the following.

1. Showing the distribution of blood types in a group of patients
2. Presenting treatment outcomes (e.g., improved, stable, worsened)
3. Displaying causes of death in a population

Example
A study investigates the distribution of blood groups among patients at a clinic. The pie chart in ***Figure 6.1*** shows the following data:

Blood Group	Frequency (%)
O+	40
A+	25
B+	20
AB	15

Figure 6.1: Pie chart showing the blood type distribution

Bar Graphs

Bar graphs display quantities or frequencies of different categories or groups using rectangular bars. These bars can be vertical or horizontal, and their height or length represents the value. Bar graphs are used to compare the size or frequency of different categories and are suitable for discrete or categorical data.

They are excellent for:

1. Comparing quantities across distinct groups
2. Showing changes over time for separate intervals
3. Presenting frequencies or counts

In biomedical science research, bar graphs can be used for:

1. Average drug dosage administered across different age groups
2. Number of cases of a specific disease per year
3. Comparison of mean cholesterol levels between a control and a treatment group
4. Frequency of different genetic mutations in a study population

Example

A study investigates the effectiveness of three different treatments in lowering blood pressure among patients. The number of patients who experienced a significant drop in blood pressure is recorded for each treatment.

Treatment	No. of successful cases
Herbal Remedy X	18
Standard Drug Y	25
Exercise Program Z	20

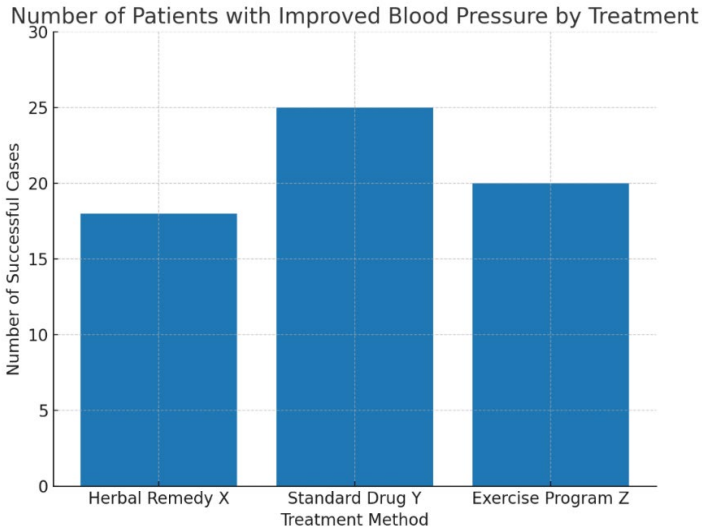


Figure 6.2: A bar graph showing the number of patients who experienced improved blood pressure across the three treatment methods, clearly identifying which method was most effective.

Scatter Plots

Scatter plots are graphs that use dots to represent the values for two different numerical variables. Each dot is positioned on the horizontal axis (X-axis) corresponding 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 increase, does the other increase too?).

Scatter plots help reveal the type of relationship or correlation (positive, negative, or no correlation) between two continuous variables. 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 include

1. Relationship between daily exercise minutes and blood pressure
2. Correlation between drug concentration in blood and patient response

3. Association between age and bone density
4. Visualising individual patient data points in a clinical trial to see response variation

Note

Graphs can sometimes be misleading if the Y-axis scale is changed to make differences look big. To avoid this, always start your scale at zero, especially scatter plot, use regular intervals and only adjust the scale if you have a reason.

Example

A group of biomedical researchers in Ghana studied how fasting blood glucose levels affect the time it takes for minor wounds to heal in adult patients attending a community clinic. They recorded the fasting glucose levels (in mmol/L) and the corresponding wound healing times (in days). The data is shown below:

Fasting Blood Glucose (mmol/L)	Healing Time (days)
4.3	7.5
4.7	7.0
5.1	6.8
5.6	6.2
6.1	5.9
6.6	5.2
13.6 *(outlier)*	14.8

Figure 6.3: A scatter plot showing the relationship between fasting blood glucose levels and wound healing time among Ghanaian adults. Note how the outlier (13.6 mmol/L) stands out from the overall trend

Summary Table

Graph Type	Best Used For	Data Type	Example
Pie	Proportions of a whole	Categorical (%)	Blood group distribution
Bar	Comparing frequency or amount	Categorical	Side effect counts
Scatter	Relationships between variables	Continuous	Sleep vs. memory reaction time

Why Use 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.

Activity 6.1 Investigate Variables in Biomedical Studies

Objective: To identify independent and dependent variables in a biomedical scenario and explain how sample size affects research findings.

Materials needed

1. Notebook and pen
2. Quiet space to read and reflect

Procedure

1. Read this simple research scenario:

   A scientist wants to test if a new medication lowers blood pressure. 10 patients take the drug daily for 2 weeks. Their blood pressure is measured before and after.
2. Jot down the independent variable and the dependent variable.
3. Give a reason for your choice in (2)
4. Is the sample size large enough? Why or why not?
5. Share with someone how a larger sample could improve the findings.
6. Do you think the result of this study can be applied to the whole Ghanaian population? Why or why not?

Activity 6.2 Doing Your Own Data Analysis

Objective: To calculate mean, mode, median, range, and standard deviation from a biomedical data set.

Materials needed

1. Notebook
2. Calculator or phone
3. Pencil or pen

Procedure

1. You have the following blood sugar levels (in mg/dL) of 7 patients after eating:

   85, 90, 85, 100, 95, 90, 85

2. Calculate the following

   a. Mean

      Add all the blood sugar levels together: 85 + 90 + 85 + 100 + 95 + 90 + 85 = ___

      Divide the total by the number of patients (7). Mean = Total ÷ 7 = ___

   b. Mode: Look for the most frequently occurring value in the dataset. The mode is ___

   c. Median

      Sort the blood sugar levels in ascending order. The middle value is ___

   d. Range

      Find the highest blood sugar level:
      Find the lowest blood sugar level:
      Subtract the lowest value from the highest value. Range = ___

   e. Standard deviation

      Find the mean (calculated earlier). Mean = ___
      Subtract the mean from *each* blood sugar level and square the result. *For example,*
      Calculate $(85 - \text{mean})^2$ = ___
      Calculate $(90 - \text{mean})^2$ = ___
      Find the average of these squared results. Average = ___
      Take the square root of that average. Standard Deviation = √Average = ___

3. How might these statistics be used in real health research.

Activity 6.3 Draw a Graph and Change the Scale

Objective: To construct a bar graph or scatter plot and observe how changing the Y-axis scale affects interpretation.

Materials needed

1. Ruler
2. Graph paper or lined paper
3. Pencil and eraser
4. Coloured pens or pencils

Procedure

1. Use this data showing number of malaria cases in 4 regions:
   a. Ashanti: 200
   b. Volta: 180
   c. Northern: 220
   d. Greater Accra: 150
2. Draw two bar graphs. Set up your graph:
   a. Draw the Y-axis (vertical) and label it with values from 0 to 250 for first graph and 150 to 230 for the second graph.
   b. Draw the X-axis (horizontal) and label it with the four regions: Ashanti, Volta, Northern, Greater Accra for each graph.
3. On the first graph, plot the data on Y-axis:

   For Ashanti (200), draw a bar up to 200.

   For Volta (180), draw a bar up to 180.

   For Northern (220), draw a bar up to 220.

   For Greater Accra (150), draw a bar up to 150.
4. On the second graph, plot on Y-axis:

   For Ashanti (200), draw a bar up to 200.

   For Volta (180), draw a bar up to 180.

   For Northern (220), draw a bar up to 220.

   For Greater Accra (150), draw a bar up to 150.
5. Compare the two graphs:
   a. Identify which graph makes the differences between the regions appear larger.
   b. Analyse the height of the bars in both graphs.
   c. Consider how changing the Y-axis affects how the data is perceived.

d. Write down how the scale can exaggerate or reduce the differences between values.

e. Reflect on how this can be misleading in real research.

FROM QUESTION TO EXPERIMENT - DESIGN AND ANALYSIS

The Scientific Inquiry Process in Biomedical Research

All scientific discoveries start with a question. In biomedical science, these questions often arise from observing health and illness in our everyday lives and communities. For instance, consider prevalent health beliefs or practices in West Africa, such as using local herbs like neem leaves for treating fever or how traditional diets influence well-being. A scientist's initial task is to convert these everyday observations into specific, testable questions, such as "Does bitter leaf truly help with malaria?" or "Is excessive consumption of fried foods harmful to heart health?" This stage is known as the questioning phase. It requires a solid understanding of existing scientific literature and careful consideration to ensure that the questions can be systematically studied, leading to measurable results that yield clear answers.

As discussed in the first two years, experiment design becomes crucial once a research question is identified. This begins with crafting a clear hypothesis, which serves as an "educated guess," followed by a specific prediction of what the expected outcome will be. When designing the experiment, it is important to define the methods clearly, identifying the independent variable (what you change), the dependent variable (what you measure), and the controlled variables that must remain constant. A key aspect of this design is incorporating a **control group** for comparison to ensure the results are trustworthy. After collecting data carefully, the analysis phase commences, where statistics play a vital role in interpreting the results and determining whether the hypothesis is supported.

Let us explore an example illustrating how an everyday observation can lead to the development of a scientific experiment.

Investigating the Hypothetical Effect of Traditional Diets on Learner Energy Levels

1. **Observation and Questioning**

   Observations indicated that many Senior High School (SHS) learners in Ghana consumed traditional foods like fufu and light soup, while others opted for fast food. Some learners reported feeling more energetic after meals that included traditional dishes. This led to the question: Did consuming traditional Ghanaian foods hypothetically impact the energy levels of SHS learners compared to fast food options?

2. **Hypothesis and Prediction**

   To explore this, the hypothesis was formed: If SHS learners ate traditional Ghanaian foods, then they would report higher energy levels within two hours post-meal, as these foods were often perceived to be more nutritious and balanced compared to fast food. Consequently, it was predicted that learners who hypothetically consumed traditional meals would perform better on a physical activity task administered two hours after eating, compared to those who opted for fast food.

3. **Experimentation (Methods and Data Collection)**

   A total of 40 SHS learners were recruited from a school in Ghana, aged 15-17. The independent variable was the type of meal (traditional Ghanaian food versus fast food), while the dependent variable was the energy levels, measured by performance on a physical endurance task (e.g., a 5-minute run).

   Controlled variables

   To control external factors that can interfere with the outcome, several variables were kept constant.

   a. Time of day for the exercise test
   b. Type and amount of food consumed
   c. Duration between eating and testing
   d. Environment of the test (e.g., a clear outdoor space)
   e. Learners' prior food intake (all learners were required not to eat for 4 hours before the experiment)

   The learners were randomly divided into two groups: a **control group** of 20 who consumed a traditional meal, and an **experimental group** of 20 who consumed a fast-food meal. After exactly two hours, a 5-minute endurance test was administered to all learners, and the distance each learner ran was recorded for both groups.

   a. Control Group (traditional meal): 20 learners consumed traditional foods.
   b. Experimental Group (fast food): 20 learners consumed fast food.

   After exactly two hours, a 5-minute endurance test was administered to all learners. The distances each learner ran were recorded as follows:

   a. Control Group (traditional meal, distance in meters): 800, 820, 780, 790, 810, 830, 850, 800, 840, 760, 790, 810, 820, 830, 840, 850, 860, 780, 800, 810.
   b. Experimental Group (fast food, distance in meters): 600, 580, 620, 590, 550, 610, 570, 580, 600, 590, 560, 550, 620, 600, 580, 570, 590, 600, 550, 540.

4. **Analysis and Conclusion**

   After collecting the data, the average distance run for each group was calculated. Simple statistical analysis, such as comparing means, was used to determine if there was a significant difference between the two averages. For instance, after collecting the data, the average distance run for each group was calculated:

   a. Control Group Average: 805.0 meters

b. Experimental Group Average: 580.0 meters

Simple statistical analysis, such as comparing means, was used to determine if there was a significant difference between the two averages. For instance, if the average distance for the traditional food group was found to be 805 meters and for the fast-food group it was 580 meters, this indicated a notable difference.

Based on the statistical analysis, the conclusions were drawn:

a. If the traditional food group ran significantly further, it suggested that consuming traditional Ghanaian foods positively affected the energy levels of SHS learners, supporting the hypothesis.

b. Conversely, if there was no significant difference, it indicated that the results did not support the hypothesis that consuming traditional meals led to higher energy levels.

This example illustrates how everyday observations about diets can lead to systematic investigation using the scientific method, transforming curiosity into measurable research.

Note

- Controlled variables = things you keep constant on purpose.
- Confounding variables = things you forget to control, and they mess up your results. Example is learners' prior fitness level. To control this, pre-test all learners' endurance levels or randomly assign participants to groups.

Activity 6.4 Finding the BMI of learners in My Class

Objective: To check the BMI (Body Mass Index) of learners and find out how many are in the healthy range.

Materials needed

1. A measuring tape
2. A weighing scale
3. Notebook and pen
4. Calculator
5. Graph paper or Excel (optional)
6. A BMI chart (from textbook or online)

Procedure

1. Write your research question in your notebook.
   For example: What is the BMI range of learners in my class?
2. Write your guess (hypothesis)
   State what you think will happen. For example: Most learners will have a healthy BMI.
3. Collect data from at least 10 classmates.
   a. Measure each person's height in meters.

   b. Measure each person's weight in kilograms.
   c. Use the formula to calculate BMI:
      BMI = weight ÷ (height × height)
      Record the results neatly in your notebook.
4. Organise your data
   a. Put each student's BMI in a table.
   b. Use the BMI chart to classify each student as underweight, healthy, overweight, or obese.
   c. Count how many learners fall into each group.
   d. Draw a bar chart or pie chart to show your findings.
5. Summarise your findings
   a. Say whether your guess was correct or not.
   b. Mention anything surprising you noticed.
   c. Explain what your results say about your class's overall health.
6. Create a short report which include
   a. your research question.
   b. the graph you created.
   c. a short summary of what you learned.
   d. one health tip for learners. *(Example: "Exercise daily and eat a balanced diet to stay healthy.")*

ANALYSING THE DATA

Once an experiment is carefully designed and data is collected, the next important step is data interpretation. This means making sense of the raw data and observations and turning them into meaningful insights that answer your original research question and hypothesis. It is not just about looking at individual results; it is about seeing the bigger picture, recognising trends, and understanding the significance of the findings.

Effective interpretation often uses visual aids like graphs and charts, which can show patterns that might be missed in tables of numbers. In this stage, you will apply the statistical methods you have learned before to determine if your findings truly support your hypothesis and to identify any limitations that could affect your conclusions. This process helps you gain a deeper understanding of the scientific method.

As you interpret your findings, consider the following: Did your results support the hypothesis? What limitations did you face in your experiment?

Let us revisit the previous experiment to investigate if diet affects the short-term energy levels of SHS learners in Accra.

After collecting the distance covered in a 5-minute run from both the control group (traditional diet) and the experimental group (fast food), you can interpret the data as follows:

1. **Organise the Data**

   First, the running distances for each student in both groups were listed:

   a. Control Group (traditional meal, distance in meters): 800, 820, 780, 790, 810, 830, 850, 800, 840, 760, 790, 810, 820, 830, 840, 850, 860, 780, 800, 810.
   b. Experimental Group (fast food, distance in meters): 600, 580, 620, 590, 550, 610, 570, 580, 600, 590, 560, 550, 620, 600, 580, 570, 590, 600, 550, 540.

2. **Calculate Averages (Mean)**

   Refer to the previous exploration on statistics and the calculation of central tendencies.

   a. Control Group Average: 805.0 meters
   b. Experimental Group Average: 580.0 meters

3. **Visualise the Data**

   A simple bar chart is an effective way to visually compare the average distances run by the two groups.

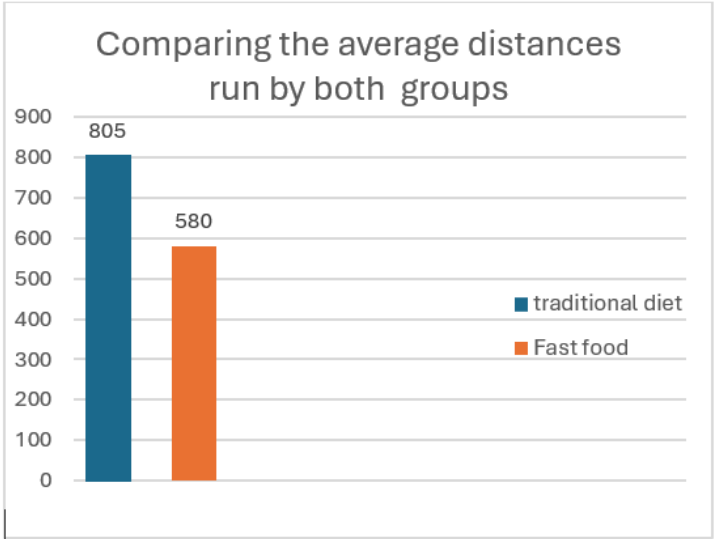


Figure 6.4: A graph visually comparing the average distance covered by learners who ate traditional diet and those who ate fast food.

4. **Interpret the Results and Draw a Conclusion**

   Looking at the averages and the bar chart, a noticeable difference is observed. The control group, on average, covered significantly more distance (805.0 meters) compared to the experimental group (580.0 meters).

   a. Did the results support the hypothesis?

   Yes, the findings confirmed the hypothesis that consuming traditional Ghanaian

meals boosts energy levels more effectively than fast food among SHS learners. Learners who ate traditional meals performed significantly better in the endurance activity.

b. What are the limitations of the experiment?

While the study provided useful insights, it had some limitations due to it small scale, including:

i. Sample Size: Only 40 learners were tested. Using more learners could make the results stronger and more reliable.

ii. Meal Variety: The experiment tested just one traditional dish and one fast food item. Other meals might produce different outcomes.

iii. Endurance Test: A 5-minute run may not fully assess all components of physical energy.

iv. Short-term Effect: Only short-term energy levels were measured (immediately after the meal). Longer-term effects were not observed.

v. Individual Differences: Factors such as learners' prior health conditions, sleep patterns, or typical dietary habits could influence their individual responses, even though attempts were made to control for these variables by ensuring fasting.

This straightforward analysis, utilising simple averages and a visual chart, helps to clearly interpret the data, draw a conclusion about the hypothesis, and critically evaluate the experiment's limitations, much like a real biomedical scientist would.

Activity 6.5 Investigating a Health Issue in Your School Community

Objective: Conduct an independent research project to explore a health problem, formulate hypotheses, collect and analyse data, and communicate your findings.

Materials needed

1. Notebook or digital document for recording data
2. Survey template (Google Forms or paper)
3. Measuring tools (e.g., scales, blood pressure monitors)
4. Access to textbooks and online resources
5. Statistical tools (e.g., Excel, Google Sheets)
6. Presentation software (e.g., PowerPoint, Google Slides)

Procedure

1. Choose a Health Topic
   a. BMI patterns among learners
   b. Effects of breakfast on concentration
   c. Blood pressure profiles

2. Formulate a statement (hypothesis).
3. Design a questionnaire to gather data, ensuring anonymity (confidentiality)
   a. Share it with classmates and record their responses.
   b. Use statistical methods to calculate averages and create graphs.
4. Write a report with
   a. Title
   b. Introduction
   c. Hypothesis
   d. Methodology
   e. Results
   f. Conclusion
5. Create a brief presentation (5-10 minutes) summarising your research. Include key findings and health implications. Share a short reflection on what you learned and any challenges you faced.

Activity 6.6 Investigating Health Through the Scientific Method

Objective: Carry out a simple investigation to explore a health issue using surveys, data analysis, and comparison with scientific and media sources.

Materials needed

1. Notebook
2. Pen
3. Paper for surveys
4. Calculator (optional)

Procedure

1. Choose a common health issue that affects learners, for example: the effect of energy drinks on sleep, awareness of malaria prevention, or how often learners wash their hands.
2. Write a clear hypothesis
3. Create a short 5-question survey using a rating scale (e.g., 1 = strongly disagree to 5 = strongly agree) with questions like:

   Do you know how sugary drinks affect your brain?

   How often do you drink energy drinks before class?
4. Give the survey to at least 10 classmates, politely explain the purpose, and assure them their responses are private.

5. Calculate the average (mean) and mode of responses, then draw a bar graph to compare responses, for example: one bar for "aware" vs another for "not aware."
6. Find one media article (e.g., from Ghana Web Health or BBC News) and one scientific article (e.g., from Ghana Medical Journal or WHO), then list the main points and note any differences, for example, does the media simplify or exaggerate compared to the science?
7. Summarise your results in 5–6 sentences, explain if your findings support your hypothesis, and present it to your class. Ask: "Were you surprised?", "Do we need more health education on this topic?"

Alternative without Internet

If you do not have internet access, you can use textbooks or printed materials from your school library for background information. You can also ask teachers or healthcare providers for insights on health topics. This way, you can still gather valuable information to support your investigation!

EXTENDED READING

1. Agravante, M. (2022, August 30). *What is the meaning of variables in research?* Sciencing. https://www.sciencing.com/meaning-variables-research-6164255/

2. Twist, B. (2023, August 12). *Definitions of control, constant, independent and dependent variables in a science experiment*. Sciencing. https://www.sciencing.com/definitions-dependent-variables-science-experiment-8623758/

REVIEW QUESTIONS 6

1. Scenario

A group of SHS 3 Biomedical Science learners is investigating how regular jogging affects resting heart rate in young adults. They recruited 8 volunteers from their school who agreed to jog for 30 minutes every morning for three weeks. The learners measured each participant's resting heart rate (in beats per minute) before the jogging program and again after the 3 weeks. Here is the data they collected:

Participant	Before Jogging	After Jogging
1	82	74
2	85	78
3	79	72
4	88	81
5	91	83
6	84	76
7	86	78
8	90	81

a. Calculate the mean, median, range, and standard deviation for the heart rates before and after jogging. Then, write a short scientific report comparing the two data sets, interpreting how exercise affected cardiovascular performance.

b. Based on your findings, propose a research-based health recommendation for SHS learners and explain how these findings could support public school fitness policies in Ghana.

c. Design a community awareness campaign (poster, video, or flyer) that uses your results to explain to non-scientific audiences how daily jogging may impact heart health. Include one graph and one message in local context.

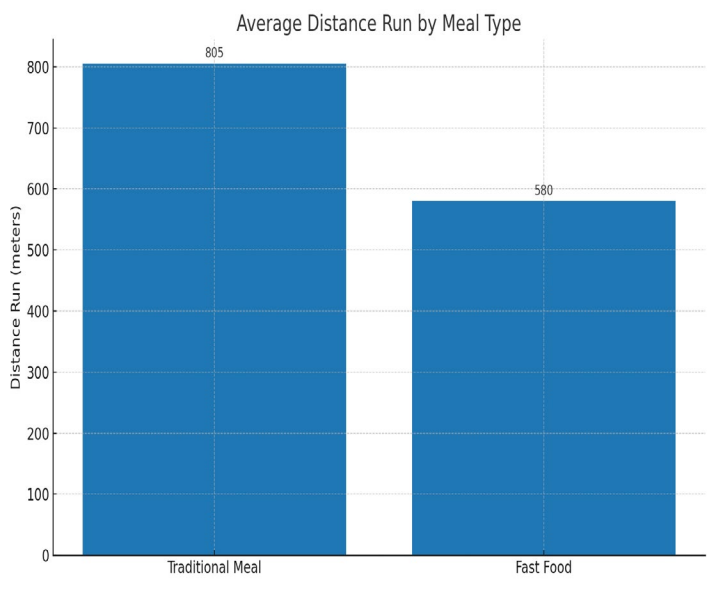


Figure A: Average Distance Run by Meal Type

2. Using the data from ***Figure A***, design a follow-up study to investigate how type of breakfast and hydration together affect physical stamina. Define your hypothesis, variables, control groups, and outline how data would be collected and analysed.

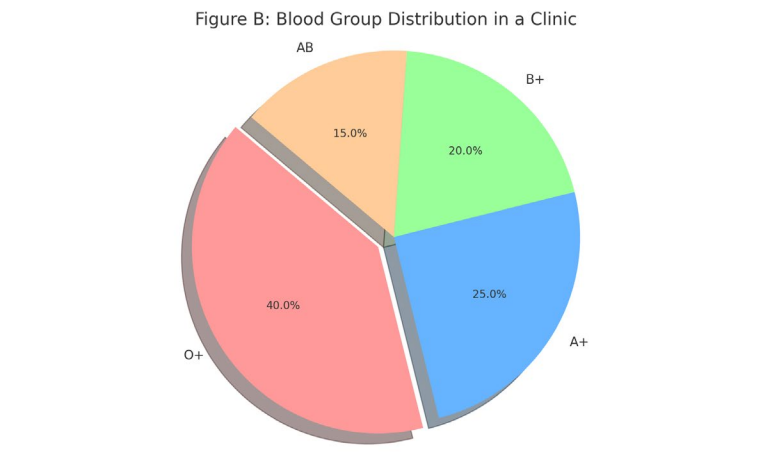


Figure B: Blood Group Distribution in a Clinic

3. Interpret the blood group distribution in ***Figure B***. Then, create a strategic plan for blood donation in your school or district, using biomedical reasoning and explaining how your plan supports Ghana's national health priorities.
4. Design a full biomedical experiment to test the effect of eating breakfast on SHS learners' concentration. Include: research question, hypothesis, variables, controls, sampling, ethical concerns, data analysis and how findings could influence school health policy.
5. Recreate two bar graphs with different Y-axis scales (0–250 and 150–230) for the same malaria data. Analyse how changing the scale might mislead readers and discuss the ethical responsibility of researchers when visualising health data.

6. Evaluate whether mean, median, or mode best represents a dataset with an outlier. Simulate the effect of removing the outlier and explain how this changes interpretation in biomedical research.
7. Critically assess the validity of a salt-reduction study with only 6 participants. Redesign the study with improved sampling and justify how this would improve the reliability of findings.
8. Create a graph to visualise BMI data: Underweight (15), Healthy (60), Overweight (20), Obese (5). Then, write a summary for the Ghana School Health Programme recommending health interventions based on the data.
9. Identify a confounding variable in a study comparing fast food and traditional diets. Propose a method to control for this confounding factor in future research.
10. Design a full research project investigating how breakfast affects SHS test performance. Include variables, sampling, analysis methods, visualisation tools and how your findings could inform national education policy.
11. Critique the use of a pie chart to compare average heart rates between two groups. Suggest and draw a better graph, explaining why it is more appropriate.

ANSWERS TO REVIEW QUESTIONS 1

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

Essay type

1.

a.

- Comparison: 25 patients understood partially, while 5 refused to consent.
- Interpretation: Many patients may not fully understand the content, but instead of refusing, they sign without being fully informed. This suggests that consent may be given without clarity, which is ethically risky.

b.

- Barrier 1: Use of technical or medical language that patients do not understand.
- Barrier 2: Lack of time spent explaining procedures due to busy schedules or poor communication skills.

c. Strategy: Use of translated materials or verbal explanations in local languages (e.g., Twi, Ewe, Ga) and use simple diagrams or role-play to explain procedures.

2.

a. If 35% of patients did not fully understand or refused consent, the lab may face legal consequences for carrying out procedures without proper consent. It may also invalidate the consent form in court.

b. Patients may lose trust in healthcare providers if they feel misled or uninformed. Poor understanding may result in non-compliance with treatment or legal complaints after adverse outcomes.

c. Step: Provide standard consent form templates in plain language and train staff to explain each section carefully before a patient signs.

3.

a.

- Comparison: Negligence (40%) is more common than malpractice (30%).
- Interpretation: Day-to-day carelessness (like skipping SOPs) happens more often than deliberate or serious professional errors.

b. Negligence is often due to forgetfulness, time pressure, or assuming minor steps do not matter, unlike malpractice which involves more severe violations.

c. Training Focus: Regular training on Standard Operating Procedures (SOPs), with practice simulations and reinforcement of biosafety and lab ethics.

4.

a.

- Breach of confidentiality may expose personal health data, leading to stigma or discrimination.
- Unreported errors can cause misdiagnosis or delayed treatment, affecting patient safety.

b. Even if they are less frequent, their impact is severe. For example, one unreported error in an HIV test could change someone's life. Hence, they deserve equal attention.

c. Recommendation: Introduce a "no-blame" error-reporting system where staff can report mistakes confidentially and receive support rather than punishment.

Case Scenario 1: Medication Administration Error

a. Immediate Actions: The nurse should immediately inform the attending physician and the pharmacy about the error, monitor the patient's vital signs, and document the incident thoroughly. They should also prepare to provide any necessary treatment for the side effects.

b. Improvement Measures: The hospital can implement a standardised checklist for medication administration, provide training on effective communication during shift changes, and use electronic health records to minimize human error.

Case Scenario 2: Informed Consent in Surgery

a. Steps for Informed Consent: The surgeon should have explained the procedure, risks, benefits, and alternatives in clear, understandable language. They should also have encouraged questions and confirmed that the patient comprehended the information before obtaining consent.

b. Hospital Improvements: Hospitals can conduct regular training sessions on informed consent practices, utilise standardised consent forms that are easy to understand, and involve patient advocates to ensure patients fully grasp the information.

Case Scenario 3: Laboratory Sample Mislabelling

a. Preventive Protocols: The lab should implement a double-check system for sample labelling, use barcoding technology, and ensure that all staff are trained in proper sample handling protocols.
b. Legal Implications: The technician may face disciplinary action for negligence, and the clinic could be held liable for damages in a civil suit, especially if the patient suffers physical or emotional harm due to the error.

Case Scenario 4: Breach of Confidentiality

a. Ethical and Legal Responsibilities: Healthcare workers are legally and ethically obligated to protect patient confidentiality. They must not disclose any patient information without consent, except in cases where there is a risk to public health.
b. Addressing the Breach: The health centre should conduct a thorough investigation, provide retraining on confidentiality policies, and establish clear consequences for breaches to reinforce the importance of patient privacy.

Case Scenario 5: Neglecting Safety Protocols

a. Safety Protocols: The technician should have worn appropriate PPE, such as gloves, goggles, and lab coats, as required for handling hazardous materials. Regular training on safety protocols should also be enforced.
b. Consequences of Behaviour: If this behaviour continues, the technician may face disciplinary action, and the laboratory could be subject to inspections or penalties from regulatory bodies. This could also lead to increased risk of accidents and a loss of trust in the laboratory's safety standards.

Case Scenario 6: Patient Confidentiality

a. Three professional or ethical responsibilities the biomedical scientist did not follow:
    - Maintain confidentiality of patient information
    - Share information only with authorised personnel
    - Respect the patient's right to privacy
    - Follow institutional policies on handling sensitive information
    - Adhere to professional codes of conduct (e.g. Ghana Medical and Dental Council / Allied Health Professions Council ethics)
b. Two short-term effects this behaviour may have on the patient:
    - Emotional distress, anxiety, or embarrassment
    - Fear of stigma or discrimination (especially with conditions like HIV)
    - Loss of trust in healthcare professionals
    - Refusal to return for treatment or follow-up care

c. Two long-term consequences for the biomedical scientist (legal and professional):

- Disciplinary action from regulatory bodies (e.g. suspension or revocation of licence)
- Legal consequences such as fines or lawsuits for breach of confidentiality
- Damage to professional reputation
- Loss of employment or demotion
- Requirement to undergo ethical retraining

d. Two actions the biomedical scientist should have taken to protect patient privacy:

- Discussed results only with staff directly involved in patient care
- Stored and shared data securely and discreetly
- Asked for guidance or clarification if unsure about confidentiality
- Participated in regular training on patient privacy laws and ethics

Case Scenario 7: Comparing Perspectives – Ethics and Consent

i. Two expectations or responsibilities of the biomedical scientist in both situations:

- Perform duties with accuracy and honesty (no falsification or shortcuts)
- Obtain informed consent before tests or research participation
- Maintain patient confidentiality
- Follow SOPs and safety procedures to avoid malpractice or negligence

ii. Two expectations or concerns of the patient in both situations:

- Receive full and understandable information before procedures
- Trust that the biomedical professional will act with care and integrity
- Be protected from harm caused by careless errors
- Have control over their participation in tests or treatments

iii. One way the scientist's failure could affect the patient's trust or health:

- The patient may avoid future medical treatment due to mistrust
- Errors could lead to misdiagnosis, delayed treatment, or harmful outcomes
- Damaged patient-provider relationships, affecting communication and care
- Increased anxiety and fear of the healthcare system

Case Scenario 8: Errors and Consequences

a. Three errors in reasoning or laboratory procedures:

- Skipped reviewing SOP despite time gap since last performance of the test

- Did not check the reagent's expiry date
- Failed to label samples correctly, leading to result mix-up
- Dismissed the error as minor, showing poor judgement

b. Is this negligence or malpractice? Justify your answer:

- *Malpractice:* The actions involved knowingly skipping critical procedures despite being trained, which is a failure to meet professional standards
- *Could also be viewed as gross negligence:* Carelessness beyond a simple mistake, especially given the consequences to the patient
- Shows disregard for duty of care and standard protocols

c. Two consequences for the patient and two for the scientist:
Patient

- Receives incorrect treatment or medication, possibly worsening their condition
- Emotional distress or anxiety due to the misdiagnosis

Scientist

- Investigation, possible disciplinary action, or loss of licence
- Legal consequences if patient sues for damages
- Damage to career reputation

Case Scenario 9: Designing an Investigation into Negligence

a. Clear problem statement

There has been an increase in mislabelled samples and reporting delays in the laboratory. These issues may be caused by negligence, weak safety protocols, or documentation failures. Identifying the root causes is essential to prevent harm, reduce liability, and improve laboratory practices.

b. Three methods to collect data

- Direct observation of laboratory practices and workflow
- Staff interviews or anonymous surveys to gather honest feedback
- Review of past error logs or incident reports
- Audit of documentation records (e.g. labelling and reporting timelines)

c. How to identify whether errors are due to negligence, malpractice, or system failure

- Negligence: Patterns of careless or repeated mistakes by individuals without ill intent
- Malpractice: Serious or deliberate violations of protocol by trained professionals
- System failure: Lack of training, unclear SOPs, poor staffing or supervision contributing to errors

- Cross-check staff actions with SOPs and training records

d. How to present findings to help improve practices and reduce liability:
   - Compile findings into a report with summaries, charts, and recommended changes
   - Present findings to lab management and safety committee
   - Suggest training sessions, new SOPs, or better tracking systems
   - Develop action plans to prevent future occurrences and monitor compliance

ANSWERS TO REVIEW QUESTIONS 2

1. B
2. B
3. B
4. D
5. C
6. B
7. B
8. C
9. C
10. **Scenario**: Identifying Safety Risks

a.

- Risk of infection or illness – When biohazard bags are left open, harmful bacteria or viruses can escape and infect people.
- Accidental injuries – If sharps containers are overfilled, someone might get cut or pricked by a needle or blade.
- Improper waste disposal – Throwing PPE like gloves or masks in the wrong bin can expose waste handlers to dangerous materials.
- Chemical exposure – Unsealed waste could contain chemicals that release harmful fumes or cause spills.
- Messy and unsafe work area – These practices make the lab disorganised, which increases the chances of mistakes or accidents.

b.

- Disease spread to the public – Improper disposal of lab waste could cause infections to spread through waste collection or animals.
- Environmental pollution – Chemicals or infectious materials may leak into the soil or water, harming animals and people.
- Loss of public trust – If people find out labs are unsafe; they may stop trusting scientific results or health services.
- Higher costs – Cleanup, legal issues and health problems could become expensive for the lab or hospital.

c.

- Used syringes thrown in open bins can lead to HIV or hepatitis infections if someone is accidentally pricked.
- Lab gloves with chemicals thrown in regular waste can release harmful substances.
- Leaking biohazard bags during transport can affect health workers or waste collectors.
- Overfilled sharps containers have led to real injuries in many healthcare settings.

11. Scenario: Understanding the Role of PPE and the Hierarchy of Controls

a.

- PPE only works if people wear it correctly, which does not always happen.
- It does not remove the danger, only blocks it from reaching the person.
- If PPE is damaged, it may give false protection.
- People may forget or use the wrong PPE, making it unreliable.
- It protects the individual, not the whole team.

b.

- Elimination removes the hazard completely, such as choosing not to use a harmful chemical.
- Engineering controls reduce risk by using physical barriers like fume hoods or sealed containers.
- These methods are more reliable because they do not depend on people remembering to follow steps.
- They protect everyone in the lab, not just one person.
- Better equipment or procedures reduce risk without extra effort from staff.

c.

- A biosafety cabinet protects users from airborne diseases and keeps the air clean.
- Safer chemical substitutions help avoid exposure to toxic substances.
- Machine guards or shields prevent injury from equipment even if gloves are forgotten.
- Waste containers with lids and colour codes help prevent mistakes during disposal.

12. Scenario: The Importance of Risk Assessment

- It helps identify what could go wrong and how to prevent it.
- It allows proper planning to keep everyone safe.
- It ensures the right equipment, PPE, and waste systems are ready.
- It avoids dangerous mistakes and saves time by being prepared.
- It is required for safety compliance in most labs.
- Hazard identification – This is spotting things that could cause harm, like hot plates, sharp tools or chemicals. It prepares people to avoid danger.
- Risk evaluation – This looks at how likely harm is and how serious it could be. If a risk is high, stronger controls are needed.
- Control measures – These are actions taken to reduce risk, such as using fume hoods or storing samples properly.
- Monitoring and review – This involves checking that safety plans are working and updating them if needed.
- Waste bins with colour codes (like yellow for infectious waste) help avoid mistakes.

- PPE must be selected based on risks identified before the experiment starts.
- Planning prevents problems like sample mix-ups or accidental exposure to chemicals.

13. **Scenario**: Planning Weaknesses and Biosafety Standards

- Disposal containers were not prepared, so waste may be placed incorrectly or left exposed.
- Labelling waste at the end increases the risk of confusion or incorrect disposal.
- Lack of preparation may lead to contamination or accidents during the experiment.
- Delays in clean-up can cause safety risks for the next lab users.
- Someone may be exposed to chemicals or infections from mismanaged waste.
- Important samples may be thrown away by mistake.
- The lab may fail safety inspections and lose approval to run experiments.
- Staff may be harmed or sued if serious accidents happen.
- Set up and label all disposal bins before the experiment begins.
- Include waste handling steps in the lab's risk assessment.
- Train staff on proper disposal and container use.
- Check that all equipment and materials are in place before starting.

14. **Scenario**: Analysing a Laboratory Audit Report

- Safety rules are not being followed consistently.
- Staff may not take biosafety seriously or lack proper training.
- The lab may lack strong supervision or regular checks.
- There may be no clear consequences for unsafe behaviour.
- Poor or irregular training of staff.
- No one is assigned to monitor safety regularly.
- Lack of clear instructions or reminders.
- Staff may be too busy or lack the right tools.
- Train all staff on biosafety procedures with regular updates.
- Assign a safety officer to monitor compliance and guide the team.
- Place clear signs and labels near bins, PPE stations and exits.
- Schedule regular safety checks and feedback meetings.

ANSWER TO REVIEW QUESTION 3

1.

a. Analyse the trends in ATP production
   - During light jogging, ATP production increases steadily and remains relatively stable.
   - During sprinting, ATP spikes quickly but levels off and may drop due to rapid energy use and limited oxygen supply.

b. Explanation (aerobic vs anaerobic)
   - Light jogging uses aerobic respiration (with oxygen), which is efficient and produces lots of ATP.
   - Sprinting relies on anaerobic respiration (without oxygen), which is faster but produces less ATP and causes lactic acid buildup.

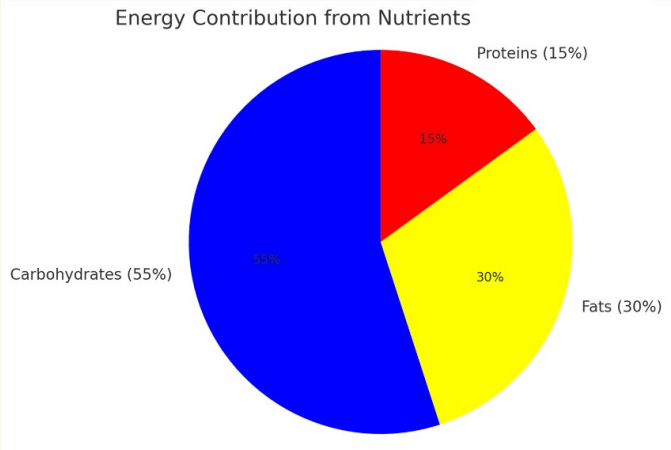
c. System responses
   - Circulatory system: Heart beats faster in both; stronger in sprinting.
   - Respiratory system: Breathing deepens to bring in more oxygen; very rapid during sprinting.
   - Muscular system: Muscles contract harder during sprinting and use more energy quickly.

d. If activity continued for 30 minutes
   - Muscle fatigue would increase more in sprinting due to lactic acid buildup.
   - Light jogging could be sustained longer as energy comes from ongoing aerobic respiration.

e. Training/recovery strategies
   - Interval training to boost endurance.
   - Hydration and balanced meals with carbs for sustained energy.
   - Rest and active recovery, like stretching or walking.

2.

a. Pie Chart:



b. Roles of nutrients

- Carbohydrates: Main source of quick energy. Broken down into glucose.
- Fats: Provide more energy per gram, used during long, low-intensity exercise.
- Proteins: Used when carbs/fats are low; help repair muscles.
  i. Used first: Carbohydrates.
  ii. Most energy per gram: Fats.
  iii. Used for repair when energy is low: Proteins.

c. Changes in different people

- Long-distance runner: Uses more fat after carbs are used up.
- Person recovering from surgery: Needs more protein for tissue repair.

3. Systems in Action (Sprint)

a. What each organ is doing

- Lungs: Bring in oxygen quickly.
- Heart: Pumps blood faster to muscles.
- Muscles: Use glucose and oxygen to move.
- Blood vessels: Carry nutrients and remove waste.
- Brain: Controls movement, focus, and balance.
- Digestive organs: Slow down; not a priority during exercise.

b. How systems work together

- Respiratory system brings oxygen.
- Circulatory system transports oxygen and glucose.
- Muscular system uses energy to contract.
- Nervous system coordinates movement and reactions.

c. Oxygen + glucose in muscles

Travel through blood → enter muscle cells → used in respiration → make ATP, the energy currency.

d. If oxygen is reduced

Cells switch to anaerobic respiration → less ATP → more fatigue and muscle cramps.

e. Two strategies to improve performance

- Endurance training to increase lung and heart efficiency.
- Balanced diet rich in carbs and hydration for energy.

4. Enzyme Deficiency and Physical Fatigue

a. Why fatigue occurs

- Enzyme deficiency: Poor digestion → fewer nutrients absorbed → less energy.
- Anaemia: Less haemoglobin → less oxygen transported → tiredness.

b. Affected systems
- Digestive system (enzymes)
- Circulatory system (anaemia)
- Muscular system (fatigue from low ATP)

c. Two interventions
- Medical: Enzyme supplements and iron tablets.
- Lifestyle: Iron-rich diet, smaller frequent meals, rest.

5. Multi-System Breakdown Map (Example: Asthma)

a. Systems affected
- Respiratory: Narrowed airways → hard to breathe.
- Circulatory: Less oxygen in blood.
- Muscular: Less oxygen → muscle fatigue.

b. Connections
- If lungs cannot supply oxygen, the heart and muscles struggle to perform.
- Less ATP made → less energy for movement and organ function.

6.

a. Food to energy: Food is digested → nutrients enter cells → broken down in mitochondria → ATP is made.

b. Oxygen + nutrients to muscles
- Brought by blood from lungs and gut.
- Delivered to muscles during exercise.

c. When oxygen is limited: Body switches to anaerobic respiration → makes less ATP + lactic acid.

d. Nervous + muscular system
- Nerves send fast signals to muscles.
- Muscles contract quickly and repeatedly for movement.

e. Support your guide with
- Diagrams: energy conversion, muscle-blood link.
- Examples: sprinting, cycling, football.

7. Oxygen Use and Energy Output During Exercise

8. Compare oxygen uptake

- Student A has higher oxygen uptake over time.
- Student B's oxygen uptake rises slowly and stays lower.

a. Oxygen vs ATP
   - More oxygen → more aerobic respiration → more ATP.
   - Student A produces more ATP because of better oxygen use.

b. Possible system differences
   - Student A may have stronger heart/lungs.
   - Student B might have weaker breathing muscles or smaller lung capacity.

c. Longer performance impact
   - Student B will fatigue faster.
   - Student A can maintain exercise longer.

d. Interventions
   - Cardio training to improve oxygen use.
   - Breathing techniques like nose-breathing.
   - High-carb diet before exercise.

ANSWERS TO REVIEW QUESTION 4

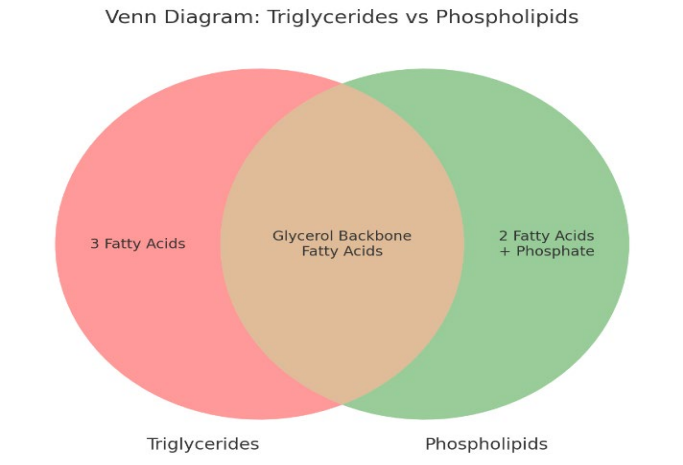
1. B. It enhances the visibility of blood vessels under X-ray imaging
2. A. LDL may decrease and HDL may increase
3. C. limit saturated fat and increase fibre intake
4. A. a clot forms and may block the vessel entirely
5. D. removes cholesterol from arteries efficiently
6. B. Cholesterol is hydrophobic and needs transport help
7. D. Triglycerides from liver to tissues for storage
8. A. Increases LDL levels and promotes plaque buildup
9. B. Exercise regularly and eat unsaturated fats daily
10. C. contain both water-loving and water-fearing ends
11. D. They contain polar heads and nonpolar tails.
12. C. LDL adds cholesterol to arteries, HDL removes it.
13. A. lead to arterial plaque buildup and eventual heart disease.
14. D. LDL cholesterol accumulation forming plaque
15. C. LDL moves cholesterol to cells; HDL returns it to the liver.

Short Answer Type

1. LDL contributes to plaque buildup in arteries, narrowing the vessels. Low HDL means less cholesterol is removed from the bloodstream, worsening the buildup and increasing the risk of atherosclerosis and heart attack.
2. A phospholipid has a hydrophilic (water-attracting) head and two hydrophobic (water-repelling) tails. This causes them to align in a bilayer with heads facing outward and tails inward, forming a flexible barrier.
3. Reducing fried foods lowers intake of saturated fats, which decreases LDL production. Exercise increases HDL, helping to remove excess cholesterol from the blood.
4. Narrowed arteries restrict blood flow to the heart muscle, reducing oxygen supply. Without oxygen, heart tissue may die, leading to a heart attack.
5. Lipids provide more energy per gram than carbohydrates and are stored compactly in fat tissue, making them more efficient for long-term energy needs.

Essay Type

6.



The Venn diagram should contain:

Similarities (T Ç P): Both contain glycerol and fatty acids.

Triglycerides (T): 3 fatty acids, used for energy.

Phospholipids (P): 2 fatty acids + phosphate, used in membranes.

a. He's overconsuming saturated triglycerides, which may increase LDL cholesterol levels and risk of heart disease or atherosclerosis.

b. Healthy meal plan:

- Breakfast: Boiled egg (phospholipids)
- Lunch: Palava sauce with kontomire and boiled yam (triglycerides + unsaturated fats)
- Snack: Avocado (steroid precursor)
- Dinner: Grilled tilapia and rice with salad (phospholipids, healthy fat)

7.

a. If Patient A adopts a healthy lifestyle, the following changes in the bar chart would show reduced cardiovascular risk:

- The LDL (bad cholesterol) bar would decrease, for example from 170 mg/dL down to below 130 mg/dL.
- The HDL (good cholesterol) bar would increase, for example from 30 mg/dL up to 50 mg/dL or more.

Explanation of Physiological Improvement

- A lower LDL level means less cholesterol is being delivered to the arteries, which reduces the chance of plaque buildup (atherosclerosis).
- A higher HDL level means the body is better at removing excess cholesterol from the blood and transporting it back to the liver for elimination.
- These changes improve blood flow and lower the risk of heart attacks and strokes.

Together, these shifts in the bar chart reflect a healthier cholesterol balance and improved heart health.

b. If Patient B begins eating a diet high in saturated fats (such as fried foods, fatty meats, and full-cream dairy), the following changes might occur:

LDL (bad cholesterol) level may increase, for example from 90 mg/dL to 140 mg/dL, because saturated fats raise LDL levels in the blood.

HDL (good cholesterol) level may decrease slightly, for example from 65 mg/dL to 50 mg/dL, because unhealthy eating can reduce the body's ability to remove excess cholesterol.

This shift would increase Patient B's risk of plaque buildup in arteries, which could lead to heart disease or stroke.

c. Patient A's Plan

Graph Values

- LDL: 170 mg/dL (very high)
- HDL: 30 mg/dL (low)

Lifestyle Recommendations

- Diet: Eat foods rich in unsaturated fats like avocados, nuts, and fish (e.g., salmon). Add oats, beans, and vegetables to meals to reduce LDL.
- Physical Activity: Exercise at least 30 minutes per day, 5 days a week (e.g., brisk walking, cycling).
- Avoid: Fried foods, sugary snacks, and processed meat.

Clinical Reasoning

- Lowering LDL will reduce the amount of cholesterol deposited in the arteries.
- Increasing HDL will help remove cholesterol from the blood, reducing plaque buildup.
  Together, these changes improve blood flow and reduce the risk of heart attacks.

Patient B's Plan

Graph Values

- LDL: 90 mg/dL (normal)
- HDL: 65 mg/dL (good)

Lifestyle Recommendations

- Maintain current healthy habits, including a balanced diet with fruits, vegetables, whole grains, and healthy fats.
- Continue regular physical activity (e.g., jogging, swimming).
- Limit intake of saturated fats to prevent LDL from rising.

Clinical Reasoning

- Keeping LDL low and HDL high protects the arteries.
- This balance supports a healthy cardiovascular system and lowers the risk of future heart disease.

8. Cholesterol is transported in the bloodstream by lipoproteins, primarily LDL and HDL.

- LDL (low-density lipoprotein) carries cholesterol from the liver to the cells of the body where it is used for cell membrane formation and hormone production. However, when in excess, LDL deposits cholesterol in the arterial walls, leading to plaque formation, a condition known as atherosclerosis.
- HDL (high-density lipoprotein), on the other hand, transports cholesterol away from the arteries and tissues back to the liver for excretion or recycling. HDL helps protect the heart by removing excess cholesterol from circulation.
- Thus, LDL is often referred to as "bad" cholesterol due to its role in plaque buildup, while HDL is called "good" cholesterol for its protective function.

9. An angiogram is a diagnostic imaging tool that uses contrast dye and X-ray technology to visualise blood vessels. In the provided image, the narrowing (stenosis) of a coronary artery is clearly visible in the circled section.

This narrowed segment indicates restricted blood flow to the heart muscle, which may lead to chest pain (angina), heart attacks, or other forms of coronary artery disease. Such images help physicians confirm the presence, location, and severity of arterial blockages. This guides treatment decisions such as whether to insert a stent, prescribe medications, or recommend bypass surgery. The clear visualisation enables early and accurate diagnosis of heart disease.

10.

- LDL and HDL have opposite effects on heart health.
- High levels of LDL lead to the deposition of cholesterol in the arterial walls, forming plaques that narrow the arteries (atherosclerosis). This reduces blood flow to the heart and increases the risk of heart attacks and strokes.
- Conversely, HDL removes excess cholesterol from the bloodstream and arterial walls, carrying it back to the liver for disposal. This reverse transport mechanism helps prevent plaque formation.
- A high LDL/low HDL profile increases cardiovascular risk, while low LDL/high HDL is protective. Maintaining this balance is critical. Scientific studies confirm that lowering LDL and increasing HDL reduces heart disease risk.

11. Compare and contrast the different types of lipids found in the human body. How do their structures relate to their functions?

- There are three main types of lipids: triglycerides, phospholipids, and sterols (like cholesterol).
- Triglycerides consist of three fatty acids attached to a glycerol backbone. They serve as the body's main energy storage molecules.

- Phospholipids have two fatty acids and a phosphate group; they are amphipathic and form the bilayer structure of cell membranes.
- Cholesterol has a ringed structure and regulates membrane fluidity. It is also the precursor for bile salts, vitamin D, and steroid hormones.
- While all lipids are hydrophobic, they differ in structure and function. Triglycerides store energy, phospholipids form structural barriers, and cholesterol maintains cell membrane integrity.

12. a.

- Kwame's lipid profile shows high LDL (170 mg/dL) and low HDL (30 mg/dL), both of which are concerning.
- High LDL increases the likelihood of plaque buildup in the coronary arteries, narrowing the vessels and reducing blood flow.
- Low HDL reduces the body's ability to remove excess cholesterol, compounding the risk.
- Together, this profile places Kwame at high risk for heart disease, including myocardial infarction (heart attack), stroke, and hypertension.

b.

- First, Kwame should increase his physical activity (e.g., daily brisk walking or cycling). This helps raise HDL and lower LDL levels.
- Second, he should adopt a heart-healthy diet rich in vegetables, fruits, whole grains, and healthy fats (like olive oil), while reducing intake of saturated fats and red meat. This dietary change directly lowers LDL and supports weight management.

13.

a.

- Fatima's triglyceride level of 200 mg/dL is borderline high.
- Elevated triglycerides contribute to the thickening and hardening of arterial walls (atherosclerosis), increasing the risk of stroke and heart disease.
- They are often linked to other components of metabolic syndrome such as high blood pressure, insulin resistance, and obesity.
- High triglyceride levels may also increase the risk of pancreatitis in extreme cases.

b.

- First, Fatima should reduce her intake of simple sugars and refined carbohydrates, which are quickly converted into triglycerides by the liver.
- Second, she should increase her consumption of omega-3 fatty acids from sources like salmon or flaxseeds, which have been shown to reduce triglyceride levels and improve overall heart health.

ANSWERS TO REVIEW QUESTION 5

1.

a. Bioinstrumentation, Biomechanics, Clinical Engineering, Rehabilitation Engineering, Tissue Engineering, Medical Imaging, Neural Engineering

b.

- Bioinstrumentation: Designing tools to check health, like machines that measure heartbeat or temperature.
- Biomechanics: Studying how the body moves and designing things like artificial joints or walking aids.
- Clinical Engineering: Making sure hospital equipment works properly and is safe to use.
- Rehabilitation Engineering: Creating devices to help people move or live better after an injury or illness.
- Tissue Engineering: Working on ways to repair or grow body parts using cells and materials.
- Medical Imaging: Making machines that help doctors see inside the body, like X-ray or ultrasound.
- Neural Engineering: Working on devices that help the brain or nerves, such as hearing aids or brain implants.

c.

- Bioinstrumentation helps doctors monitor a patient's condition accurately (e.g. heart rate monitors).
- Biomechanics allows patients with broken limbs to walk again using prosthetics.
- Clinical Engineering ensures medical equipment is safe and works correctly during treatment.
- Rehabilitation Engineering improves the lives of people with disabilities by helping them move independently.
- Tissue Engineering helps in healing wounds or replacing damaged organs.
- Medical Imaging helps doctors diagnose problems early and avoid surgery when possible.
- Neural Engineering allows people who are deaf to hear through hearing devices.

d.

Branch	Example Device/System
Bioinstrumentation	Digital thermometer, Glucometer
Biomechanics	Artificial leg, Knee brace
Clinical Engineering	Hospital bed with sensors, Suction machine
Rehabilitation Engineering	Wheelchair, Crutches, Standing frame
Tissue Engineering	Skin grafts, Lab-grown cartilage
Medical Imaging	Ultrasound scanner, X-ray machine
Neural Engineering	Hearing aid, Brain-computer interface

e.

- Biomedical engineers ask doctors and nurses about patient needs before designing equipment.
- They train health workers on how to use machines safely.
- They work with computer scientists to create health apps or electronic record systems.
- In rural clinics, they may help fix broken devices like thermometers or infusion pumps.
- In hospitals, they work as part of the healthcare team to keep machines running smoothly.

2.

a. Empathise

- I would talk to the nurses and ask them about the specific problems they face with the current intravenous fluid stand.
- I would also watch how they use it during their work to see when and where the problem happens.
- Example: I may observe that the stand is too heavy to push or that it gets stuck on the floor.

Define

- I would write down the main problem as: “Nurses find it difficult to move the intravenous fluid stand quickly and safely during emergencies because it is too heavy.”

- This helps me focus on what exactly needs to be improved.

Ideate

- I would brainstorm many possible solutions with my team. Some ideas include:
  - Use lighter materials like aluminium or plastic.
  - Add strong wheels with brakes.
  - Make a foldable or height-adjustable design.
  - Stand made with hollow aluminium rods (lightweight and strong).
  - Four large plastic wheels for easy movement.
  - Brakes to stop the stand from rolling away.
  - A hook for hanging the IV bag and an adjustable height pole.
  - Rubber handles for easy grip.
- Even simple ideas like adding handles for pushing can be helpful.

Prototype

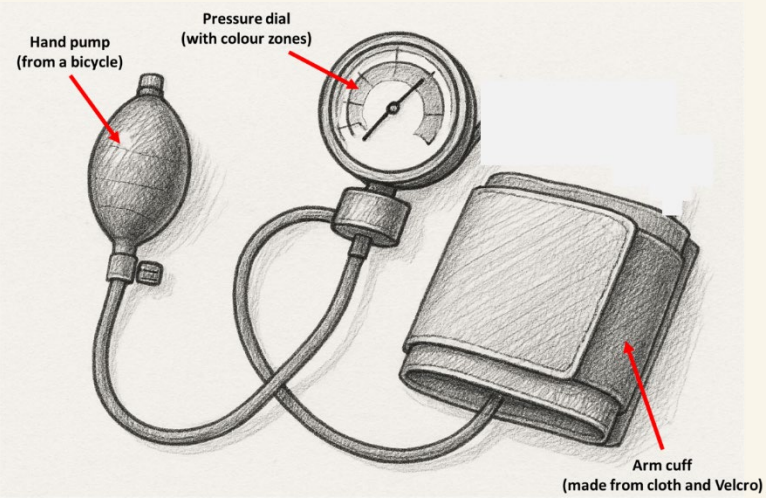
- I would make a simple model of the new stand using cardboard, plastic tubes, or wood if available.
- This model will not work like the real one but will show the shape, size, and features.

Test

- I would let the nurses try the model to see if it is easier to move.
- I would ask for their feedback and note what they like or dislike.
- Then, I would make changes to improve the design.

b. How do these steps help you create a better intravenous fluid stand?

- Empathise helps me understand the real problems faced by the people who will use the device.
- Define helps me stay focused on solving the main issue.
- Ideate gives many possible solutions, not just one, so I can compare and choose the best.
- Prototype allows me to test the idea without spending too much money.
- Test helps me know if my design is truly helpful, and I can improve it before making the final version.



c. Justification of how user needs influenced your design decisions

Model Answer

I designed the device to be

- Cheap: Because most rural clinics have very low budgets, I used recycled materials like bicycle pumps and old clock dials.
- Easy to use: I made sure the pump could be used by hand and the dial had colour zones so nurses could quickly check readings.
- Portable: Since some nurses travel from house to house, I made the monitor small and light.
- Durable: I added a clear cover over the dial to protect it from dust and made the arm cuff with strong cloth that can be washed.

4.

a. Model Answer

The device is a small, hand-held blood testing machine. It checks for common health problems like malaria, anaemia, or high blood sugar using just one drop of blood from a finger. The results appear on a screen or with coloured lights, so even nurses without lab training can understand them. It helps rural health workers, school clinics, and patients who do not live near hospitals. It works without electricity, using batteries or solar power.

b. Model Answer

The device is mainly for nurses, community health workers, and small rural clinics. These users need a machine that is:

- Portable and light to carry
- Easy to use without lab training
- Able to give quick results

3.

a.

- Empathise: In this stage, I talked to community nurses and patients in rural areas to understand their problems. Many said they struggle with checking blood pressure because the devices are expensive, hard to carry, or need electricity. I also noticed that some devices get spoiled easily due to dust and heat. This helped me understand what users really need.
- Define: The main problem is: *"Nurses in rural clinics do not have easy access to affordable, portable, and durable blood pressure monitors that work without electricity."* This problem statement helps guide the rest of the design.
- Ideate: I brainstormed many ideas to solve this problem. I thought of using hand-powered or solar-powered devices. I considered using plastic bottles, rubber pumps, and manual pressure gauges. My goal was to create a simple and affordable device that can check blood pressure without batteries or electricity. I chose to design a manual blood pressure monitor with a hand pump and an easy-to-read dial.
- Prototype: I built a basic model using local and recycled materials. I used:
    - A bicycle hand pump to inflate the cuff
    - A plastic tube to connect the pump to the pressure dial
    - A cloth band with Velcro to wrap around the patient's arm
    - A large clock face to act as the pressure dial
    - A clear plastic cover to protect the dial from dust
- Test: I tested the model with a nurse at a local clinic. She said the cloth band was easy to wrap and the pump was smooth. But the numbers on the dial were too small. So, I changed the dial to a larger one and added colours:
    - Green for normal pressure
    - Yellow for warning
    - Red for high pressure

  This made it easier for nurses to use, even without reading glasses.

b. Sketches or labelled diagrams of your prototype

Model Answer

A sample description is given here to guide the sketch.

- Affordable for small clinics
- Not dependent on electricity
  This will help them serve patients who live far from hospitals and cannot wait for lab results.

c. Model Answer

Many existing blood test machines are expensive and need electricity or special lab staff to operate. Some imported kits cost more than 500 Ghana cedis. Our device is cheaper, uses local materials, and can work with batteries or solar energy. It is easier to use and shows results with colour codes (like red for danger and green for normal), so nurses can decide quickly what to do. It is also designed to handle dust and heat, which are common problems in rural clinics.

d. Model Answers

- Visit rural clinics to demonstrate how the device works.
- Print posters in English and local languages.
- Organise free testing days during market days.
- Work with NGOs and district health offices.
- Share short videos on WhatsApp and Facebook showing the device in use.
- Offer one free trial device to clinics that attend a training session.
- Partner with health teacher associations to introduce the device in schools.
- Air short adverts or jingles on community radio.
- Put up demo booths during community health fairs or immunisation campaigns.

e. Model Answer

- Month 1–2: Finish design and test the first model at one clinic.
- Month 3: Collect feedback from nurses and improve the design.
- Month 4: Produce the first 20 devices.
- Month 5–6: Begin marketing in three districts with posters and demo visits.
- Month 7: Train users and give out trial devices.
- Month 8: Apply for approval from the Ghana Food and Drugs Authority.
- Month 9 and beyond: Expand to other regions and seek large donor funding.

5.

a. Model Answers

- Add a waterproof rubber seal around the battery and circuit area.
- Use a plastic casing with tight-fitting parts and no open gaps.
- Apply a thin waterproof coating (like varnish or resin) on the circuit board.
- Add a small drainage hole to let out any trapped moisture.

b. Model Answer

- Waterproof rubber seal: The rubber seal will stop water or sweat from entering the inside of the thermometer. It will be placed around the joint where the case opens. It can still be opened by hand or with a screwdriver when needed, and the rubber can be reused.

- Tight-fitting plastic casing: If the thermometer is made with fewer holes and stronger joints, water cannot easily get in. The case can be clicked or screwed open, so it can still be repaired or cleaned.

- Waterproof coating on circuit board: This clear layer protects the wires and chips from water. Even if a little water gets in, it will not damage the electronics. The board can still be removed and replaced when needed.

- Small drainage hole: If any moisture enters the thermometer, this hole will let it escape. It prevents water from staying inside. The hole will be small and placed at the bottom to avoid direct splash entry.

c. Model Answer

Adding waterproof seals or special coatings may increase the cost of materials. Also, making the case tighter could make it harder to open for repairs or battery replacement. If not done properly, a drainage hole could also let in more dust or dirt, making it harder to keep the device clean.

6.

a. Model Answer

Manual B is easier to read because it uses simple language and pictures. This makes it safer for users who may not understand medical terms. It also gives a better user experience because users can quickly understand how to use the device without needing extra help. Manual A may confuse users with its long sentences and hard words, which could lead to mistakes when using the device.

b. Model Answers

- Uses short and simple sentences that are easy to understand.
- Includes diagrams showing how to place the cuff and read the results.
- Uses bold labels and clear headings to separate steps.
- Uses local languages or translations for better understanding.
- Shows safety warnings using symbols (e.g. ⚠️) to catch attention.

c. Now, create a hybrid version that includes the best features of both.

Model Answer:

Hybrid Manual Example:

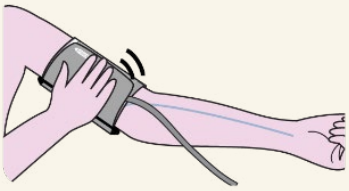
Title: *How to Use Your Digital Blood Pressure Monitor*

i. Step 1: Prepare the Monitor

- Make sure the batteries are working.
- Place the monitor on a flat table.

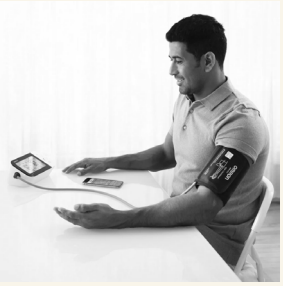
ii. Step 2: Wrap the Cuff Around Your Arm

- Put the cuff on your upper arm (see picture below).
- The tube should face downwards.
- Tighten it gently. That is, not too loose or too tight.



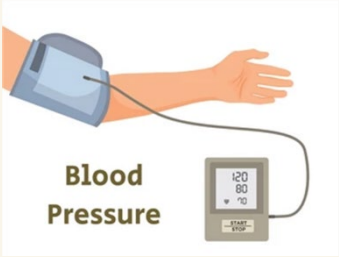
iii. Step 3: Take a Reading

- Press the 'Start' button.
- Sit quietly while the monitor works.
- Wait until the numbers stop changing.



iv. Step 4: Read the Results

- Your blood pressure will show as two numbers.
- Example: 120/80 mmHg (normal range).



Safety Tips

⚠️ Do not take readings immediately after exercise.

⚠️ Keep the monitor away from water.

d. Model Answer

I chose to combine the simple language and diagrams from Manual B with some helpful details from Manual A, like correct pressure values and safety tips. This makes the manual easy for people with little education to understand, while also giving enough information to use the device properly. Diagrams help users follow steps without needing someone to explain. These choices help users stay safe and use the monitor on their own, even in rural areas without regular medical support.

7.

a. Model Answer

Before a Class III infusion pump can be used in hospitals, it must pass several important regulatory checks:

- Pre-clinical Testing: The device must be tested in a laboratory to check if it works well and is safe. For example, it should deliver the right amount of fluid at the right speed.
- Clinical Trials: The device must be tested on real patients under the supervision of doctors to see how it performs in real conditions.
- Regulatory Review: All test results must be submitted to the local regulatory agency, such as FDA Ghana. They will check if the device meets safety and quality standards.
- Approval and Licensing: The device must be officially approved and given a licence before it can be sold or used in any hospital.
- Post-Market Surveillance: After the device is in use, the manufacturer must continue to monitor its performance and report any problems.

These checks help to make sure the device is safe, reliable, and works properly for patients.

b. Model Answers

- Concern 1: The device comes from a country with weak regulations.

  Response: We will require that it meets international standards like ISO 13485 and gets approval from trusted bodies like the U.S. FDA or European CE mark, in addition to FDA Ghana.

- Concern 2: There is no proof that the device works well in hospitals.

  Response: We will request clinical trial results and performance data showing the device has been used successfully in other hospitals.

- Concern 3: It may break down easily or be hard to repair.

  Response: We will ask for details about the materials used, the warranty, and

whether training and spare parts will be provided locally.

- Concern 4: Staff may not know how to use the new pump.

  Response: We will include user training in the purchase plan and request simple manuals in English or local languages.

- Concern 5: The device might be too expensive to maintain.

  Response: We will check the total cost of ownership and compare it to other pumps. If the upfront cost is low and it is durable, it may still be a good choice.

c. Model Answer

After reviewing the safety checks, test data, and international approvals, I recommend that the hospital accept the infusion pump for limited use under supervision or pilot testing. This allows us to try the device in a real hospital setting while closely monitoring performance and safety. If it meets standards set by FDA Ghana and performs well, we can move to full use. This cautious approach protects patients while giving us access to a potentially useful and affordable device.

8.

a. Model Answers

- Pre-clinical testing: to check the machine in a lab to see if it works safely.
- Clinical trials: to test the machine on real patients under doctor supervision.
- Regulatory review: to check if all test results meet safety and quality standards.
- Approval and licensing by FDA Ghana: to get permission to use the device in Ghana.
- Post-market surveillance: to monitor how the machine works after it starts being used.
- Factory inspection: to ensure the place where the machine was made follows safety rules.
- Label and user manual check: to make sure instructions are clear and safe for users.

b. Model Answer

Each step in the safety process helps to protect patients and health workers. Pre-clinical testing checks that the ultrasound does not overheat or give wrong readings. Clinical trials show how it works in real situations, so doctors know it is reliable. Regulatory review makes sure the machine meets Ghana's safety rules. Licensing confirms that the device is safe to use in hospitals. Post-market surveillance ensures any problems after use are reported and fixed quickly. Skipping these steps can lead to dangerous situations like wrong diagnoses or electric shock.

c. Model Answer

I think the hospital should accept the ultrasound machine only for testing and research purposes until it passes all safety checks. This way, the hospital does not waste a good donation, but also does not risk using unsafe equipment on patients. If the machine works well during testing and is later approved by FDA Ghana, then it can be used fully in the hospital. This approach protects patients and makes sure the hospital follows proper safety rules.

ANSWERS TO REVIEW QUESTION 6

1.

a. Jogging and Heart Rate Report

- Before Jogging: Mean = 85.625, Median = 85, Range = 12, SD = 3.59
- After Jogging: Mean = 77.875, Median = 78, Range = 11, SD = 3.45
- Interpretation: The average and variability of heart rates decreased after the jogging program, suggesting improved cardiovascular efficiency. This supports the hypothesis that regular aerobic activity reduces resting heart rate.

b. Health Recommendation: Encourage SHS learners to jog for 30 minutes each morning. Regular jogging improves heart function and lowers resting heart rate. Schools can incorporate morning jogging clubs as part of physical health programs.

c. Community Awareness Campaign

- Message: "Jog Your Way to a Healthier Heart!"
- Visual: Bar chart comparing mean resting heart rates before and after jogging
- Note: Regular exercise like jogging strengthens your heart and improves blood flow, helping you stay healthy and energetic.

2. Follow-Up Study on Diet + Hydration

- Hypothesis: Traditional breakfast + hydration improves stamina more than other combinations.
- Variables:
  - Independent variable: Type of breakfast and hydration
  - Dependent variable: Distance run or time to exhaustion
- Controls: Age, gender, prior physical activity
- Data collection: Record performance after breakfast types over a week.

3. Blood Donation Plan

- Since O+ is the most common blood group in the clinic, focus blood campaigns on ensuring steady O+ supply.
- Use SHS donation drives, partner with local health centres, and educate on the importance of blood matching and rare blood groups.

4. Breakfast and Concentration Study

- Hypothesis: Eating breakfast improves concentration.

- Sample: At least 60 SHS learners, randomly assigned.
- Test: Simple timed concentration tests.
- Controls: Same test conditions, similar sleep patterns.
- Data Analysis: Use bar graphs, calculate means and SDs.
- Policy impact: Results could support school meal programs.

5. Bar Graph Scale Ethics
   - A 150–230 scale exaggerates small differences and may mislead viewers.
   - A 0–250 scale gives honest representation.
   - *Conclusion:* Always select Y-axis ranges that fairly represent data to avoid misinformation, especially in public health.
6. Outlier Handling
   - Median is more reliable than mean when there are outliers.
   - Example*:* A very high blood pressure reading skews the mean upward.
   - Removing the outlier can lead to more accurate representation of typical values.
7. Sample Size Critique
   - 6 participants are too small for valid conclusions.
   - Improvements:
     - Increase to ≥30 participants
     - Include a control group
     - Run study over longer period
   - This enhances generalisability and reduces bias.
8. BMI Data Interpretation
   - Best Graph: Bar chart or pie chart
   - Summary: Most learners are healthy weight. Interventions needed for underweight and overweight learners (nutrition sessions, physical education activities).
9. Confounding Variable Control
   - Confounding variable: Prior physical activity
   - Control: Use surveys to record and match physical activity levels between groups, or random assignment with stratification.
10. Research Project: Breakfast vs. Performance
    - Hypothesis: Eating breakfast improves test performance.
    - Sample: 60 learners (randomised to eat or skip breakfast).

- Controls: Same test, same environment
- Data: Test scores recorded, analysed with mean, SD
- Graph: Bar graph or box plot
- Policy: Evidence could support inclusion of breakfast in school health policy.

11. Graph Critique

- Issue: Pie charts are not suited for comparing averages.
- Better Option: Bar graph or line chart
- Why: Easier to compare group averages side-by-side.
- Example: Bar chart with heart rates on Y-axis and groups on X-axis (e.g., Joggers vs. Non-Joggers).

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GLOSSARY

Absorption	Process by which nutrients pass through the intestine lining into the blood
Accountability	Being responsible for actions and correcting mistakes
Active Site	Region on enzyme where substrate binds and reaction occurs
Adhere	To follow guidelines strictly
Adipose Tissue	Body fat that stores energy and cushions organs
Advertising Claims	Statements promoting a product, must be true and approved
Aerobic Respiration	Respiration requiring oxygen to produce ATP efficiently
Alveoli	Tiny lung sacs for gas exchange
Amino Acids	Building blocks of proteins
Amphiphilic (Amphipathic)	Molecules with hydrophobic and hydrophilic parts
Anaerobic Respiration	Respiration without oxygen, produces less ATP and lactic acid
Angiogram	Imaging technique to visualise blood vessels
Angioplasty and Stenting	Procedures to open blocked arteries
Antagonistic Muscle Pairs	Muscles working opposite each other for movement
Apolipoproteins	Proteins binding lipids for transport
Approval	Official permission to sell/use a medical device

Atherosclerosis	Plaque buildup in arteries increasing heart risk
ATP (Adenosine Triphosphate)	Energy currency of the cell
Average	Central value of dataset
Bar Graph	Data representation using rectangular bars
Batch Number	Code tracking product groups
Bias	Systematic error or unfair influence in data
Bile Acids	Compounds aiding fat digestion
Biohazard	Harmful biological substance
Biological Catalyst	Enzyme increasing reaction rate
Biosafety	Following lab safety rules
Biosafety Officer	Person ensuring lab safety compliance
Breach	Breaking a rule or agreement
Calibration	Adjusting equipment for accuracy
Capillaries	Smallest blood vessels for exchange
Cardiovascular Disease	Disorders affecting heart and vessels
Cardiovascular System	System transporting oxygen, nutrients, waste
CE Mark	Symbol showing European safety compliance
Cell Membrane	Barrier protecting cell interior
Cellular Respiration	Conversion of glucose and oxygen into ATP
Chemical Waste	Leftover chemicals needing safe disposal
Cholesterol	Fat molecule essential for body functions
Class 1 Device	Low-risk medical device
Class 2 Device	Medium-risk medical device
Class 3 Device	High-risk medical device
Class 4 Device	Very high-risk medical device
Clinical Safety	Device safety in healthcare settings

Clinical Trials	Human studies testing device safety/effectiveness
Code of Conduct	Rules for professional behaviour
Confidentiality	Keeping private information secret
Consent	Patient permission after being informed
Consent Form	Document explaining treatment/test for agreement
Contamination	Spread of harmful substances
Control Group	Experiment group without treatment
Control Measures	Steps to reduce/remove risks
Cross-Bridge Cycle	Muscle contraction process involving myosin and actin
Cross-contamination	Harmful materials moving accidentally
Data Analysis	Applying techniques to evaluate data
Defibrillator	Device delivering shock to correct heartbeat
Dependent Variable	Variable measured in experiment
Derived Lipids	Molecules formed from lipids during metabolism
Device Recall	Taking back unsafe/defective device
Digestion	Breakdown of food into absorbable molecules
Digital Thermometer	Tool measuring body temperature
Documentation	Recording important information clearly
Donning and Doffing	Correct way to put on/remove safety gear
Duty of Care	Legal obligation to provide proper care
Eicosanoids	Molecules from fatty acids involved in inflammation
Emergency Procedure	Plan for quick safe action in lab accidents
Energy Density	Calories per weight of food
Energy Systems	Processes generating ATP for activity
Enzyme	Protein speeding chemical reactions
Ethics	Rules of right/wrong in professional behaviour
Experiment	Scientific procedure testing hypothesis

Expiry Date	Final usable date of device
False Claim	Unsupported product statement
Fatty Acids	Long-term energy molecules from fats
FDA (U.S.)	U.S. medical device regulator
FDA Ghana	Ghana's medical device regulator
Fume Hood	Cabinet protecting users from harmful vapors
Glucometer	Device measuring blood sugar
Glucose	Simple sugar, main energy source
Glycerol	Fat component convertible to glucose
Haemoglobin	Protein carrying oxygen in blood
Hazard	Anything causing harm
HDL (High-Density Lipoprotein)	"Good cholesterol" removing excess cholesterol
Heart Valve Implant	Device controlling blood flow in heart
Hierarchy of Controls	System prioritising risk reduction methods
Hydrocarbons	Molecules of carbon and hydrogen
Hydrophobic	Substances not mixing with water
Hyperlipidaemia	Elevated blood lipids
Hypothesis	Testable statement predicting variable relationship
Independent Variable	Variable manipulated in experiment
Infectious Waste	Waste containing harmful organisms
Informed Consent	Patient agreement after understanding risks
Infusion Pump	Device delivering fluids/medication
Inspection	Formal check of production safety
Insulin Resistance	Cells less responsive to insulin
Interconnected Systems	Body systems working together

ISO (International Organisation for Standardisation)	Global standards body
Joint	Structure where bones meet
Label	Information on device packaging
Laboratory-acquired Infection (LAI)	Illness caught in lab
Lactic Acid	By-product of anaerobic respiration
Liability	Legal responsibility for harm
Lipid Profile	Blood test measuring lipid levels
Lipids	Hydrophobic molecules like fats and oils
Lipoproteins	Complexes transporting fats in blood
Maintenance	Regular care of medical device
Malpractice	Serious professional mistake
Manufacturer	Company producing medical device
Median	Middle value in dataset
Medical Device	Tool diagnosing/treating health conditions
Medical Device Regulation	Legal process checking device safety
Misleading Advertisement	False/exaggerated promotional claims
Mitochondria	Organelles producing ATP
Mode	Most frequent dataset value
Monounsaturated Fatty Acids	Healthy fats with one double bond
Motor Neuron	Nerve cell carrying signals to muscles
Musculoskeletal System	Bones, muscles, tendons, joints
Nebuliser	Device turning medicine into mist
Negligence	Failure to take proper care

Pacemaker	Device controlling heart rhythms
Patient Understanding	How well patient understands information
PPE (Personal Protective Equipment)	Safety gear like gloves, masks
Phospholipids	Lipids forming cell membranes
Plaque	Artery buildup restricting blood flow
Polyunsaturated Fatty Acids	Heart-healthy fats with multiple double bonds
Post-market Surveillance	Monitoring device safety after approval
Pre-clinical Testing	Lab/animal testing before human trials
Professional Misconduct	Wrong/unethical workplace behaviour
Protocols	Established procedures/guidelines
Pulmonary Circulation	Blood flow between heart and lungs
Quality Control	Steps ensuring correct/safe device production
Range	Difference between highest and lowest dataset values
Recall	Removing unsafe device from market
Regulation	Official rules controlling devices
Regulatory Agency	Organisation enforcing device standards
Regulatory Review	Examining test results before approval
Reporting	Documenting workplace errors/safety concerns
Respiratory System	System responsible for breathing
Risk Assessment	Process identifying and preventing risks
Risk Classification	Grouping devices by danger level
Risk Factors	Behaviours/conditions increasing heart disease risk
Safety Procedures	Methods ensuring patient/worker safety
Safety Standards	Rules defining safe device use

Sample Handling	Proper management of biological samples
Saturated Fatty Acids	Fats with no double bonds
Scatter Plot	Graph showing variable relationships
Segregation	Separating waste by type
Sharps Waste	Items like needles requiring special disposal
Standard Deviation	Measure of data spread
SOP (Standard Operating Procedure)	Step-by-step lab instructions
Statistics	Mathematics of data collection/analysis
Steroids	Lipids involved in hormone production
Stethoscope	Device for listening to body sounds
Substrate	Molecule fitting enzyme's active site
Systemic Circulation	Blood flow between heart and body
Training	Ongoing professional education
Triglyceride Levels	Blood concentration of triglycerides
Triglycerides	Main dietary lipids, energy reserve
Unsaturated Fatty Acids	Fats with one/more double bonds
Variable	Factor affecting experiment outcome
Vitamin D	Fat-soluble vitamin essential for bone health
VLDL (Very Low-Density Lipoprotein)	Lipoprotein transporting triglycerides
Waste Stream	Path of lab waste

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This book is intended to be used for the Year Three Biomedical Science Senior High School (SHS) Curriculum. It contains information and activities to support teachers to deliver the curriculum in the classroom as well as additional exercises to support learners' self-study and revision. Learners can use the review questions to assess their understanding and explore concepts and additional content in their own time using the extended reading list provided.

All materials can be accessed electronically from the Ministry of Education's Curriculum Microsite.

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