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BIO 107

GENERAL BIOLOGY PRACTICAL I

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Course code: BIO 107

Course title: General Biology Practical I

Course credit load: 1 Unit

Series 1: Laboratory Hazards and Safety

- **Part 1.1: Common Laboratory Hazards**
    - Sub Part 1.1.1: Chemical hazards
    - Sub Part 1.1.2: Biological hazards
    - Sub Part 1.1.3: Physical and fire hazards
- **Part 1.2: Prevention of Laboratory Hazards**
    - Sub Part 1.2.1: Personal protective equipment
    - Sub Part 1.2.2: Safe handling and storage of materials
    - Sub Part 1.2.3: Laboratory rules and conduct
- **Part 1.3: First Aid in the Laboratory**
    - Sub Part 1.3.1: First aid for chemical exposure
    - Sub Part 1.3.2: First aid for cuts, burns, and electric shock
    - Sub Part 1.3.3: First aid kit contents and emergency procedures
- **Part 1.4: Laboratory Safety Symbols and Regulations**
    - Sub Part 1.4.1: Common laboratory safety symbols
    - Sub Part 1.4.2: Waste disposal and environmental safety
    - Sub Part 1.4.3: Laboratory safety regulations and responsibilities

Introduction

A biology laboratory provides access to living organisms, chemicals, heat sources, sharp instruments, and electrical equipment, any of which can cause injury if misused or handled carelessly. Understanding the hazards present in a laboratory and the precautions needed to prevent accidents is the essential foundation of safe, effective practical work.

This Series covers the common chemical, biological, physical, and fire hazards found in biology laboratories; the prevention measures including personal protective equipment, safe materials handling, and laboratory rules; first aid responses for chemical exposure, cuts, burns, and electric shock; and the safety symbols, waste disposal principles, and regulatory responsibilities that govern laboratory conduct. This safety knowledge underpins all the practical work covered in the remaining Series of this course.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 1.1** identify and describe common chemical, biological, and physical laboratory hazards,
- **SLO 1.2** describe prevention measures including personal protective equipment, safe handling, and laboratory rules,
- **SLO 1.3** describe first aid responses for chemical exposure, cuts, burns, and electric shock, and
- **SLO 1.4** recognise common laboratory safety symbols and explain waste disposal and safety responsibilities.

1.1 Common Laboratory Hazards

1.1.1 Chemical hazards

Chemical hazards in biology laboratories arise from acids (such as hydrochloric and sulphuric acid, which can cause severe burns on contact with skin or eyes), alkalis (such as sodium hydroxide, similarly corrosive), flammable organic solvents (such as ethanol and acetone, which ignite readily and produce toxic vapour), and toxic or carcinogenic reagents (such as formaldehyde used in specimen preservation, and various staining chemicals).

Chemical hazards are particularly dangerous because many harmful chemicals have no obvious warning properties such as colour or odour at the concentrations typically encountered, making it easy to underestimate the risk; additionally, some chemical effects, such as sensitisation to an allergen or the long-term effects of repeated low-level exposure to certain chemicals, accumulate over time rather than producing immediate visible harm, reinforcing the importance of consistent preventive practice rather than only responding to obvious immediate danger.

Fill in the blank: Chemical hazards in biology labs include acids, alkalis, flammable solvents, and toxic or _____ reagents such as formaldehyde.

1.1.2 Biological hazards

Biological hazards arise from contact with microorganisms (bacteria, fungi, viruses, and parasites), biological specimens (animal or plant tissue, blood, or other body fluids), or biological waste, any of which may carry pathogens capable of causing infection if ingested, inhaled, or contacted with broken skin or mucous membranes; practical biology courses frequently involve handling living or preserved organisms, cultures, and biological samples that may present infection risk if proper precautions are not followed.

The risk level of different biological materials varies considerably, with routine instructional specimens generally carrying lower risk than clinical samples or unknown cultures, but the appropriate response is to treat all biological material as potentially infectious rather than to attempt to estimate the specific risk for each individual sample, since the presence of

contamination is not always visually obvious and the consequences of unexpected exposure can be serious.

Fill in the blank: The appropriate response to biological materials in the laboratory is to treat all biological material as potentially _____ rather than to attempt to estimate specific risk for each sample.

1.1.3 Physical and fire hazards

Physical hazards include sharp instruments (scalpels, dissecting needles, broken glassware) capable of causing cuts and puncture wounds; electrical hazards from laboratory equipment (electric shock risk, particularly when equipment is used near water or with wet hands); heat hazards from Bunsen burners, hot plates, and autoclaves; and eye hazards from flying particles, chemical splashes, and ultraviolet light sources sometimes used in laboratory work.

Fire hazards arise particularly from the combination of flammable solvents and open flame or heat sources, such as a Bunsen burner used in proximity to ethanol solutions, a scenario demanding particular care; fire can also arise from electrical faults, overloaded sockets, and improperly stored flammable materials, reinforcing that fire hazard prevention requires attention to both the materials used and the condition and arrangement of laboratory equipment.

Fill in the blank: Fire hazards arise particularly from the combination of flammable _____ and open flame or heat sources, such as a Bunsen burner used near ethanol solutions.

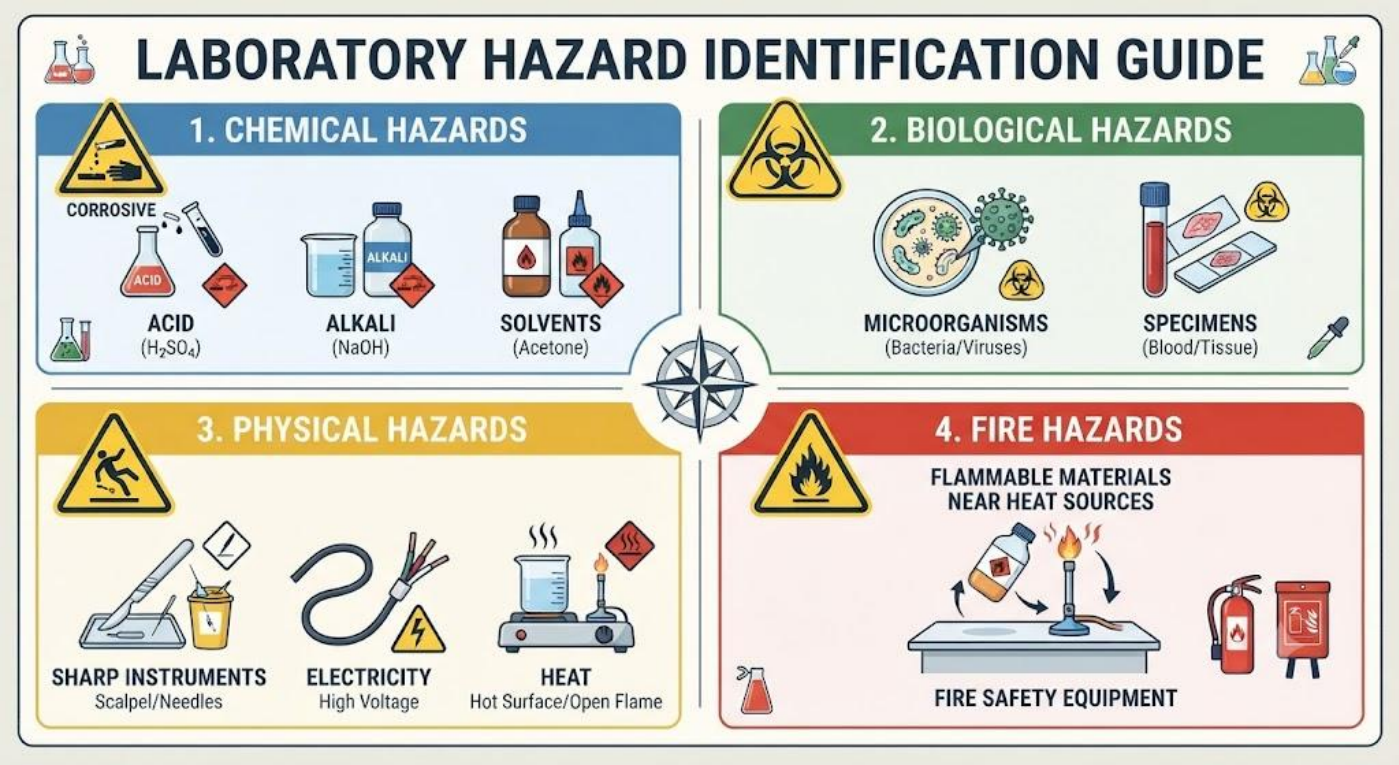

Figure 1.1: Common laboratory hazards

Pilot questions 1.1

1. Name four types of chemical hazards found in biology laboratories.
2. Explain why chemical hazards are particularly dangerous even when not immediately obvious.
3. Define biological hazard and name two sources of biological hazard in a biology laboratory.
4. Explain why all biological material should be treated as potentially infectious.
5. Name three physical hazards commonly found in biology laboratories.

1.2 Prevention of Laboratory Hazards

1.2.1 Personal protective equipment

Personal protective equipment (PPE) provides the primary physical barrier between a laboratory worker and the hazards present in the working environment; standard biology laboratory PPE includes a laboratory coat (protecting clothing and skin from chemical and biological splashes), safety goggles or spectacles (protecting eyes from chemical splashes and flying particles), gloves (protecting hands from chemical and biological contact), and, where airborne hazards are present, an appropriate face mask or respirator.

PPE is effective only when worn correctly and consistently: a laboratory coat left open, goggles pushed onto the forehead, or gloves with holes provide little meaningful protection; students should therefore understand not only which PPE is required for a given task but also how to wear it correctly, and should inspect gloves and other PPE for damage before use, replacing any items that are damaged or past their effective lifespan.

Fill in the blank: Standard biology laboratory PPE includes a laboratory coat, safety goggles, gloves, and, where airborne hazards are present, an appropriate face mask or _____ .

1.2.2 Safe handling and storage of materials

Safe chemical handling requires reading and understanding the label and safety information on every chemical container before use, using the minimum quantity of chemical needed for a task, working in a fume cupboard when handling volatile or toxic chemicals, and never pipetting by mouth (using a pipette filler or bulb instead); chemicals should never be mixed unless specifically instructed to do so, since many apparently harmless combinations produce toxic or dangerous reactions.

Safe storage requires keeping chemicals in their designated, properly labelled containers; storing flammable materials away from heat and ignition sources in appropriate, ventilated storage; keeping incompatible chemicals separate to prevent dangerous accidental reactions (such as acids and alkalis, or oxidising agents and flammable materials); and ensuring all containers are properly sealed when not in use to prevent vapour accumulation and accidental spills.

Fill in the blank: Safe chemical handling requires never pipetting by mouth, instead using a pipette _____ or bulb.

1.2.3 Laboratory rules and conduct

General laboratory rules that prevent accidents include: always wearing full PPE before entering the laboratory working area; never eating, drinking, or applying cosmetics in the laboratory; keeping the bench clear of unnecessary materials and personal belongings; tying back long hair and securing loose clothing before working near heat or rotating equipment; and reporting any accidents, spills, or equipment defects immediately to the supervising instructor rather than attempting to deal with them silently.

Students should also familiarise themselves with the location of emergency equipment in the laboratory before beginning work, including the fire extinguisher, emergency eyewash station, emergency shower, first aid kit, and fire exit, since in an actual emergency there is no time to search for these items; knowing their location and basic operation in advance could make a critical difference in the response time and effectiveness of emergency action.

Fill in the blank: Students should familiarise themselves with the location of emergency equipment including the fire extinguisher, eyewash station, emergency shower, first aid kit, and _____ before beginning work.

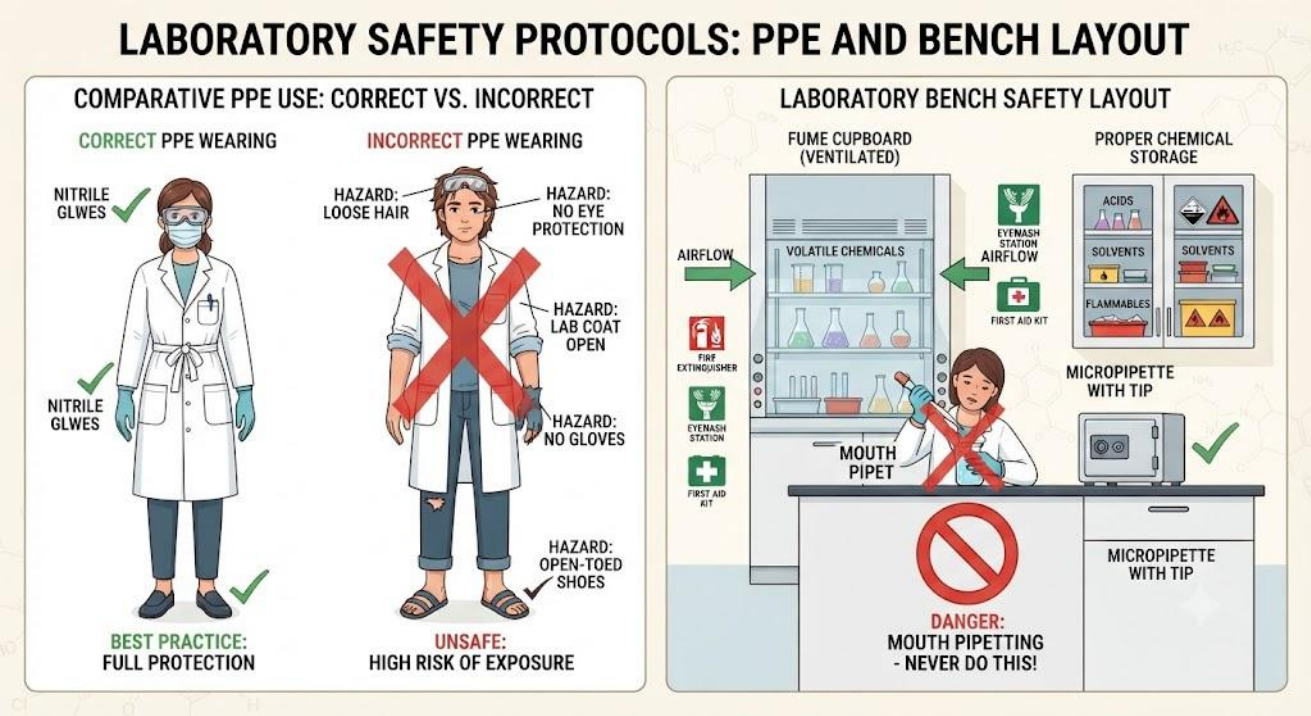

Figure 1.2: Laboratory hazard prevention

Pilot questions 1.2

1. Name four items of standard biology laboratory PPE.
2. Explain why PPE must be worn correctly to be effective.
3. Name two rules for the safe handling of chemicals.
4. Explain why incompatible chemicals must be stored separately.
5. Name five general laboratory rules that prevent accidents.

1.3 First Aid in the Laboratory

1.3.1 First aid for chemical exposure

The immediate response to chemical contact with skin or eyes is copious flushing with large amounts of running water for at least 15 to 20 minutes, which dilutes and physically removes the chemical and is effective for both acid and alkali exposure, despite the instinct to apply a neutralising agent; the emergency eyewash station should be used immediately for any chemical

entering the eye, holding the eye open during flushing, and medical attention should be sought after any significant chemical exposure to the eyes or skin.

If a chemical is swallowed, the victim should not be induced to vomit (since this can cause further damage, particularly for corrosive chemicals), but should instead be given water or milk to dilute the substance if they are conscious and able to swallow, and medical attention sought immediately; the chemical container or its label should be taken to the emergency treatment to inform medical personnel of the exact substance involved.

Fill in the blank: The immediate response to chemical contact with skin or eyes is copious flushing with large amounts of running water for at least _____ to 20 minutes.

1.3.2 First aid for cuts, burns, and electric shock

For minor cuts, the wound should be washed with clean running water, foreign material removed if visible and easily accessible, and an appropriate adhesive dressing applied; deeper or heavily bleeding cuts require direct pressure applied with a clean cloth or dressing while awaiting medical attention, and any puncture wound from a biological specimen or unknown material should be reported and assessed for infection risk even if minor.

For burns from heat or chemicals, cool (not ice cold) running water should be applied for at least 10 minutes to reduce tissue temperature and limit injury extent, then the burn covered with a clean, non-fluffy dressing; for electric shock, do not touch the victim while they remain in contact with the electrical source, but disconnect the power supply at the switch or socket immediately, then assess for consciousness and breathing and apply basic life support if needed while seeking emergency medical assistance.

Fill in the blank: For burns, cool running water should be applied for at least _____ minutes to reduce tissue temperature and limit injury extent.

1.3.3 First aid kit contents and emergency procedures

A standard laboratory first aid kit should contain adhesive wound dressings of various sizes, sterile gauze and bandages, wound closure strips, disposable gloves (for the first aider), eye wash

solution, burn gel or dressing, scissors, tweezers, and a first aid manual; the kit should be clearly identified, regularly inspected and restocked, and its location known to all laboratory users.

Emergency procedures require that all laboratory users know how to summon help (by telephone, alarm, or calling to a nearby instructor), the location of the nearest telephone, the relevant emergency contact numbers (for internal campus security, emergency services, or the nearest hospital), and the basic actions required while awaiting help, such as keeping an injured person still and warm, applying basic first aid, and ensuring the emergency services can access the building and locate the laboratory.

Fill in the blank: A standard laboratory first aid kit should contain adhesive wound dressings, sterile gauze and bandages, disposable gloves, eye wash solution, burn gel, scissors, tweezers, and a first aid _____ .

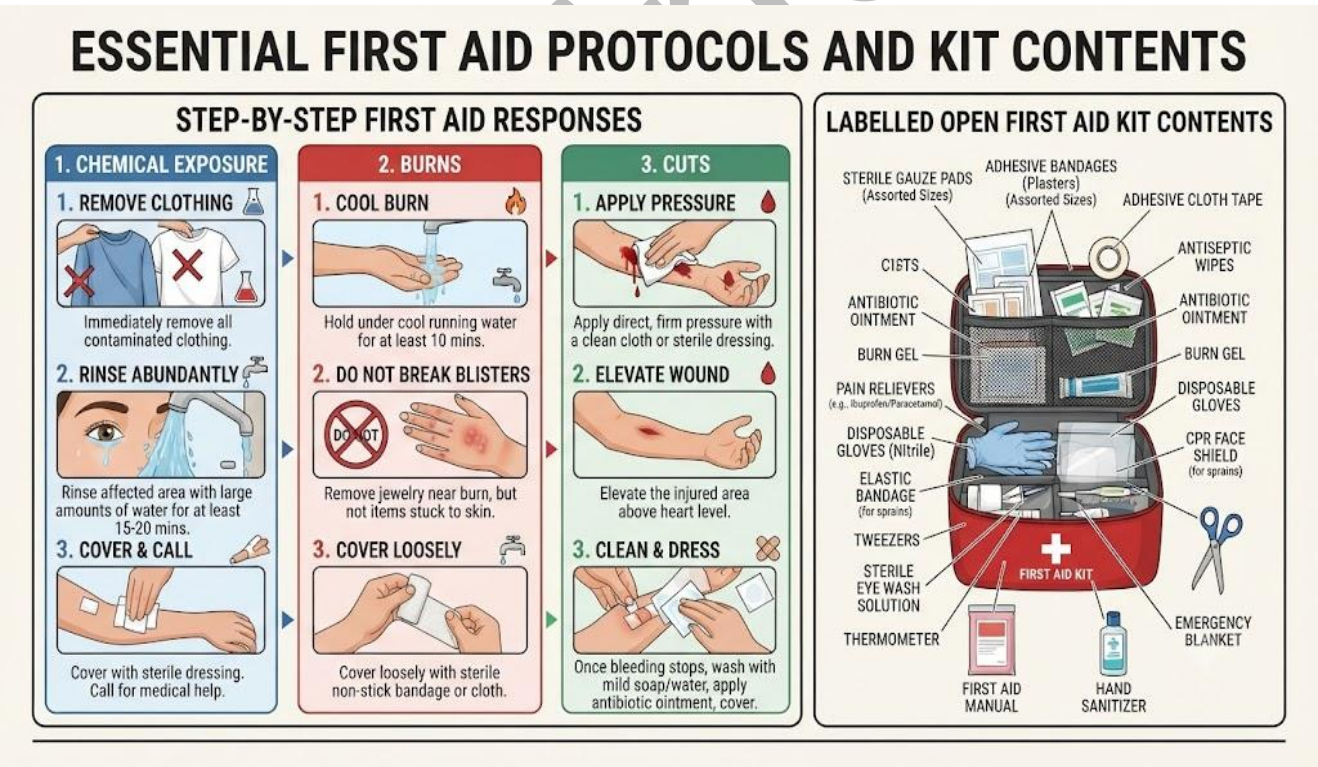

Figure 1.3: First aid in the laboratory

Pilot questions 1.3

1. Describe the immediate first aid response to chemical contact with the skin or eyes.

2. Explain why a person who has swallowed a chemical should not be induced to vomit.
3. Describe the first aid response to a minor cut in the laboratory.
4. Describe the first aid response to a burn.
5. Explain the correct response to a laboratory electric shock before touching the victim.

1.4 Laboratory Safety Symbols and Regulations

1.4.1 Common laboratory safety symbols

Standardised safety symbols provide immediate visual communication of hazards without requiring the reader to understand any specific language; common symbols include the flammable materials symbol (a flame icon, indicating highly flammable liquids or gases), the corrosive symbol (a surface and hand being damaged by dripping liquid, indicating acids and alkalis), the toxic/skull symbol (indicating acutely toxic materials), the biohazard symbol (a trefoil design indicating biological materials requiring containment), and the irritant/harmful symbol (an exclamation mark, indicating materials that are irritant, harmful, or sensitising without being severely toxic).

Additional symbols commonly encountered include the oxidising agent symbol (a flame over a circle, indicating materials that intensify fire), the eye protection symbol (goggles icon, indicating mandatory eye protection), and the general warning symbol (a yellow triangle with an exclamation mark, indicating a general hazard requiring attention); the ability to recognise and correctly interpret these symbols is a fundamental practical skill allowing laboratory users to take appropriate precautions before handling any labelled material.

Fill in the blank: The biohazard symbol, a _____ design, indicates biological materials requiring containment and careful handling.

1.4.2 Waste disposal and environmental safety

Different categories of laboratory waste require different disposal methods: chemical waste must not be poured down the sink unless specifically confirmed as safe for drain disposal (since many

laboratory chemicals are harmful to aquatic organisms or react dangerously with water or other chemicals in drains), but should instead be collected in appropriately labelled, sealed chemical waste containers for proper disposal through designated waste collection services.

Biological waste (used cultures, biological specimens, contaminated materials) must be inactivated before disposal where required (for example, by autoclaving, a high-temperature steam sterilisation process, for infectious materials), and disposed of in clearly labelled biological waste bags or bins, not in general waste; sharp items including broken glass, needles, and scalpel blades must be placed in dedicated sharps containers rather than general waste bags, protecting waste handling personnel from injury.

Fill in the blank: Sharp items including broken glass, needles, and scalpel blades must be placed in dedicated _____ containers rather than general waste bags.

1.4.3 Laboratory safety regulations and responsibilities

Laboratory safety is governed by institutional regulations (rules specific to the university or department, typically including requirements for induction training before first laboratory access, mandatory PPE use, and supervision requirements for student practical work), national occupational health and safety legislation (setting minimum standards for working environments and employer/employee responsibilities), and, for specific materials, substance-specific regulations covering handling, storage, and disposal.

Responsibility for laboratory safety is shared: the institution and supervising staff are responsible for providing a safe working environment, appropriate equipment and PPE, adequate supervision, and safety training; students are responsible for following all instructions and rules, wearing PPE correctly, reporting accidents and near-misses, and never conducting unauthorised experiments or handling materials without appropriate guidance and supervision, since both groups fulfilling their respective responsibilities is necessary for a genuinely safe laboratory environment.

Fill in the blank: Both the institution and students share responsibility for laboratory safety, with students responsible for following rules, wearing PPE correctly, and reporting accidents and _____ .

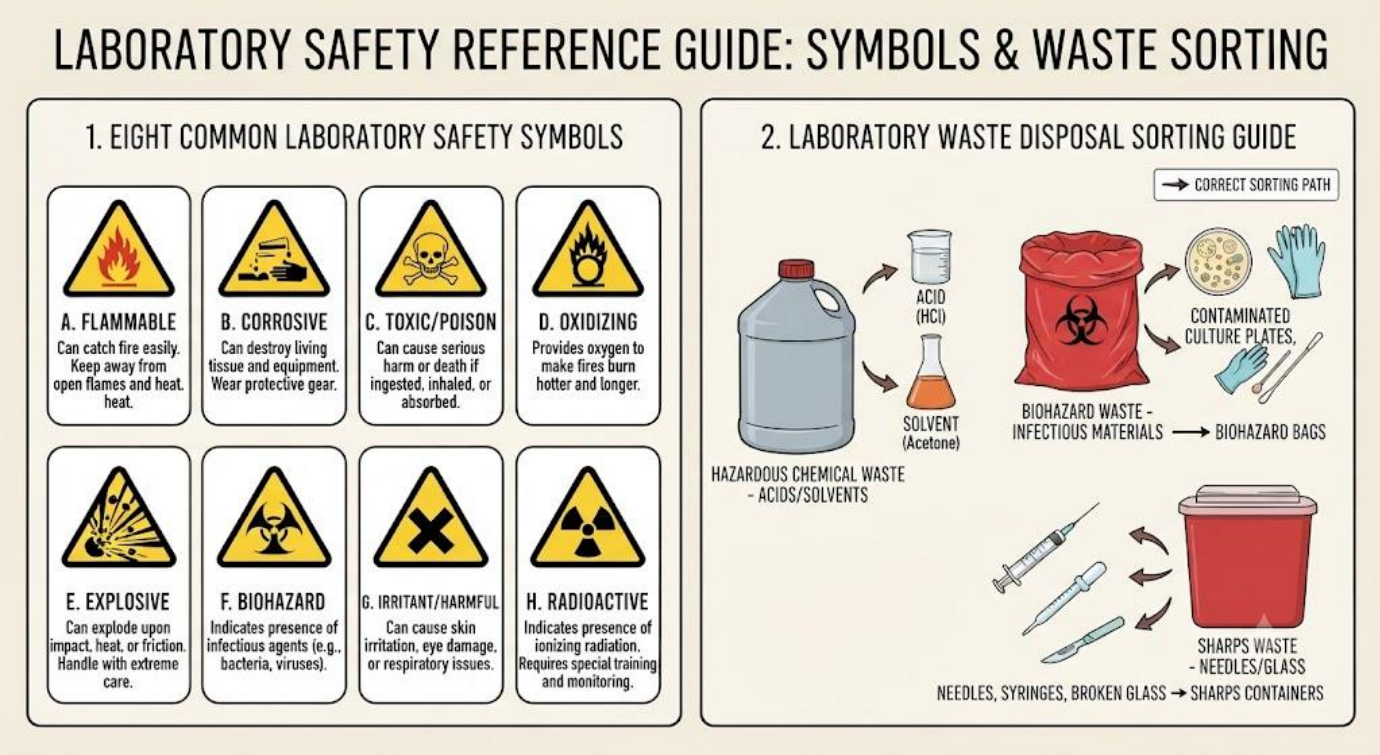

Figure 1.4: Laboratory safety symbols and waste disposal

Pilot questions 1.4

1. Describe what the biohazard symbol looks like and what it indicates.
2. Describe what the corrosive symbol looks like and what type of materials it indicates.
3. Explain why most laboratory chemical waste should not be poured down the sink.
4. Explain how biological waste should be treated before disposal where required.
5. Name two responsibilities students have for laboratory safety.

Series Summary

This Series introduced **laboratory safety principles, hazards, and emergency procedures**. Laboratory hazards include **chemical hazards** (acids, alkalis, solvents, and toxic reagents), **biological hazards** (microorganisms, specimens, and body fluids, all treated as potentially infectious), **physical hazards** (sharp instruments, electricity, and heat), and **fire hazards** involving flammable materials near ignition sources. Preventive measures include the correct use of **personal protective equipment (PPE)** such as laboratory coats, gloves, goggles, and masks, safe chemical handling practices including the use of **fume cupboards**, avoiding mouth pipetting, using only the required quantities of chemicals, and following laboratory rules such as prohibiting food and drinks, keeping benches tidy, and knowing the location of emergency equipment.

The Series also covered **first aid, safety symbols, and waste management**. Appropriate first aid includes flushing chemical exposures with water for **15–20 minutes**, cooling burns under running water for **10 minutes**, cleaning and dressing cuts after applying pressure to stop bleeding, and disconnecting the power source before assisting victims of electric shock. Students also learned to recognise common **laboratory safety symbols**, including flammable, corrosive, toxic, biohazard, irritant, oxidising, eye protection, and general warning signs. Proper disposal of laboratory waste requires the use of designated **chemical waste containers, biological waste bags, and sharps containers**, while maintaining laboratory safety is a **shared responsibility** of all laboratory users. By completing this Series, students should achieve SLOs **1.1–1.4**.

Glossary of Terms

- **Autoclave:** an apparatus using high-temperature steam under pressure to sterilise biological materials before disposal or reuse.
- **Biohazard:** a biological material that poses a risk of infection or other harm to humans or the environment.

- **Corrosive:** a chemical capable of damaging or destroying living tissue or other materials on contact.
- **Fume cupboard:** an enclosed, ventilated workspace used when handling volatile or toxic chemicals to prevent inhalation of hazardous vapour.
- **Personal protective equipment (PPE):** equipment worn to minimise exposure to hazards, including laboratory coat, goggles, gloves, and mask.
- **Sharps container:** a rigid, puncture-resistant waste container for disposing of sharp items such as needles, blades, and broken glass.
- **Biohazard symbol:** a standardised trefoil design indicating biological materials requiring containment.

Concept Check Questions [Series 1]

Objective Questions

1. Chemical hazards include acids, alkalis, flammable solvents, and toxic or _____ reagents. (Linked to SLO 1.1)
2. All biological material should be treated as potentially _____ regardless of apparent risk. (Linked to SLO 1.1)
3. Chemical exposure to skin or eyes requires flushing with running water for at least _____ minutes. (Linked to SLO 1.3)
4. Sharp items must be placed in dedicated _____ containers rather than general waste bags. (Linked to SLO 1.4)
5. The biohazard symbol uses a _____ design to indicate biological materials requiring containment. (Linked to SLO 1.4)

Short-Answer Questions

6. Name four types of standard biology laboratory PPE. (Linked to SLO 1.2)
7. Describe the immediate response to chemical contact with the eye. (Linked to SLO 1.3)
8. Name two physical hazards commonly found in biology laboratories. (Linked to SLO 1.1)
9. Name three items a standard laboratory first aid kit should contain. (Linked to SLO 1.3)
10. Explain why laboratory chemical waste should not be poured down the sink. (Linked to SLO 1.4)

Long-Answer Questions

11. Describe common laboratory hazards and the prevention measures applicable to each. (Linked to SLOs 1.1, 1.2)

12. Describe first aid responses for chemical exposure, burns, and electric shock. (Linked to SLO 1.3)
13. Explain common safety symbols, waste disposal categories, and shared safety responsibilities. (Linked to SLO 1.4)

Answers to Concept Check Questions [Series 1]

Objective Questions

1. Carcinogenic.
2. Infectious.
3. 15.
4. Sharps.
5. Trefoil.

Short-Answer Questions

6. Laboratory coat, safety goggles, gloves, and face mask/respirator.
7. Use the emergency eyewash station immediately, hold the eye open, flush for 15-20 minutes, then seek medical attention.
8. Sharp instruments and electrical hazards (or heat hazards).
9. Adhesive dressings, sterile gauze, and disposable gloves (or eye wash solution, burn gel).
10. Many laboratory chemicals are harmful to aquatic organisms or react dangerously with other drain contents.

Long-Answer Questions

11. Chemical hazards (acids, alkalis, solvents) require PPE and fume cupboard use. Biological hazards require treating all material as infectious. Physical hazards require care with sharps, electricity, and heat. Fire hazards require keeping flammables away from ignition sources.

12. Chemical exposure: flush with water for 15-20 minutes; do not induce vomiting if swallowed. Burns: cool running water for 10 minutes, then cover. Electric shock: disconnect power before touching the victim, then assess and apply life support if needed.
13. Common symbols include flammable, corrosive, toxic, biohazard, and irritant. Waste is sorted into chemical waste containers, biological waste bags, and sharps containers. Both institution and students share responsibility for maintaining a safe laboratory environment.

Answers to Pilot Questions [Series 1]

Part 1.1

1. Acids, alkalis, flammable organic solvents, and toxic or carcinogenic reagents.
2. Many chemicals lack obvious warning properties, and some harmful effects accumulate over time rather than causing immediate visible harm.
3. A biological hazard is a biological material posing infection risk; sources include microorganism cultures and biological specimens.
4. Contamination is not always visually obvious, and the consequences of unexpected exposure can be serious.
5. Sharp instruments, electrical hazards, and heat hazards (or eye hazards).

Part 1.2

1. Laboratory coat, safety goggles, gloves, and face mask/respirator.
2. PPE that is worn incorrectly, such as a coat left open or goggles pushed up, provides little meaningful protection.
3. Work in a fume cupboard for volatile chemicals and never pipette by mouth.
4. Some chemical combinations produce toxic or dangerous reactions even if the individual components seem harmless.
5. Always wear PPE; never eat or drink; keep bench clear; tie back hair; report accidents immediately.

Part 1.3

1. Flush copiously with running water for at least 15 to 20 minutes at the eyewash station, then seek medical attention.
2. Vomiting can cause further damage, particularly for corrosive chemicals.
3. Wash with clean running water, apply pressure if needed, and cover with an adhesive dressing.
4. Apply cool running water for at least 10 minutes, then cover with a clean, non-fluffy dressing.
5. Disconnect the power supply at the switch or socket before touching the victim.

Part 1.4

1. The biohazard symbol is a trefoil design; it indicates biological materials requiring containment and careful handling.
2. The corrosive symbol shows a surface and hand being damaged by dripping liquid; it indicates acids and alkalis.
3. Many laboratory chemicals are harmful to aquatic organisms or react dangerously with water or other drain contents.
4. Infectious biological waste should be autoclaved (high-temperature steam sterilisation) before disposal in labelled biological waste bags.
5. Following all rules and instructions, and wearing PPE correctly (or reporting accidents and near-misses).

References and Attributions

Textual References (Books and External Sources)

- Royal Society of Chemistry (RSC). (2023). Laboratory safety guidance. RSC, London.
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- Health and Safety Executive (HSE). (2022). Laboratory safety guidelines. HSE, UK.
- Campbell, N. A., & Reece, J. B. (2018). Biology (11th ed.). Pearson.

Figures, Plates, Tables, and Boxes

- Figure 1.1: Common laboratory hazards Attribution: AI generated. Suggested OER search string: "laboratory hazards chemical biological physical fire safety diagram biology OER".
- Figure 1.2: Laboratory hazard prevention Attribution: AI generated. Suggested OER search string: "personal protective equipment PPE laboratory safety rules bench layout diagram biology OER".
- Figure 1.3: First aid in the laboratory Attribution: AI generated. Suggested OER search string: "laboratory first aid chemical exposure burn cut electric shock kit diagram biology OER".
- Figure 1.4: Laboratory safety symbols and waste disposal Attribution: AI generated. Suggested OER search string: "laboratory safety symbols biohazard corrosive flammable waste disposal sharps diagram biology OER".

Course code: BIO 107

Course title: General Biology Practical I

Course credit load: 1 Unit

Series 2: Measurements in Biology

- **Part 2.1: Importance and Principles of Measurement**
    - Sub Part 2.1.1: Why measurement matters in biology
    - Sub Part 2.1.2: SI units used in biology
    - Sub Part 2.1.3: Accuracy, precision, and significant figures
- **Part 2.2: Measuring Length and Area**
    - Sub Part 2.2.1: Measuring length with rulers and micrometers
    - Sub Part 2.2.2: Measuring biological specimens
    - Sub Part 2.2.3: Scale and magnification calculations
- **Part 2.3: Measuring Mass, Volume, and Temperature**
    - Sub Part 2.3.1: Measuring mass with a balance
    - Sub Part 2.3.2: Measuring volume of liquids
    - Sub Part 2.3.3: Measuring temperature
- **Part 2.4: Recording and Presenting Measurements**
    - Sub Part 2.4.1: Constructing data tables
    - Sub Part 2.4.2: Constructing graphs
    - Sub Part 2.4.3: Sources of error and improving reliability

Introduction

Biology depends on careful, accurate measurement to produce reliable, reproducible results; without standardised measurement, it would be impossible to compare results between different experiments, laboratories, or researchers. This Series introduces the fundamental principles of measurement as applied in biological practical work, covering the units, instruments, and techniques used across the major measurable quantities encountered in a biology laboratory.

This Series covers the importance of measurement in biology, SI units, and the concepts of accuracy and precision; measurement of length (including scale and magnification calculations essential for microscope work); measurement of mass, volume, and temperature; and the correct methods for recording and presenting measurement data in tables and graphs, together with an understanding of measurement error and how to reduce it.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 2.1** explain the importance of measurement, state relevant SI units, and distinguish accuracy from precision,
- **SLO 2.2** measure length and calculate scale and magnification for biological specimens,
- **SLO 2.3** measure mass, volume, and temperature using appropriate laboratory instruments, and
- **SLO 2.4** construct data tables and graphs and identify sources of measurement error.

2.1 Importance and Principles of Measurement

2.1.1 Why measurement matters in biology

Measurement is fundamental to scientific work because it provides an objective, quantitative basis for describing observations, comparing results, and testing hypotheses; without

measurement, biological descriptions would remain qualitative and subjective, making it impossible to determine with confidence whether two observations are the same, different, or whether a change has occurred over time or between experimental conditions.

Consistent, standardised measurement also makes scientific results reproducible, the key criterion for scientific validity, since another researcher in a different location with the same materials should obtain the same results if they follow the same procedure and use the same measurement approach; the International System of Units (SI) provides the globally agreed standardised measurement framework that makes this reproducibility possible across national and language boundaries.

Fill in the blank: Consistent, standardised measurement makes scientific results _____ , the key criterion for scientific validity, since another researcher should obtain the same results following the same procedure.

2.1.2 SI units used in biology

The International System of Units (SI) defines seven base units, of which biology commonly uses: the metre (m) for length, the kilogram (kg) for mass, the second (s) for time, the kelvin (K) for thermodynamic temperature (though Celsius is used in most routine biology laboratory work), the mole (mol) for amount of substance, and the candela (cd) for light intensity in some specialised measurements.

Biological measurements frequently use derived or prefixed units: the centimetre (cm, one hundredth of a metre), millimetre (mm, one thousandth of a metre), micrometre (micrometres, one millionth of a metre, the typical unit for cell measurement), millilitre (mL, one thousandth of a litre, equivalent to one cubic centimetre) and milligram (mg, one thousandth of a gram) are all routinely encountered across different types of biology practical measurements.

Fill in the blank: The micrometre, one _____ of a metre, is the typical unit for measuring cells in microscopy work.

2.1.3 Accuracy, precision, and significant figures

Accuracy refers to how close a measurement is to the true value, while precision refers to how repeatable or consistent a set of measurements are with one another, regardless of whether they are close to the true value; a measurement or set of measurements can be precise but inaccurate (consistently wrong in the same direction due to a systematic error), accurate but imprecise (varying around the correct value), or both accurate and precise (the ideal outcome).

Significant figures are the meaningful digits in a measured value, reflecting the actual precision of the measuring instrument; a measurement recorded as 12.5 cm implies that the last digit is meaningful and the instrument can distinguish between, say, 12.4 cm and 12.6 cm, while recording the same measurement as 12.50 cm implies greater precision than warranted unless the instrument genuinely supports that additional digit, so recorded values should match the precision of the instrument used.

Fill in the blank: _____ refers to how close a measurement is to the true value, while precision refers to how repeatable or consistent a set of measurements are with one another.

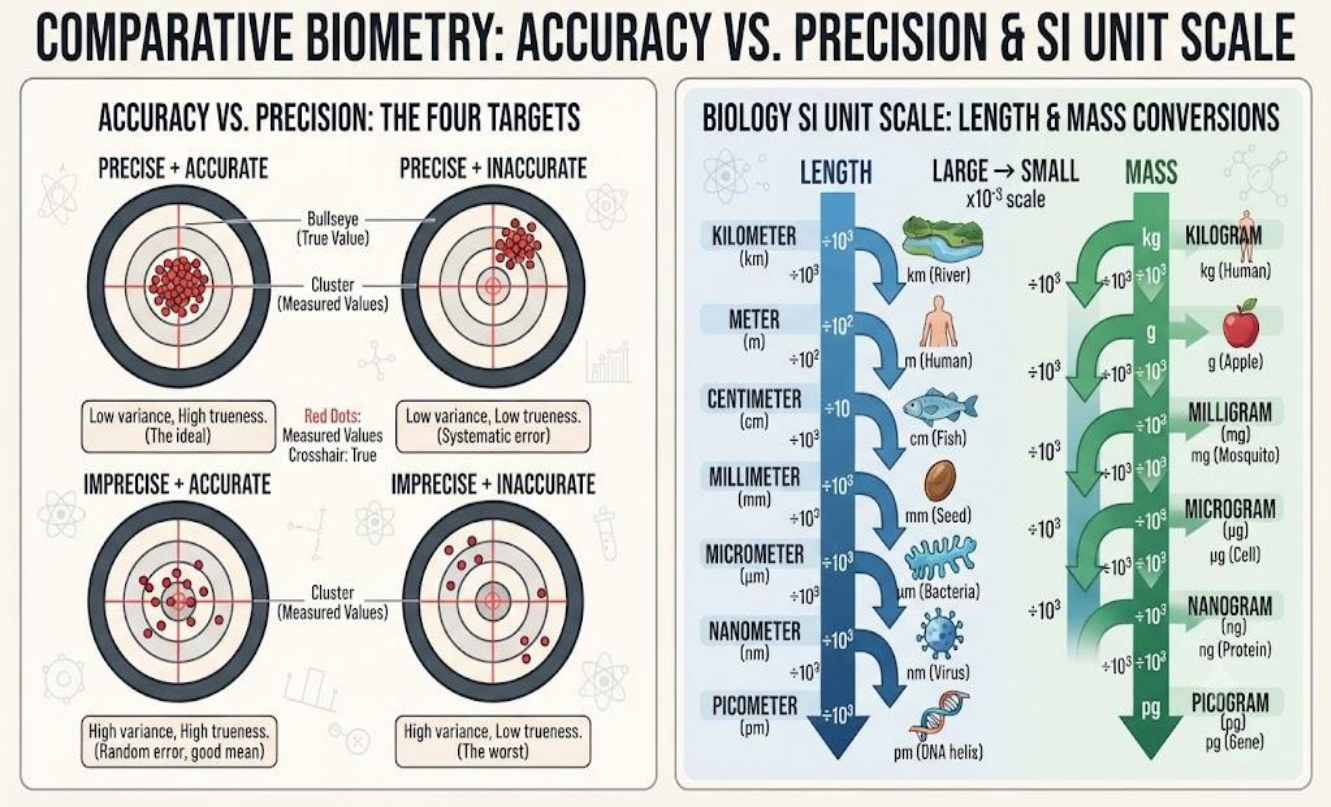

Figure 2.1: Measurement principles

Pilot questions 2.1

1. Explain why standardised measurement is essential in biology.
2. Name four SI units commonly used in biology and the quantity each measures.
3. Distinguish between accuracy and precision.
4. Give an example of a measurement that is precise but inaccurate.
5. Explain what significant figures indicate about a measurement.

2.2 Measuring Length and Area

2.2.1 Measuring length with rulers and micrometers

A ruler or metre rule measures length to the nearest millimetre, suitable for visible specimen measurements (whole organisms, organs, or plant parts), and should be read with the eye directly

above the measurement mark (not at an angle, which would introduce a parallax error due to the raised scale above the surface being measured); the zero mark of the ruler, not the end of the ruler, should be used as the starting point since the physical end of many rulers does not correspond exactly with the zero graduation.

A micrometer screw gauge measures to the nearest 0.01 mm (10 micrometres), suitable for measuring structures too small for accurate ruler measurement but larger than what is typically measured under a microscope; correct use requires closing the micrometer gently onto the specimen using the ratchet (not the main thimble) to avoid over-tightening, and reading the main scale plus the thimble scale to obtain the full measurement.

Fill in the blank: Parallax error in ruler measurement is introduced by reading the ruler at an _____ rather than with the eye directly above the measurement mark.

2.2.2 Measuring biological specimens

When measuring biological specimens, the measurement taken should be clearly defined and repeatable: for example, the length of a leaf is typically the distance from the base of the lamina to the tip, measured along the midrib or the longest axis rather than an arbitrary direction, and this definition should be stated in the method so that another person would take the same measurement; ambiguous or inconsistently defined measurements produce data that cannot be reliably compared.

Multiple measurements of the same specimen or replicate specimens should be taken where possible and the mean calculated, since biological material varies naturally and single measurements may not be representative; if one measurement differs markedly from the others (an outlier), the reason should be investigated rather than simply included in or excluded from the mean without consideration, since outliers sometimes reveal a genuine unusual value rather than simply a measurement error.

Fill in the blank: Multiple measurements should be taken and the _____ calculated to reduce the effect of natural biological variation on the result.

2.2.3 Scale and magnification calculations

Magnification is the ratio of the size of an image (as seen in a drawing or on a photograph) to the actual size of the real object, expressed as a magnification factor (for example, x40 meaning the image is 40 times the actual size); the relationship is: magnification = image size divided by actual size, which can be rearranged to find actual size = image size divided by magnification, or image size = actual size multiplied by magnification.

Scale bars are commonly used on microscope images and biological diagrams to indicate the actual size represented by a given length in the image; to use a scale bar, measure its length in the image (in the same units as the measurement of interest), then use the ratio of measured scale bar length to the stated actual size it represents to calculate the actual size of any measured feature in the same image.

Fill in the blank: Magnification equals image size divided by _____ size, and can be rearranged to calculate actual size from image size and magnification.

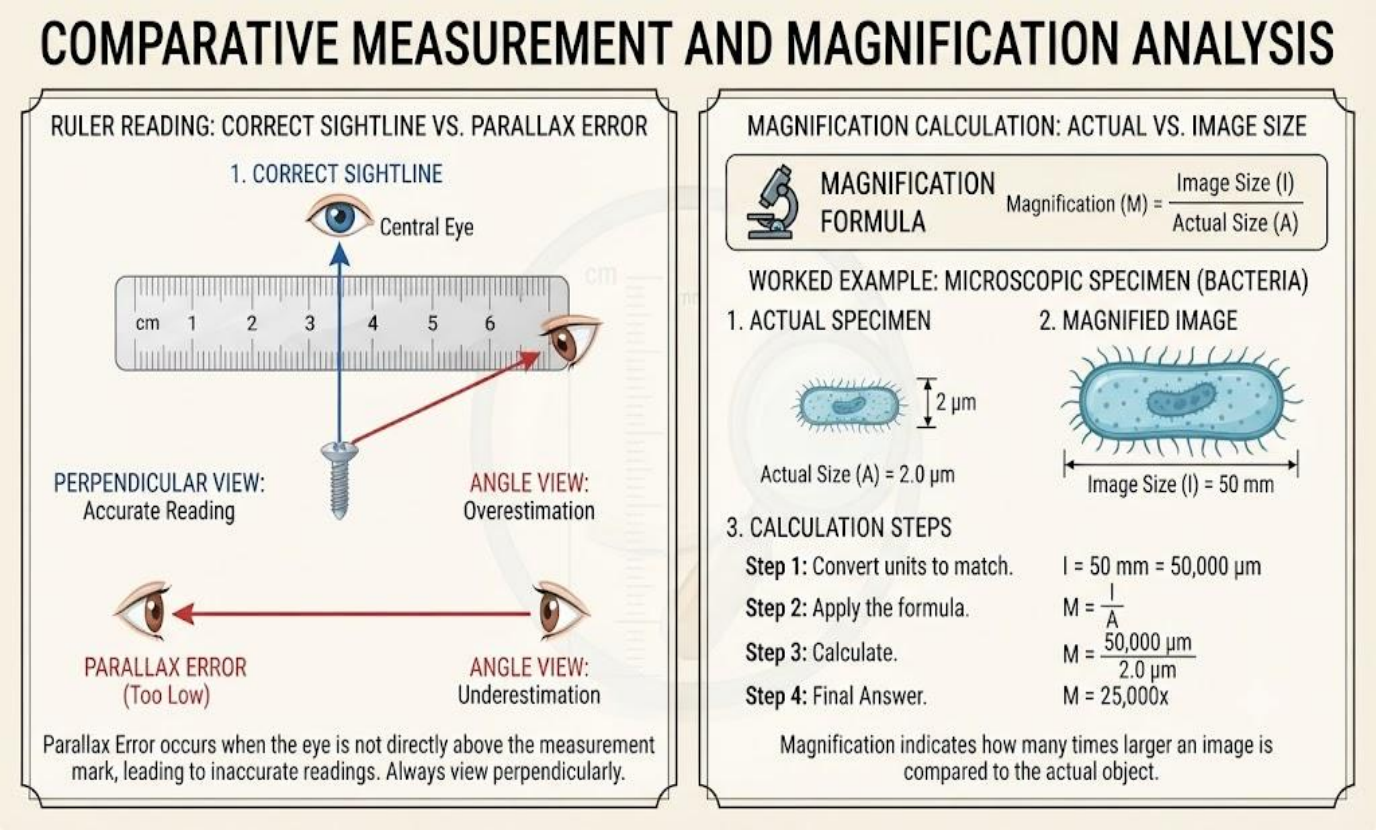

Figure 2.2: Measuring length and magnification

Pilot questions 2.2

1. Explain how parallax error occurs when using a ruler.
2. Explain why the definition of what is being measured must be clearly stated in a method.
3. Explain why multiple measurements and a mean should be taken from biological specimens.
4. State the formula for magnification.
5. Describe how to use a scale bar to calculate the actual size of a feature in an image.

2.3 Measuring Mass, Volume, and Temperature

2.3.1 Measuring mass with a balance

An electronic balance is used for most mass measurements in biology practical work, measuring to the nearest 0.01 g or 0.001 g depending on the instrument; the balance should be placed on a level surface, zeroed (tared) before each measurement, and the container or weighing paper placed on the pan before taring so that only the mass of the substance itself is recorded; the balance should be protected from draughts and vibrations that could destabilise the reading.

When measuring the mass of a liquid or a material that cannot be placed directly on the balance pan, an appropriate container (beaker, weighing boat, or watch glass) should be used and the container mass zeroed out by taring before the substance is added; where very small masses must be measured, an analytical balance with higher precision may be needed and additional precautions taken to prevent air movement affecting the reading.

Fill in the blank: The balance should be _____ (tared) before each measurement to ensure only the mass of the substance itself, and not the container, is recorded.

2.3.2 Measuring volume of liquids

Volume of liquids is measured using graduated cylinders (measuring cylinders), pipettes, or burettes depending on the required volume and precision; a measuring cylinder is suitable for approximate volumes (accurate to the nearest 1 mL or fraction thereof depending on cylinder size), while a pipette measures a fixed precise volume and a burette measures variable volumes by noting the difference between initial and final readings.

All volume measurements using graduated glassware should be read at eye level with the bottom of the meniscus (the curved liquid surface) aligned with the graduation mark, since reading from above or below the meniscus level introduces a systematic error; coloured liquids sometimes display a meniscus that is difficult to read at the bottom and may need to be read at the top surface instead.

Fill in the blank: Volume readings should be taken at eye level with the bottom of the _____ aligned with the graduation mark to avoid systematic reading error.

2.3.3 Measuring temperature

Temperature in biology laboratory work is most commonly measured using a thermometer (either a traditional liquid-in-glass type or a digital probe), and is expressed in degrees Celsius (degrees C) for routine biological work, with Kelvin used in some thermodynamic calculations; thermometers should be allowed to equilibrate in the substance being measured for sufficient time before the reading is taken to ensure the thermometer has reached the same temperature as its surroundings.

A digital temperature probe allows continuous monitoring and, in some set-ups, logging of temperature data over time, which is particularly useful in experiments examining the effect of temperature on biological processes such as enzyme activity or cell respiration rate; when using a liquid-in-glass thermometer, the reading should be taken while the thermometer remains in the substance (not after withdrawal, as the temperature may change during removal).

Fill in the blank: A thermometer should be allowed to _____ in the substance being measured before the reading is taken, to ensure it has reached the same temperature as its surroundings.

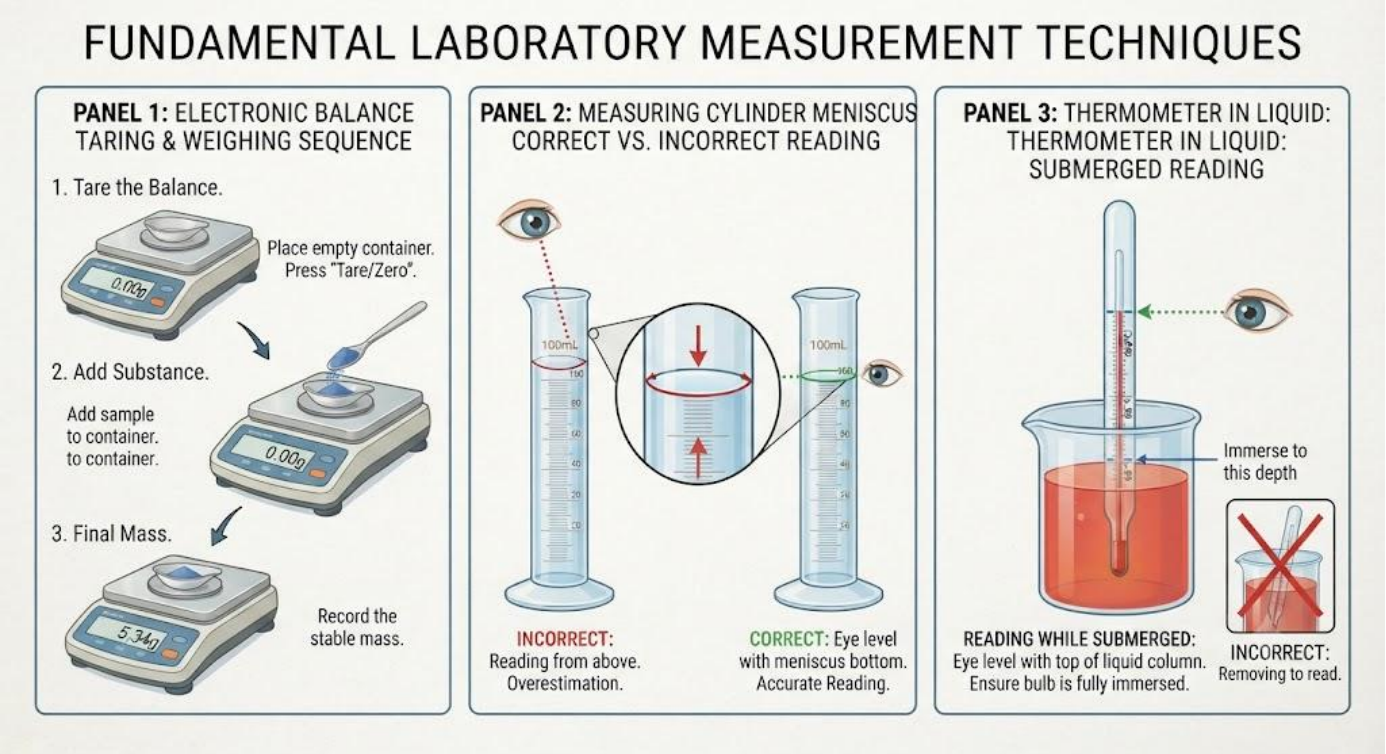

Figure 2.3: Measuring mass, volume, and temperature

Pilot questions 2.3

1. Explain why an electronic balance should be tared before each measurement.
2. Name three types of graduated glassware used to measure liquid volume.
3. Explain what the meniscus is and how it should be read in a measuring cylinder.
4. State the unit most commonly used for temperature in biology laboratory work.
5. Explain why a thermometer should remain in the substance while the reading is taken.

2.4 Recording and Presenting Measurements

2.4.1 Constructing data tables

A well-constructed data table allows results to be recorded systematically and clearly during or after an experiment; a standard data table has the independent variable (the factor deliberately changed by the experimenter) in the first column and the dependent variable (the measured

outcome) in subsequent columns, with each column headed by the variable name and its unit in brackets, and all numerical values recorded to a consistent number of decimal places reflecting the precision of the measuring instrument.

Raw data tables should record all readings taken, including any replicates, before any calculations such as means are performed; a separate column can be used for calculated values such as means, clearly distinguished from raw data columns; tables should be neat, legible, and complete, with no missing values left blank without explanation, since a complete record of all measurements taken, including those that appear unusual, supports honest and reproducible science.

Fill in the blank: A data table column heading should include both the variable _____ and its unit in brackets.

2.4.2 Constructing graphs

A line graph (used when both variables are continuous, such as time and temperature) or a bar chart (used when the independent variable consists of discrete categories, such as different species or experimental treatments) is drawn with the independent variable on the horizontal (x) axis and the dependent variable on the vertical (y) axis, each axis labelled with the variable name and unit, and with a scale chosen so the data occupies most of the available graph area rather than being compressed into a small portion.

Points on a line graph should be plotted as small crosses or dots rather than large marks that obscure the exact position, and a best-fit line (straight line or smooth curve, depending on the expected relationship) drawn through the plotted points rather than connecting each point individually, since a best-fit line averages the variability in the data and more accurately represents the underlying relationship; all graphs should have a clear, informative title.

Fill in the blank: The independent variable is plotted on the _____ axis and the dependent variable on the vertical axis of a graph.

2.4.3 Sources of error and improving reliability

Measurement errors are broadly classified as random errors (unpredictable variations affecting individual readings in different directions, caused by fluctuations in the measurement environment, limitations of the instrument, or natural biological variation, and reduced by taking multiple readings and calculating a mean) and systematic errors (consistent errors in the same direction affecting all readings, caused by an instrument fault or incorrectly defined measurement procedure, not reduced by taking more readings but by identifying and correcting the error source).

Reliability (the consistency of results across repeated measurements or repeat experiments) is improved by using calibrated instruments, defining measurement procedures precisely, keeping conditions constant where possible, training all observers to use the same method, and taking sufficient replicate measurements; where results are highly variable, additional replicates or a more controlled experimental design may be needed before reliable conclusions can be drawn from the data.

Fill in the blank: _____ errors are consistent errors in the same direction affecting all readings, not reduced by taking more readings but by identifying and correcting the error source.

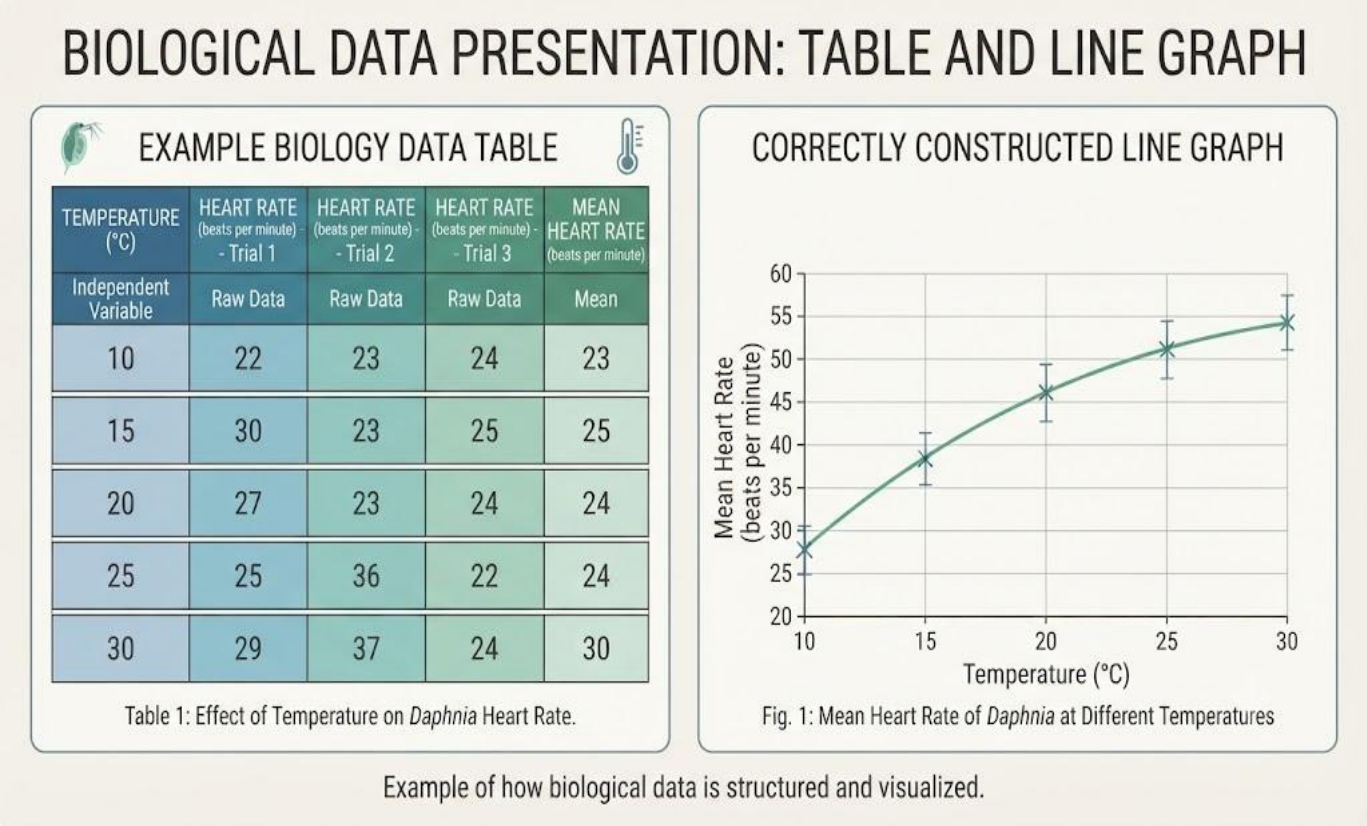

Figure 2.4: Recording and presenting measurements

Pilot questions 2.4

1. Describe the structure of a well-constructed data table for a biology experiment.
2. Explain what a column heading in a data table should include.
3. Distinguish between a line graph and a bar chart in terms of when each is appropriate.
4. Explain why a best-fit line is drawn rather than connecting each data point.
5. Distinguish between random and systematic errors.

Series Summary

This Series examined **scientific measurement principles and accurate data collection in the laboratory**. Standardised measurement ensures **accuracy, precision, and reproducibility**, using **SI units** such as the metre, kilogram, second, and mole, together with derived units such as **millimetres (mm), micrometres (µm), millilitres (mL), and milligrams (mg)**. It distinguished **accuracy** (closeness to the true value) from **precision** (repeatability of measurements) and explained the use of **significant figures** to reflect instrument precision. The Series also covered **length measurement** using rulers and micrometers, avoidance of **parallax error** by reading at eye level, taking clearly defined specimen measurements, calculating means from replicate measurements, and using the **magnification formula** and **scale bars**.

The Series also covered the **measurement of mass, volume, and temperature, as well as data recording and analysis**. Accurate measurement of mass requires proper use of the **balance** and taring before weighing, while volume is measured using **measuring cylinders, pipettes, and burettes** with the meniscus read at eye level. Temperature measurements require allowing the **thermometer to equilibrate** before taking readings. Students also learned how to organise results in **data tables** with correctly labelled variables and units, present data using **line graphs and bar charts**, and distinguish between **random and systematic errors**. Reliability is improved through **replicate measurements** and the use of **calibrated instruments**. By completing this Series, students should achieve SLOs **2.1–2.4**.

Glossary of Terms

- **Accuracy:** how close a measurement is to the true value.
- **Best-fit line:** a straight line or smooth curve drawn through plotted data points to represent the underlying relationship, averaging out variability.
- **Magnification:** the ratio of image size to actual size of a specimen.
- **Meniscus:** the curved upper surface of a liquid in a container, used as the reference point for volume readings.

- **Parallax error:** a measurement error caused by reading an instrument scale from an angle rather than directly above the graduation.
- **Precision:** how repeatable or consistent a set of measurements are with one another.
- **Systematic error:** a consistent error in the same direction affecting all readings, caused by an instrument fault or flawed procedure.

Concept Check Questions [Series 2]

Objective Questions

1. Standardised measurement makes results _____ , enabling other researchers to obtain the same results. (Linked to SLO 2.1)
2. The micrometre is one _____ of a metre, the typical unit for cell measurements. (Linked to SLO 2.1)
3. Magnification equals image size divided by _____ size. (Linked to SLO 2.2)
4. Volume readings should be taken at eye level with the bottom of the _____ aligned with the graduation. (Linked to SLO 2.3)
5. _____ errors are consistent errors in the same direction, not reduced by taking more readings. (Linked to SLO 2.4)

Short-Answer Questions

1. Distinguish between accuracy and precision. (Linked to SLO 2.1)
2. Explain how parallax error occurs and how to avoid it. (Linked to SLO 2.2)
3. Name three types of graduated glassware for measuring volume. (Linked to SLO 2.3)
4. Describe what a data table column heading should include. (Linked to SLO 2.4)
5. Explain why a best-fit line is preferred over connecting each data point. (Linked to SLO 2.4)

Long-Answer Questions

1. Explain the importance of measurement, SI units, and accuracy versus precision. (Linked to SLO 2.1)
2. Describe how to measure length and calculate magnification. (Linked to SLO 2.2)
3. Describe how to measure mass, volume, and temperature, and how to record and present results. (Linked to SLOs 2.3, 2.4)

Answers to Concept Check Questions [Series 2]

Objective Questions

1. Reproducible.
2. Millionth.
3. Actual.
4. Meniscus.
5. Systematic.

Short-Answer Questions

1. Accuracy is closeness to the true value; precision is consistency or repeatability of repeated measurements.
2. Parallax error occurs by reading the scale at an angle; it is avoided by placing the eye directly above the measurement mark.
3. Measuring cylinder, pipette, and burette.
4. The variable name and its unit in brackets.
5. A best-fit line averages the variability in data to represent the underlying relationship more accurately than point-to-point connections.

Long-Answer Questions

1. Measurement enables objective comparison and reproducibility. Biology uses SI units including metre, kilogram, and derived units such as mm and micrometre. Accuracy is closeness to the true value; precision is repeatability; significant figures reflect instrument capability.
2. Rulers measure to the nearest mm, avoiding parallax error by direct eye position. Specimens need clearly defined measurement points and multiple replicates for a mean. Magnification = image size divided by actual size; scale bars allow actual size calculation from image measurements.
3. Balance: tare before use to exclude container mass. Measuring cylinder/pipette/burette: read meniscus at eye level. Thermometer: equilibrate before

reading. Data tables record independent and dependent variables with units; graphs use appropriate type with labelled axes and best-fit lines; random errors are reduced by replicates, systematic errors by identifying and correcting the error source.

Answers to Pilot Questions [Series 2]

Part 2.1

1. Standardised measurement allows results to be compared and reproduced across different researchers and locations.
2. Metre (length), kilogram (mass), second (time), mole (amount of substance).
3. Accuracy is closeness to the true value; precision is how consistent repeated measurements are with one another.
4. A set of measurements that all read 12.3 cm when the true value is 11.5 cm is precise but inaccurate.
5. Significant figures indicate the precision of the measuring instrument and should match the instrument capability.

Part 2.2

1. Parallax error occurs when the eye is not directly above the scale mark, causing the apparent reading to be displaced.
2. Without a clear definition of what is being measured, different people may take different measurements, making comparison unreliable.
3. Biological material varies naturally; multiple measurements and a mean reduce the effect of this variation on the result.
4. Magnification = image size divided by actual size.
5. Measure the scale bar length in the image, then use the ratio of that length to the stated actual size to calculate the actual size of any feature.

Part 2.3

1. Taring zeroes out the container mass so that only the mass of the added substance is recorded.
2. Measuring cylinder, pipette, and burette.
3. The meniscus is the curved upper surface of a liquid; it should be read at its lowest point (bottom of the curve) at eye level.
4. Degrees Celsius.
5. The temperature may change as the thermometer is withdrawn, giving an inaccurate reading.

Part 2.4

1. A data table has the independent variable in the first column and dependent variable(s) in subsequent columns, each headed with variable name and unit in brackets, with all readings recorded to consistent decimal places.
2. The variable name and its unit in brackets.
3. A line graph is used when both variables are continuous; a bar chart is used when the independent variable is in discrete categories.
4. A best-fit line represents the underlying trend by averaging variability, rather than exaggerating each individual measurement error.
5. Random errors vary unpredictably between readings and are reduced by replicates; systematic errors are consistent in direction and require identifying and correcting the error source.

References and Attributions

Textual References (Books and External Sources)

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Figures, Plates, Tables, and Boxes

- Figure 2.1: Measurement principles Attribution: AI generated. Suggested OER search string: "accuracy precision SI units biology measurement diagram laboratory OER".
- Figure 2.2: Measuring length and magnification Attribution: AI generated. Suggested OER search string: "magnification calculation scale bar ruler measurement parallax error biology diagram OER".
- Figure 2.3: Measuring mass, volume, and temperature Attribution: AI generated. Suggested OER search string: "balance taring mass measuring cylinder meniscus volume thermometer temperature biology diagram OER".
- Figure 2.4: Recording and presenting measurements Attribution: AI generated. Suggested OER search string: "data table graph construction line graph bar chart biology measurements recording OER".

Course code: BIO 107

Course title: General Biology Practical I

Course credit load: 1 Unit

Series 3: Microscope Functions and Maintenance

- **Part 3.1: Types of Microscopes**
    - Sub Part 3.1.1: The compound light microscope
    - Sub Part 3.1.2: The dissecting (stereoscopic) microscope
    - Sub Part 3.1.3: Comparing the two microscope types
- **Part 3.2: Parts of the Compound Microscope and Their Functions**
    - Sub Part 3.2.1: Illumination and stage components
    - Sub Part 3.2.2: Optical components
    - Sub Part 3.2.3: Mechanical and focusing components
- **Part 3.3: Using the Microscope**
    - Sub Part 3.3.1: Setting up and focusing
    - Sub Part 3.3.2: Preparing a wet mount
    - Sub Part 3.3.3: Estimating specimen size under the microscope
- **Part 3.4: Care and Maintenance of the Microscope**
    - Sub Part 3.4.1: Handling and storage
    - Sub Part 3.4.2: Cleaning the microscope
    - Sub Part 3.4.3: Common problems and troubleshooting

Introduction

The microscope is the most important and most frequently used instrument in biology practical work, extending human vision far beyond what the unaided eye can resolve and making possible the observation of cells, tissues, microorganisms, and the fine structural details that underpin much of what is known about living systems. Understanding how the microscope works, how to use it correctly, and how to care for it properly is therefore a foundational practical skill for any biology student.

This Series covers the two main microscope types used in biology practical teaching, the compound light microscope and the dissecting microscope; the parts of the compound microscope and their individual functions; the correct procedure for setting up, focusing, and preparing specimens for microscopy; and the handling, cleaning, and troubleshooting procedures needed to keep microscopes in good working order.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 3.1** distinguish the compound light microscope and the dissecting microscope in terms of structure and use,
- **SLO 3.2** identify the parts of the compound microscope and describe the function of each,
- **SLO 3.3** describe the correct procedure for setting up, focusing, and preparing specimens for microscopy, and
- **SLO 3.4** describe correct handling, cleaning, and troubleshooting of the microscope.

3.1 Types of Microscopes

3.1.1 The compound light microscope

The compound light microscope uses visible light and two or more lenses (the objective lens close to the specimen and the eyepiece lens at the top of the instrument through which the user looks) to produce a magnified image of a specimen; it is called compound because it uses multiple lenses in combination to achieve greater magnification than a single lens could provide, with typical total magnifications ranging from about x40 to x400 in routine biology teaching use, and up to x1000 or beyond with oil immersion objectives.

Because the compound microscope illuminates the specimen from below and the image is formed by light passing through the specimen, specimens must generally be thin enough for light to penetrate them, typically prepared as thin sections or smears mounted on a glass slide and covered with a cover slip; the compound microscope is used to examine cellular and subcellular structures in thin sections of tissue, smear preparations of microorganisms, and similar thin transparent preparations.

Fill in the blank: The compound light microscope is called compound because it uses multiple _____ in combination to achieve greater magnification than a single lens could provide.

3.1.2 The dissecting (stereoscopic) microscope

The dissecting microscope (also called a stereoscopic or stereo microscope) uses two separate optical paths, one for each eye, producing a three-dimensional image of the specimen with a perception of depth; it operates at lower magnifications than the compound microscope (typically x7 to x45), but provides a much greater working distance between the objective and the specimen, allowing the specimen to be manipulated, dissected, or moved during observation.

The dissecting microscope illuminates the specimen from above (reflected light) rather than from below, meaning the specimen does not need to be thin or transparent and can be examined whole, intact, and even living; it is therefore used for tasks requiring manipulation of intact specimens, such as dissection work, examination of whole small organisms or plant structures,

and inspection of surfaces and three-dimensional features that would be lost if the specimen were sectioned.

Fill in the blank: The dissecting microscope uses _____ light from above rather than transmitted light from below, allowing intact, opaque specimens to be examined.

3.1.3 Comparing the two microscope types

The compound microscope offers higher magnification (up to x1000 or more), a flat two-dimensional image, transmitted light through thin transparent specimens, and a short working distance making manipulation during observation impossible; the dissecting microscope offers lower magnification (up to about x45), a three-dimensional image, reflected light from the specimen surface, a long working distance allowing manipulation, and no requirement for specimen preparation such as sectioning.

The choice between the two microscopes depends on the nature of the specimen and the purpose of the observation: cellular and subcellular detail in thin sections requires a compound microscope, while examination of external features, dissection, or observation of whole small organisms requires a dissecting microscope; both instruments are standard equipment in a biology practical laboratory and complement one another for different tasks.

Fill in the blank: The compound microscope provides _____ magnification than the dissecting microscope but requires thin, transparent specimens and provides a two-dimensional image.

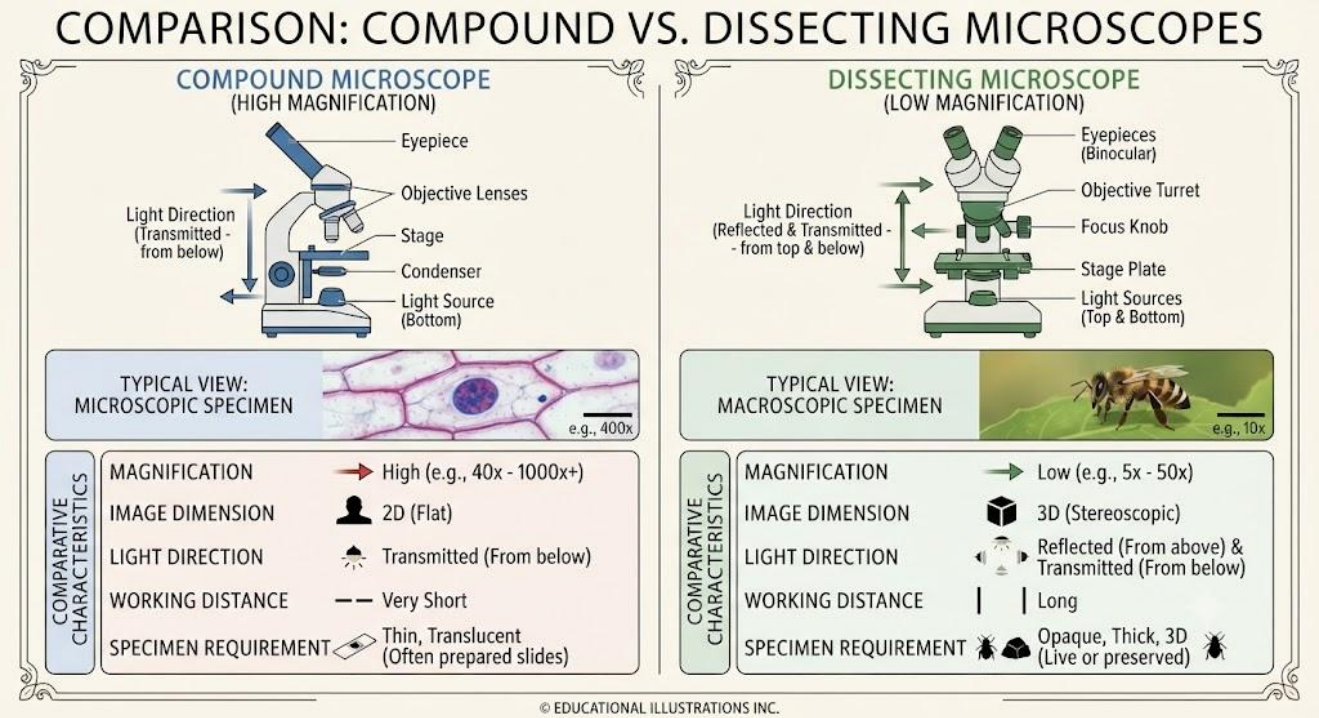

Figure 3.1: Compound and dissecting microscope comparison

Pilot questions 3.1

1. Explain why the compound microscope is called compound.
2. State the typical magnification range of a compound microscope in biology teaching use.
3. Explain why specimens for compound microscopy must be thin.
4. Explain the main advantage of the dissecting microscope over the compound microscope for dissection work.
5. State one situation in which you would choose a compound microscope and one in which you would choose a dissecting microscope.

3.2 Parts of the Compound Microscope and Their Functions

3.2.1 Illumination and stage components

The light source (a built-in electric lamp in most modern microscopes, or a mirror in older instruments directing external light) provides the illumination that passes through the specimen to form the image; the condenser, a lens system located beneath the stage, focuses the light from the source onto the specimen to provide even, bright illumination, and is adjusted for each objective lens to optimise illumination intensity and quality.

The stage is the flat platform on which the glass slide carrying the specimen is placed during observation; most stages have a central aperture through which the light from below passes, and stage clips or a mechanical stage to hold and move the slide in a controlled manner; the iris diaphragm, a variable aperture below the condenser, controls the amount of light entering the optical system and is adjusted to optimise image contrast alongside the condenser.

Fill in the blank: The _____ is a lens system beneath the stage that focuses light from the source onto the specimen to provide even, bright illumination.

3.2.2 Optical components

The objective lenses are located on the rotating nosepiece directly above the stage, and are the lenses closest to the specimen; a typical compound microscope has three or four objectives of different magnification, commonly x4 (scanning), x10 (low power), x40 (high power), and sometimes x100 (oil immersion); the magnification marked on each objective is its individual magnification, which is multiplied by the eyepiece magnification to give the total magnification of the microscope.

The eyepiece (ocular lens), located at the top of the microscope body tube through which the observer looks, typically magnifies the image formed by the objective by a further x10 (or occasionally x5 or x15); total magnification is therefore calculated as objective magnification multiplied by eyepiece magnification, so a x40 objective used with a x10 eyepiece gives a total magnification of x400; some microscopes have a binocular head (two eyepieces) for more comfortable observation, while others have a monocular head (one eyepiece).

Fill in the blank: Total microscope magnification is calculated as objective magnification _____ eyepiece magnification.

3.2.3 Mechanical and focusing components

The arm is the curved structural component connecting the body tube (carrying the optical components) to the base, and is the correct part to grip when carrying the microscope; the base provides a stable, weighted platform supporting the instrument; the body tube maintains the correct distance between the objective and eyepiece lenses, essential for proper image formation.

The coarse focus knob moves the stage or body tube rapidly up and down over a large range, used initially to bring the specimen approximately into focus at low magnification; the fine focus knob then makes small, precise adjustments to achieve sharp focus and is the only focusing control that should be used when observing at high magnification to avoid accidentally driving the objective into the slide; the nosepiece rotates to bring different objective lenses into position above the specimen.

Fill in the blank: The _____ focus knob makes small, precise adjustments for sharp focus and is the only focusing control that should be used when observing at high magnification.

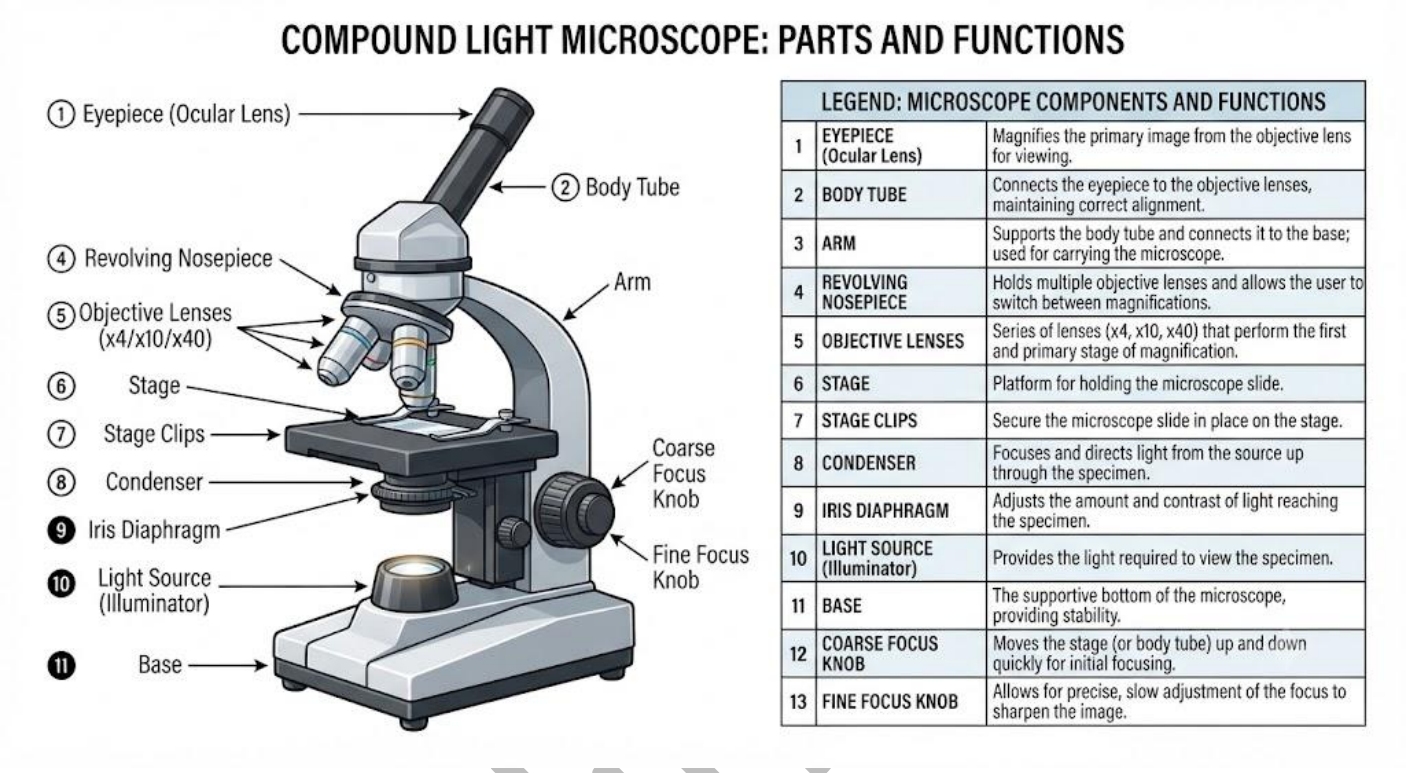

Figure 3.2: Parts of the compound microscope

Pilot questions 3.2

1. State the function of the condenser.
2. State the function of the iris diaphragm.
3. Name the three or four objective lenses typically found on a compound microscope and their magnifications.
4. Calculate the total magnification when using a x40 objective and a x10 eyepiece.
5. Distinguish between the coarse and fine focus knobs in terms of use.

3.3 Using the Microscope

3.3.1 Setting up and focusing

The correct procedure for setting up and focusing a compound microscope begins with placing the microscope on a level surface, plugging in and switching on the light source, and rotating the

nosepiece to the lowest power objective (x4 or x10); the slide is then placed on the stage with the specimen over the central aperture and held with the stage clips, and the coarse focus knob used to raise the stage (or lower the body tube) to its closest position to the objective while looking from the side, not through the eyepiece, to avoid accidentally contacting the slide with the objective.

The observer then looks through the eyepiece and uses the coarse focus knob to slowly move the stage downward (or tube upward) until the specimen comes approximately into focus, then switches to the fine focus knob to achieve sharp focus; once focused at low power, higher power objectives can be selected by rotating the nosepiece, using only the fine focus knob to sharpen the image, since a specimen centred and focused at low power should remain approximately centred and in focus when switching to a higher power objective on a well-aligned instrument.

Fill in the blank: When setting up the microscope, the stage should be raised to its closest position to the objective while looking from the _____ , not through the eyepiece, to avoid contacting the slide.

3.3.2 Preparing a wet mount

A wet mount is the most common basic preparation for compound microscopy, consisting of a small amount of material (a thin smear of liquid, a small piece of thin biological material, or a drop of pond water) placed on a clean glass slide, covered by a thin glass cover slip to flatten and protect the specimen and reduce evaporation; a small drop of water is placed on the slide first if the specimen is dry, then the cover slip is lowered at an angle onto one edge of the drop and allowed to fall gently to avoid trapping air bubbles.

Staining may be applied before covering (by adding a small drop of stain, such as iodine solution for starch or methylene blue for cell nuclei, to the specimen on the slide before adding the cover slip) or by capillary action after covering (by placing a drop of stain at one edge of the cover slip and drawing it under by touching absorbent paper to the opposite edge), enhancing contrast and making specific structures more visible under the microscope.

Fill in the blank: A wet mount cover slip is lowered at an _____ onto one edge of the water drop and allowed to fall gently to avoid trapping air bubbles.

3.3.3 Estimating specimen size under the microscope

The diameter of the field of view (the circular area visible through the eyepiece at a given magnification) can be measured using a stage micrometer (a slide with a finely graduated scale) or estimated from the known field diameter at one magnification scaled to other magnifications; knowing the field diameter allows the approximate size of any specimen within the field to be estimated by expressing the specimen as a fraction of the total field diameter.

Actual specimen size can be calculated from image size and magnification using the formula introduced in the measurements context: actual size equals image size divided by magnification; in practice, the image size is measured directly on a photograph or drawing of the field, and then divided by the total magnification used when the image was taken, giving the actual size of the specimen in the same unit as the image measurement, converted to the appropriate biological unit such as micrometres.

Fill in the blank: To calculate actual specimen size from a microscope image, actual size equals image size _____ by total magnification.

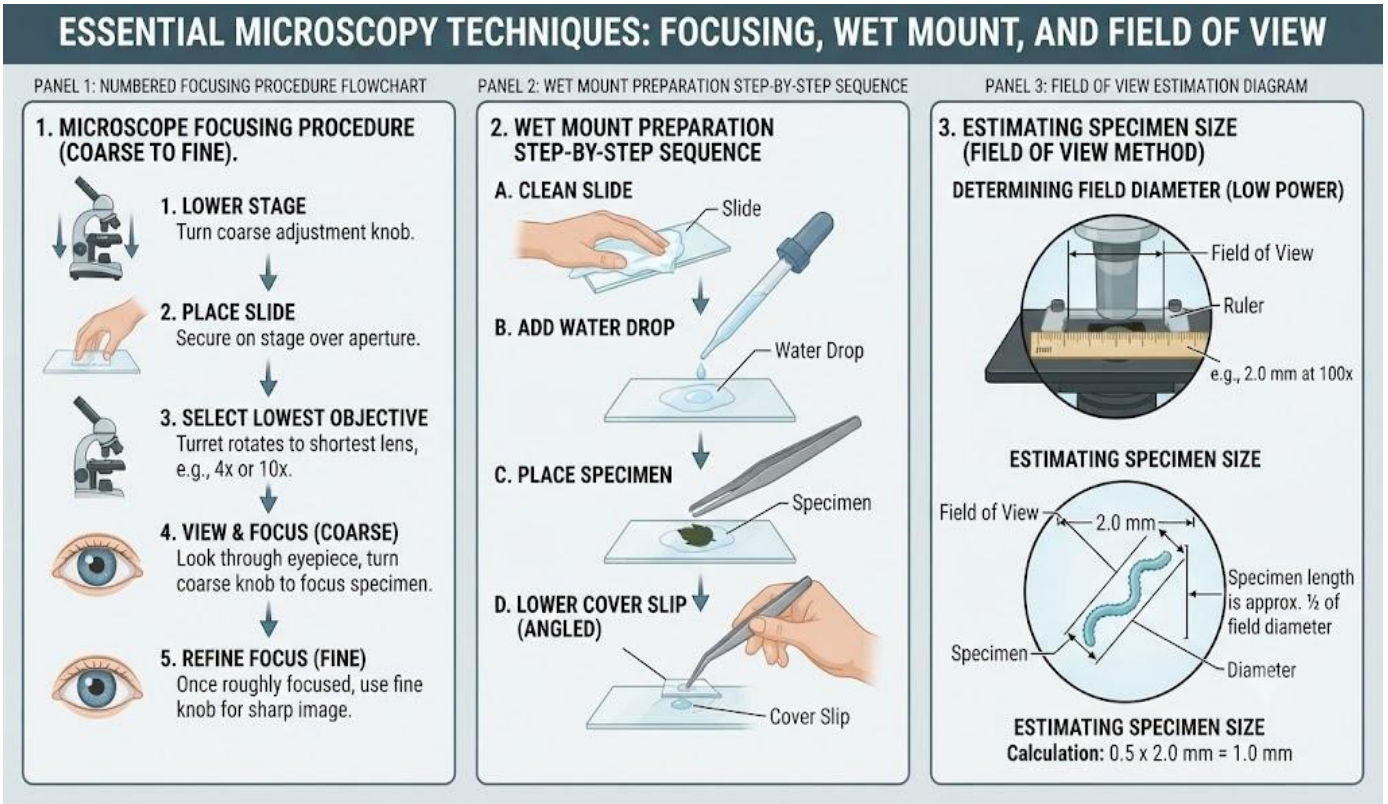

Figure 3.3: Using the compound microscope

Pilot questions 3.3

1. Describe the correct sequence of steps for setting up and focusing a compound microscope.
2. Explain why the stage should be raised while looking from the side during setup.
3. Describe how to prepare a wet mount.
4. Explain how to apply a stain to an already-covered wet mount preparation.
5. Explain how to estimate the actual size of a specimen visible under the microscope.

3.4 Care and Maintenance of the Microscope

3.4.1 Handling and storage

A microscope should always be carried with both hands, one hand gripping the arm and the other supporting the base, to prevent the instrument from swinging or tilting and potentially dropping;

it should never be carried by the body tube or held with one hand only, since an accidental knock could result in expensive damage to the optical components or body structure.

When not in use, the microscope should be stored with the lowest power objective in place (rotated into the working position), the stage lowered to its maximum distance from the objective, and the coarse focus returned toward its central position, then covered with a dust cover or placed in its storage case to protect the optical surfaces from dust; storage should be in a clean, dry location away from direct sunlight, chemical fumes, and moisture, all of which can damage optical glass and metal components over time.

Fill in the blank: A microscope should be carried with one hand gripping the _____ and the other supporting the base, never by the body tube or with one hand only.

3.4.2 Cleaning the microscope

Optical surfaces (eyepiece lens, objective lenses, and condenser) should only be cleaned with lens tissue or a soft lint-free cloth specifically designed for optical cleaning, never with ordinary paper, cloth, or fingers, since all of these can scratch or leave oily residues on the precision optical glass surfaces; a gentle circular wiping motion with lens tissue, sometimes moistened with a small amount of lens cleaning solution or 70% ethanol, is the correct technique.

The body, arm, and stage of the microscope can be wiped with a damp cloth to remove dust and biological material, but care must be taken to prevent liquid from entering the internal optical system or the electrical components of the light source; immersion oil used with the x100 objective must be removed promptly after use with lens tissue, since dried immersion oil is considerably more difficult to remove and can cause lasting damage to the objective surface if left in contact.

Fill in the blank: Optical surfaces should only be cleaned with lens _____ or a soft lint-free cloth designed for optical cleaning, never with ordinary paper or fingers.

3.4.3 Common problems and troubleshooting

A dim or unevenly lit image is most often caused by a dirty condenser or objective lens, an incorrectly positioned or closed iris diaphragm, or a failing light source bulb; the solution is to clean the relevant optical surface, adjust the iris diaphragm and condenser position, or replace the bulb as appropriate; a completely dark field when the light appears on may indicate the nosepiece is between objectives rather than locked in position, which is corrected by rotating the nosepiece until a click indicates the objective is correctly locked.

Blurred or hazy images that cannot be resolved by focusing typically indicate a dirty objective or eyepiece lens, a specimen preparation problem (such as too much material or an air bubble over the area of interest in a wet mount), or a coverslip too thick for the objective design, corrected by cleaning the lenses, re-preparing the specimen, or using the correct cover slip thickness; oil immersion images that are hazy after switching from another objective often result from oil contamination of the lower-power objective, which must be cleaned promptly.

Fill in the blank: A completely dark field when the light is on may indicate the nosepiece is between objectives rather than _____ in position, corrected by rotating until a click is heard.

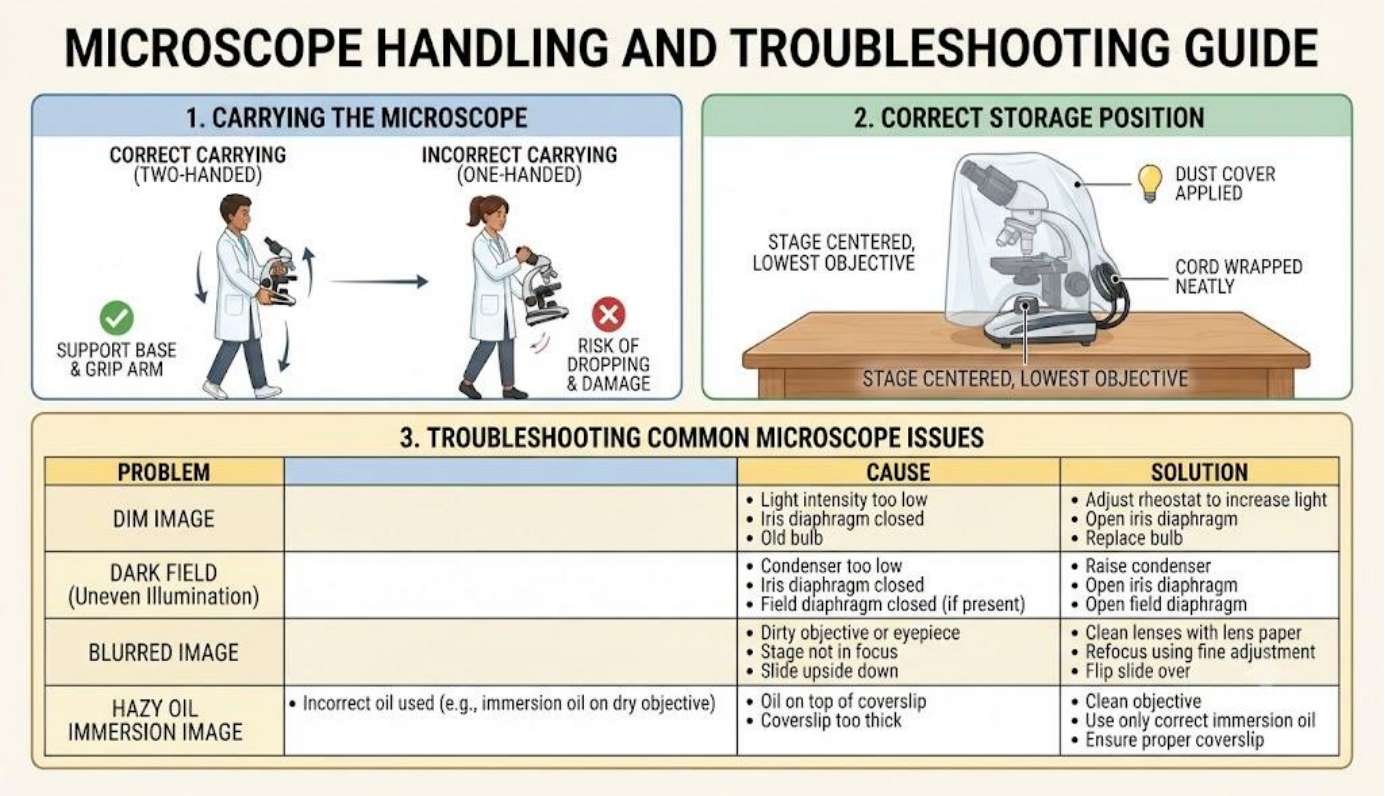

Figure 3.4: Microscope care and troubleshooting

Pilot questions 3.4

1. Describe the correct technique for carrying a microscope.
2. Describe the correct storage position for a microscope when not in use.
3. Explain why ordinary cloth or paper should not be used to clean optical surfaces.
4. Describe the correct technique for cleaning a microscope objective lens.
5. State a possible cause and solution for a completely dark field when the light is switched on.

Series Summary

This Series examined **the types, structure, and use of microscopes in biological laboratories**. It compared the **compound light microscope**, which uses transmitted light, multiple lenses, magnifications of about **×40–×1000**, and is suitable for thin transparent specimens producing two-dimensional images, with the **dissecting (stereo) microscope**, which uses reflected light, magnifications of about **×7–×45**, provides three-dimensional images, and is suitable for intact specimens due to its longer working distance. The Series also covered the functions of major microscope parts, including the **light source, condenser, iris diaphragm, stage, objective lenses (×4, ×10, ×40, ×100), eyepiece (×10), revolving nosepiece, arm, base, and coarse and fine focus knobs**, and explained that **total magnification = objective magnification × eyepiece magnification**.

The Series also covered **microscope operation, specimen preparation, and maintenance**. Proper use involves beginning with the **lowest-power objective**, focusing first with the **coarse adjustment** and then the **fine adjustment**, while viewing the stage from the side when raising it to avoid damaging the slide. Students learned how to prepare **wet mounts** by placing the specimen in a drop of water, lowering the coverslip at an angle to prevent air bubbles, and applying stains where necessary. The Series also explained how to estimate specimen size using **actual size = image size ÷ magnification**. Proper microscope care includes carrying it with **both hands**, storing it with the **lowest objective in position and the stage lowered**, cleaning optical surfaces only with **lens tissue**, and troubleshooting common problems such as dim, dark, or blurred images. By completing this Series, students should achieve SLOs **3.1–3.4**.

Glossary of Terms

- **Condenser:** a lens system beneath the microscope stage that focuses light onto the specimen for even, bright illumination.
- **Field of view:** the circular area visible through the eyepiece at a given magnification.

- **Iris diaphragm:** a variable aperture below the condenser that controls the amount of light entering the optical system.
- **Nosepiece:** the rotating component holding the objective lenses, allowing different magnifications to be selected.
- **Objective lens:** the lens closest to the specimen in a compound microscope, providing the primary magnification.
- **Total magnification:** the product of objective lens magnification and eyepiece magnification.
- **Wet mount:** a microscope preparation in which a specimen is placed in a drop of water on a slide and covered with a cover slip.

Concept Check Questions [Series 3]

Objective Questions

1. The compound microscope uses multiple _____ to achieve greater magnification than a single lens. (Linked to SLO 3.1)
2. The _____ focuses light from the source onto the specimen beneath the stage. (Linked to SLO 3.2)
3. Total magnification equals objective magnification _____ eyepiece magnification. (Linked to SLO 3.2)
4. A wet mount cover slip is lowered at an _____ to avoid trapping air bubbles. (Linked to SLO 3.3)
5. Optical surfaces should only be cleaned with lens _____, never ordinary paper or cloth. (Linked to SLO 3.4)

Short-Answer Questions

1. Distinguish the compound and dissecting microscope in terms of light direction and image dimension. (Linked to SLO 3.1)
2. State the function of the iris diaphragm. (Linked to SLO 3.2)
3. Describe the wet mount preparation procedure. (Linked to SLO 3.3)
4. Describe the correct technique for carrying a microscope. (Linked to SLO 3.4)
5. Calculate total magnification for a x40 objective and x10 eyepiece. (Linked to SLO 3.2)

Long-Answer Questions

1. Distinguish compound and dissecting microscopes and identify the parts of the compound microscope. (Linked to SLOs 3.1, 3.2)
2. Describe the correct procedure for setting up, focusing, and preparing specimens for microscopy. (Linked to SLO 3.3)
3. Describe the correct care, cleaning, and troubleshooting of a compound microscope. (Linked to SLO 3.4)

Answers to Concept Check Questions [Series 3]

Objective Questions

1. Lenses.
2. Condenser.
3. Multiplied by.
4. Angle.
5. Tissue.

Short-Answer Questions

1. Compound: transmitted light from below, flat two-dimensional image. Dissecting: reflected light from above, three-dimensional image.
2. The iris diaphragm controls the amount of light entering the optical system to optimise image contrast.
3. Place specimen and water drop on slide, lower cover slip at an angle onto the edge of the drop, allow to fall gently.
4. One hand grips the arm, the other supports the base; never carry by the body tube or with one hand only.
5. 40 multiplied by 10 equals x400 total magnification.

Long-Answer Questions

1. The compound microscope uses transmitted light and multiple lenses for high magnification of thin, transparent specimens producing a 2D image; the dissecting microscope uses reflected light for lower magnification of intact specimens with a 3D image. Parts include light source, condenser, iris diaphragm, stage, objective lenses, eyepiece, nosepiece, arm, base, and coarse and fine focus knobs.
2. Set up on lowest power, place slide on stage with specimen over aperture, raise stage from the side, look through eyepiece and use coarse then fine focus. Prepare wet mount by placing specimen and water on slide, lowering cover slip at an angle.

Estimate size as fraction of field diameter or using actual size equals image size divided by magnification.

3. Carry with two hands (arm and base), store with lowest objective and stage lowered under a dust cover, clean optical surfaces with lens tissue only, clean body with damp cloth. Troubleshoot: dim image (dirty lens or closed diaphragm), dark field (nosepiece between objectives), blurred image (dirty lens or preparation problem).

Answers to Pilot Questions [Series 3]

Part 3.1

1. It is called compound because it uses multiple lenses in combination to achieve greater magnification than a single lens could provide.
2. Typically x40 to x400 in routine biology teaching use, up to x1000 with oil immersion.
3. Light must pass through the specimen to form the image, so the specimen must be thin enough for light to penetrate.
4. The dissecting microscope has a long working distance allowing the specimen to be manipulated or dissected during observation.
5. Compound: examining cells in a thin tissue section. Dissecting: examining a whole insect or performing a dissection.

Part 3.2

1. The condenser focuses light from the source onto the specimen to provide even, bright illumination.
2. The iris diaphragm controls the amount of light entering the optical system, adjusted to optimise image contrast.
3. x4 (scanning), x10 (low power), x40 (high power), and x100 (oil immersion).
4. 40 multiplied by 10 equals x400.

5. Coarse focus is used for initial approximate focus at low magnification; fine focus is used for precise sharp focus, especially at high magnification.

Part 3.3

1. Lowest power objective, slide on stage, raise stage from side, look through eyepiece, coarse focus, then fine focus.
2. To avoid accidentally driving the objective into the slide, which could damage both the slide and the objective lens.
3. Place specimen on slide, add water drop, lower cover slip at an angle from one edge of the drop to avoid air bubbles.
4. Place a drop of stain at one edge of the cover slip and draw it under by touching absorbent paper to the opposite edge.
5. Actual size equals image size divided by total magnification, expressed in the appropriate unit such as micrometres.

Part 3.4

1. One hand grips the arm, the other supports the base; never carry by the body tube or with one hand only.
2. Lowest power objective in place, stage lowered, coarse focus in central position, covered with dust cover in a clean, dry location.
3. Ordinary materials can scratch precision optical glass or leave oily residues that impair image quality.
4. Gently wipe the lens surface with lens tissue, sometimes moistened with lens cleaning solution or 70% ethanol, using a circular motion.
5. The nosepiece may be between objectives rather than locked in position; rotating until a click is heard should correct this.

References and Attribution

Textual References (Books and External Sources)

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Figures, Plates, Tables, and Boxes

- Figure 3.1: Compound and dissecting microscope comparison Attribution: AI generated. Suggested OER search string: "compound light microscope dissecting stereoscope comparison diagram biology OER".
- Figure 3.2: Parts of the compound microscope Attribution: AI generated. Suggested OER search string: "compound microscope parts labelled diagram eyepiece objective condenser stage focus biology OER".
- Figure 3.3: Using the compound microscope Attribution: AI generated. Suggested OER search string: "microscope focusing procedure wet mount preparation field of view size estimation diagram biology OER".
- Figure 3.4: Microscope care and troubleshooting Attribution: AI generated. Suggested OER search string: "microscope handling storage cleaning troubleshooting care maintenance diagram biology OER".

Course code: BIO 107

Course title: General Biology Practical I

Course credit load: 1 Unit

Series 4: Biological Drawings and Illustrations

- **Part 4.1: Purpose and Principles of Biological Drawing**
    - Sub Part 4.1.1: Why biological drawings matter
    - Sub Part 4.1.2: General rules for biological drawings
    - Sub Part 4.1.3: Equipment needed for biological drawings
- **Part 4.2: Accuracy, Proportion, and Scale**
    - Sub Part 4.2.1: Accuracy in biological drawings
    - Sub Part 4.2.2: Proportion in biological drawings
    - Sub Part 4.2.3: Scale and magnification in drawings
- **Part 4.3: Drawing Techniques for Different Specimens**
    - Sub Part 4.3.1: Drawing whole organisms and external features
    - Sub Part 4.3.2: Drawing cells and microscopic specimens
    - Sub Part 4.3.3: Drawing dissected specimens
- **Part 4.4: Labelling and Presenting Biological Drawings**
    - Sub Part 4.4.1: Labelling conventions
    - Sub Part 4.4.2: Titles, magnification, and scale bars
    - Sub Part 4.4.3: Common errors and how to avoid them

Introduction

Biological drawing is a scientific skill, not an artistic one: the purpose of a biological drawing is to produce an accurate, clearly labelled record of what was actually observed, enabling the observer to communicate specific structural details to others and to consolidate their own understanding of the specimen examined. A well-executed biological drawing requires careful observation, disciplined technique, and attention to accuracy, proportion, and labelling conventions.

This Series covers the purpose and general rules of biological drawing; accuracy, proportion, and scale as the three central technical requirements; drawing techniques appropriate to different specimen types, including whole organisms, cells, and dissected specimens; and the correct conventions for labelling, titling, and presenting completed drawings, together with the most common errors students make and how to avoid them.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 4.1** explain the purpose and general rules of biological drawing,
- **SLO 4.2** apply accuracy, proportion, and scale to biological drawings,
- **SLO 4.3** use appropriate drawing techniques for whole organisms, cells, and dissected specimens, and
- **SLO 4.4** apply correct labelling, titling, and magnification conventions to biological drawings.

4.1 Purpose and Principles of Biological Drawing

4.1.1 Why biological drawings matter

Biological drawings serve several important scientific functions: they require the observer to look carefully and actively at a specimen rather than passively glancing at it, promoting the close observation that underlies good scientific understanding; they produce a permanent, annotated record of what was actually seen that can be referred to later; and they communicate structural information to others in a precise, internationally understood visual format that does not depend on language or descriptive vocabulary alone.

A biological drawing is not intended to be a beautiful or artistic representation of a specimen; it is intended to be an accurate, informative record of the specific structural features observed, with irrelevant artistic detail omitted in favour of clarity; for this reason, biological drawings are always made in pencil (not pen or colour), drawn with clean, confident lines rather than shading, and labelled with reference lines and text to identify the structures shown.

Fill in the blank: Biological drawings are always made in _____ rather than pen or colour, drawn with clean confident lines and labelled to identify the structures shown.

4.1.2 General rules for biological drawings

The general rules for biological drawing are: draw only what is actually visible in the specimen or field of view, never add structures from memory or expectation; use a sharp pencil and draw single, clean lines without sketching (no overlapping lines, no shading, no crosshatching, no colouring); make the drawing large enough to show all relevant detail clearly, typically occupying most of the available space on the page; and always draw the drawing on unlined white paper rather than in a notebook or on lined paper if possible.

Lines in a biological drawing should be clear, single, and confident, not fuzzy multi-stroke lines that result from repeated hesitant strokes over the same position; internal structures should be shown with their relative sizes and positions correct relative to one another; and any structure visible in the specimen but not clearly resolved should be omitted rather than guessed at, since an accurate incomplete drawing is more scientifically valuable than an inaccurate complete one.

Fill in the blank: In a biological drawing, draw only what is actually _____ in the specimen, never adding structures from memory or expectation.

4.1.3 Equipment needed for biological drawings

The equipment required for biological drawing is deliberately simple: a sharp HB or H pencil (hard enough to produce clean, fine lines but not so soft that it smudges easily), a good quality eraser (for correcting errors cleanly without damaging the paper surface), a ruler (for drawing straight label lines and scale bars), unlined white drawing paper or a dedicated drawing frame, and the specimen or microscope view to be drawn.

No pens, felt tips, coloured pencils, or other drawing materials should be used for biological drawings in scientific practical work, since these do not allow clean correction, cannot be adjusted for line weight in the same way as a pencil, and are not the accepted convention in scientific biological illustration; colour is only added to biological drawings when specifically instructed and when it conveys genuine scientific information, such as the actual colour of a specimen feature.

Fill in the blank: A sharp _____ or H pencil is recommended for biological drawing, hard enough for clean fine lines but not so soft that it smudges easily.

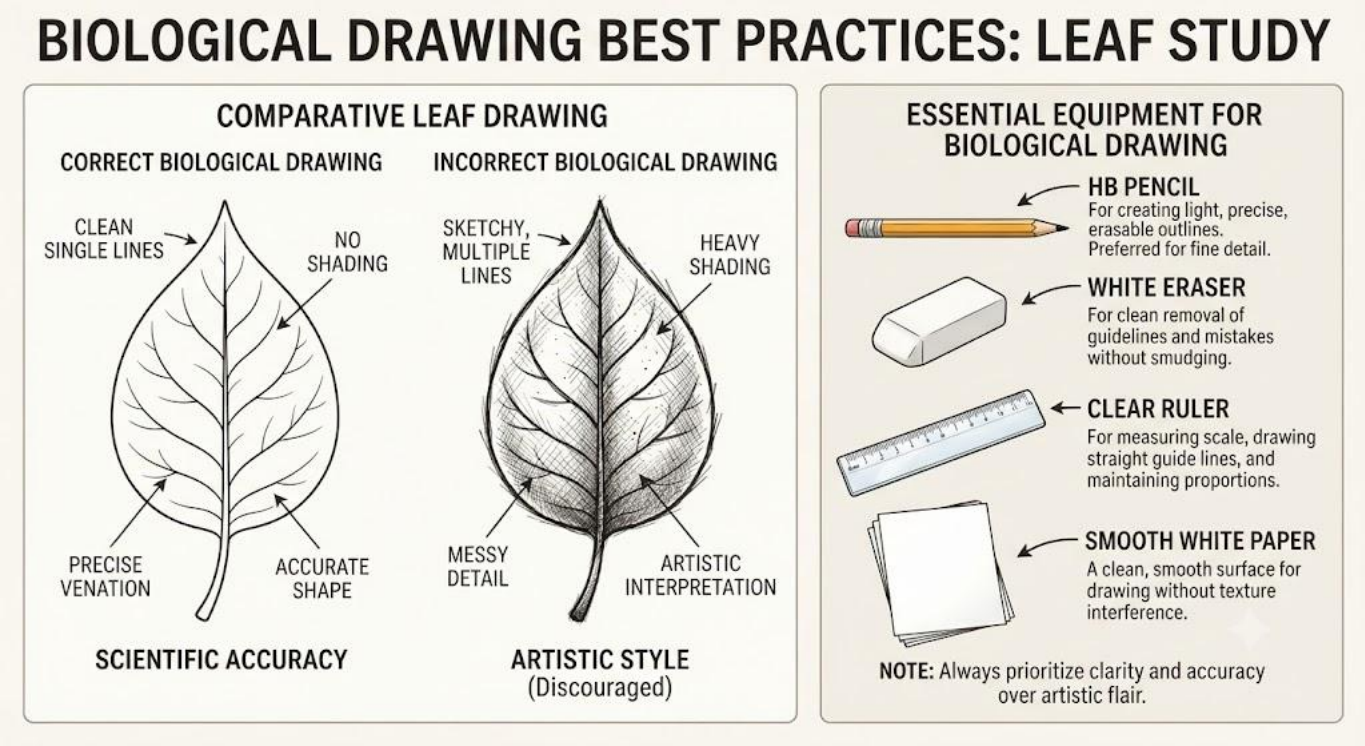

Figure 4.1: Purpose and rules of biological drawing

Pilot questions 4.1

1. State two scientific purposes of biological drawing.
2. Explain why biological drawings are made in pencil rather than pen.
3. State the rule about what structures to include in a biological drawing.
4. Describe the correct line quality for a biological drawing.
5. Name the equipment needed for biological drawing.

4.2 Accuracy, Proportion, and Scale

4.2.1 Accuracy in biological drawings

Accuracy in biological drawing means that the structures drawn faithfully represent what was actually observed in the specimen, with their shapes, boundaries, and relative arrangements correct; accuracy is achieved by looking at the specimen frequently and carefully while drawing,

checking each line against what is actually visible rather than drawing from memory, and correcting any errors with the eraser before proceeding further rather than drawing over them.

Common accuracy errors include drawing structures with incorrect shapes (rounding sharp angles, or adding curves where straight boundaries are present), omitting visible structures, including structures not actually visible in the specimen, or incorrectly showing the connectivity or adjacency of structures, all of which produce a drawing that, however neat, does not accurately represent the specimen observed and therefore fails in its primary scientific purpose.

Fill in the blank: Accuracy in biological drawing is achieved by looking at the specimen _____ and carefully while drawing, checking each line against what is actually visible.

4.2.2 Proportion in biological drawings

Proportion in a biological drawing means that the relative sizes of different structures within the drawing match their relative sizes in the actual specimen; if structure A is twice as wide as structure B in the specimen, it should also be approximately twice as wide in the drawing, regardless of the overall size of the drawing on the page; incorrect proportions produce a drawing that is systematically misleading about the actual structural relationships in the specimen.

Proportion is checked by estimating the relative sizes of major structures in the specimen before drawing begins, setting these proportional relationships on the page at the start, and periodically comparing the drawing with the specimen to verify that proportional relationships are being maintained as the drawing develops; a common error is to draw the first structure too large and then be unable to fit subsequent structures at the correct relative size within the available space.

Fill in the blank: If structure A is twice as wide as structure B in the specimen, it should be approximately _____ as wide in the drawing, regardless of the overall drawing size.

4.2.3 Scale and magnification in drawings

The magnification of a drawing is the ratio of the drawing size to the actual specimen size, calculated using the same formula applied to microscope images: magnification equals drawing

size divided by actual size; a drawing magnification should be stated on the drawing (for example, x5 or x0.5 if the drawing is half the actual size) and is an essential piece of information allowing the reader to determine actual specimen dimensions from the drawing.

A scale bar, a line of stated actual length drawn on the drawing (for example, a 1 cm line labelled as representing 1 mm actual size), provides an alternative and often more practical way to convey the relationship between drawing size and actual size, since it allows actual size to be calculated from any feature in the drawing without requiring the reader to know the exact drawing magnification; both magnification statements and scale bars should use SI units consistently.

Fill in the blank: A scale _____ , a line of stated actual length drawn on the illustration, allows the reader to calculate actual specimen size without needing to know the exact magnification.

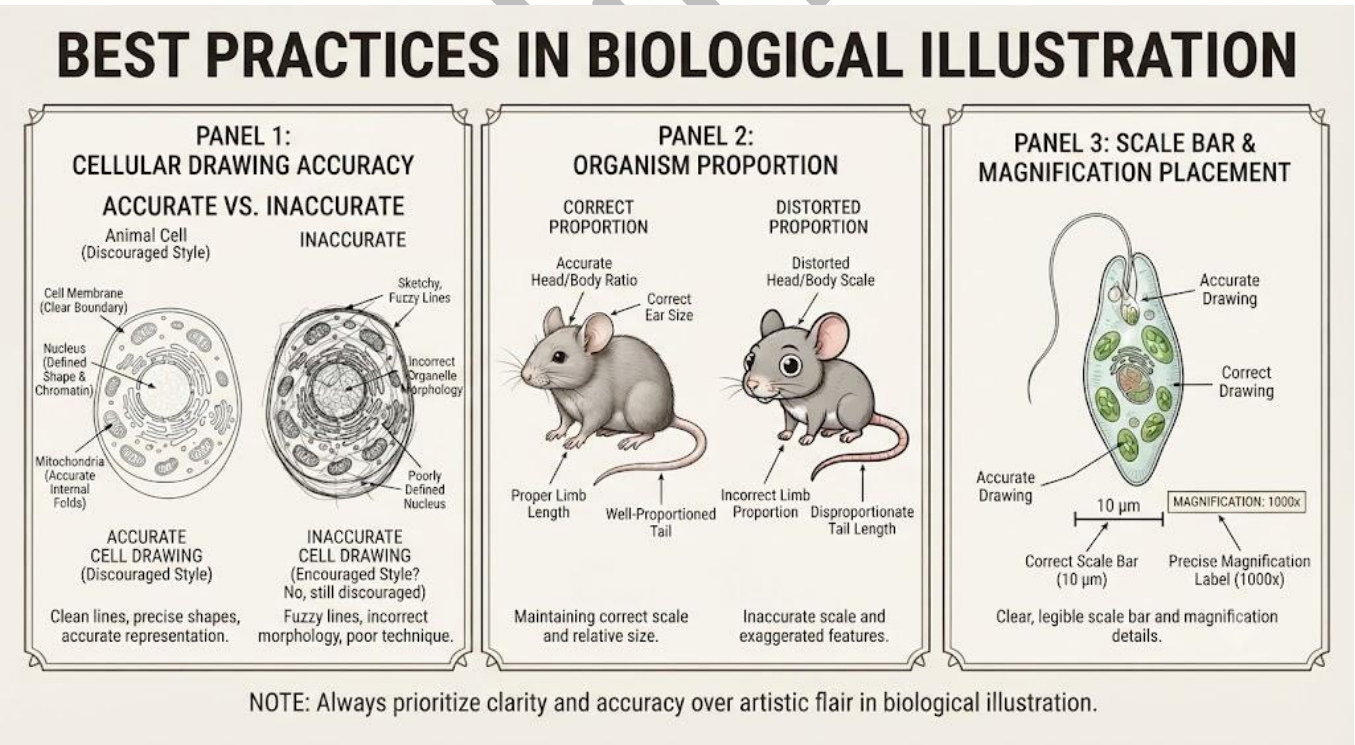

Figure 4.2: Accuracy, proportion, and scale in biological drawings

Pilot questions 4.2

1. Define accuracy in biological drawing.
2. Name two common accuracy errors in biological drawing.
3. Define proportion in biological drawing.
4. Explain how to check proportion during drawing.
5. Distinguish between a magnification statement and a scale bar.

4.3 Drawing Techniques for Different Specimens

4.3.1 Drawing whole organisms and external features

When drawing a whole organism or its external features (such as a leaf, insect, or flower), begin by lightly sketching the overall outline and major proportional relationships before adding any internal or detailed structures, to ensure the overall form and proportions are correct before investing time in fine detail; the outline should then be firmed up with clean, confident single lines, and internal features (veins, surface markings, appendages) added progressively in the correct relative positions.

Three-dimensional features of a specimen should be represented in a two-dimensional drawing using conventional approaches such as overlapping lines to show which structure is in front, or slight curves to suggest rounded surfaces, but artistic shading or shadow should never be added; the goal is to show the spatial arrangement of structures clearly and unambiguously, not to create an artistic impression of depth or texture.

Fill in the blank: When drawing a whole organism, begin by lightly sketching the overall _____ and major proportional relationships before adding any internal or detailed structures.

4.3.2 Drawing cells and microscopic specimens

When drawing cells or microscopic specimens as seen through the compound microscope, only the structures actually clearly visible in the field of view should be drawn; do not draw structures

expected to be present from prior knowledge if they are not clearly visible in this specific preparation, since the drawing should represent the actual observation, not a generic diagram from memory; the cell outline should be drawn first, then internal structures added in their correct relative positions within it.

For microscope drawings, a representative field of view or a small number of representative cells is typically drawn rather than attempting to draw every cell visible; the drawing should show the cell contents proportionally, with no shading (membrane boundaries shown as single clean lines, nuclear and organelle boundaries similarly), and should be large enough to show all relevant visible detail, typically occupying at least a half-page of drawing space to allow adequate room for labelling.

Fill in the blank: In a microscope cell drawing, only structures actually clearly _____ in the field of view should be drawn, not structures expected from prior knowledge.

4.3.3 Drawing dissected specimens

Drawings of dissected specimens show the internal structures revealed by dissection and typically require more complex arrangement decisions than external feature drawings, since the dissection itself may have displaced or altered the natural arrangement of structures; the drawing should show the structures as they appear in the actual dissected specimen, not as a textbook diagram might show them in an idealised state, though additional care is needed to avoid letting prior knowledge override careful observation of the actual arrangement.

Dissection drawings are typically made at lower magnification than microscope drawings and often cover a larger area of the page; if the dissection has been performed well and the natural arrangement of organs is clearly visible, the drawing should attempt to show the spatial relationships among the organs accurately, including which structure overlies or underlies which, since these spatial relationships are among the most important pieces of information a dissection drawing can communicate.

Fill in the blank: A dissection drawing should show the structures as they appear in the actual dissected specimen, not as a _____ diagram might show them in an idealised state.

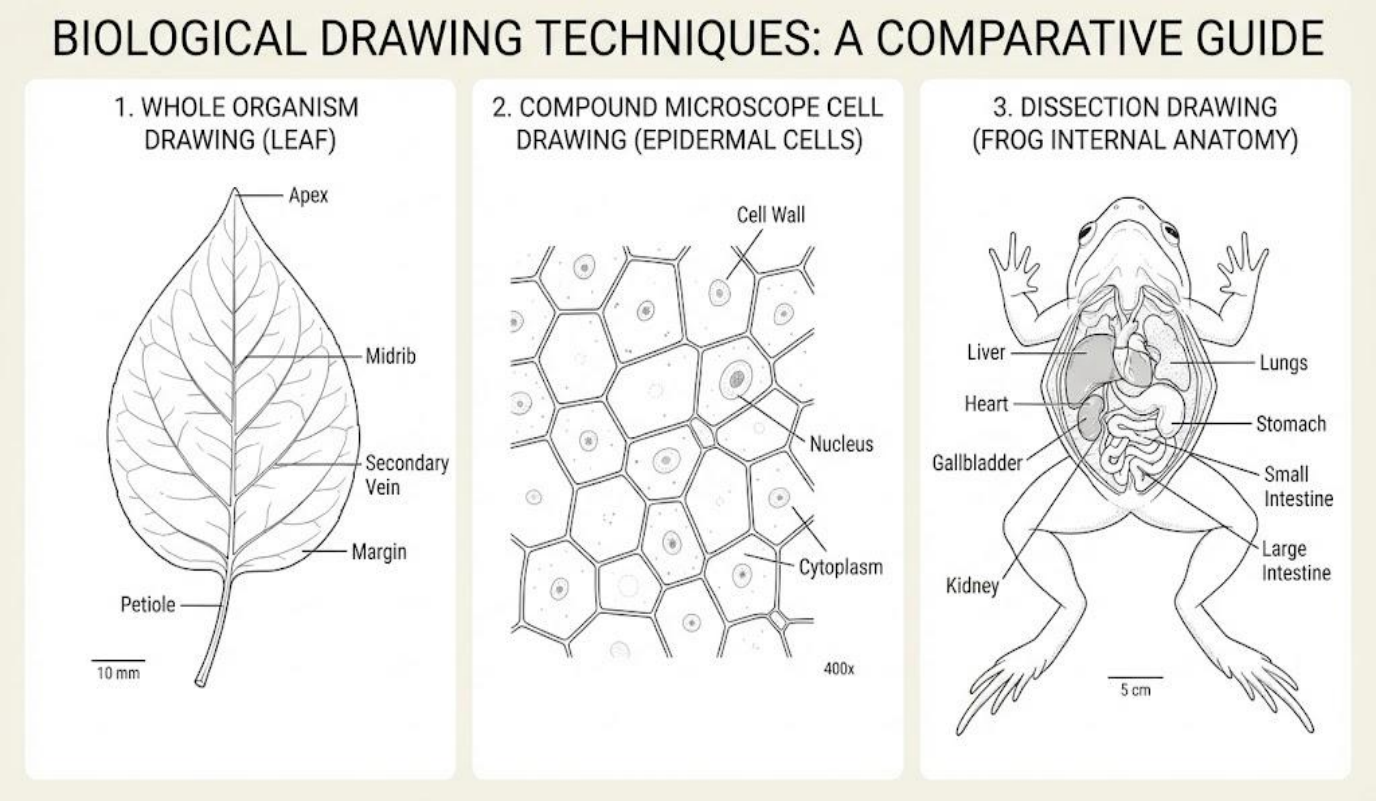

Figure 4.3: Drawing techniques for different specimen types

Pilot questions 4.3

1. Describe the correct sequence of steps when beginning a drawing of a whole organism.
2. Explain how three-dimensional features should be represented without artistic shading.
3. Explain what structures should be included in a microscope cell drawing.
4. Explain why a microscope drawing should typically occupy at least a half-page of space.
5. Explain why a dissection drawing should show what is actually observed rather than a textbook representation.

4.4 Labelling and Presenting Biological Drawings

4.4.1 Labelling conventions

Labels in a biological drawing are connected to the structure they identify by a label line (a thin, straight, horizontal line drawn with a ruler from the label text to the structure, ending at the structure boundary or interior), never by an arrow with an arrowhead; label lines must be straight, must not cross one another where possible, and must clearly point to the specific structure being identified rather than ending vaguely near it.

Label text should be written horizontally (never at an angle, even if the label line runs at an angle to reach its end point), neatly, and consistently in the same style throughout the drawing; labels should be placed outside the drawing boundaries whenever possible to keep the drawing itself unobscured; all major visible structures should be labelled, since an unlabelled drawing communicates considerably less information than a fully labelled one.

Fill in the blank: Label lines in biological drawings must be straight, drawn with a _____ , and must not cross one another where possible.

4.4.2 Titles, magnification, and scale bars

Every biological drawing must have a title stating what the drawing shows (including the species name or common name if known, what type of section or view is shown, and the stain used if any), written above or below the drawing; the title should be specific and informative enough that a reader unfamiliar with the practical session could understand what the drawing represents without additional explanation.

The magnification of the drawing (the ratio of drawing size to actual size, expressed as x followed by the magnification factor) or a scale bar (a line of stated actual length drawn on or beside the drawing) must be included for any drawing where the actual size of the specimen is relevant, as it is in virtually all microscope drawings and most other biological drawings; both the title and the magnification or scale bar are part of the expected standard presentation for any completed biological drawing in practical biology.

Fill in the blank: Every biological drawing must have a _____ stating what the drawing shows, including the organism name, type of view, and any stain used.

4.4.3 Common errors and how to avoid them

The most common errors in biological drawings include: shading or colouring structures instead of using clean lines (corrected by using only pencil line boundaries with no fill); sketchy or multiple overlapping lines instead of clean single lines (corrected by drawing slowly and deliberately, erasing and redrawing rather than overwriting); label lines that are curved, have arrowheads, or cross one another (corrected by using a ruler and planning label placement before drawing lines).

Additional common errors are: drawing too small to show visible structures clearly, leaving insufficient space for labels (corrected by planning the drawing size before beginning and using most of the available page); omitting the title, magnification, or scale bar (corrected by establishing the habit of completing these elements for every drawing before moving on); and drawing from memory or expectation rather than from the actual specimen (corrected by regularly looking back at the specimen while drawing and only drawing what is clearly visible).

Fill in the blank: Drawing too _____ to show visible structures clearly leaves insufficient space for labels and is corrected by planning the drawing size before beginning.

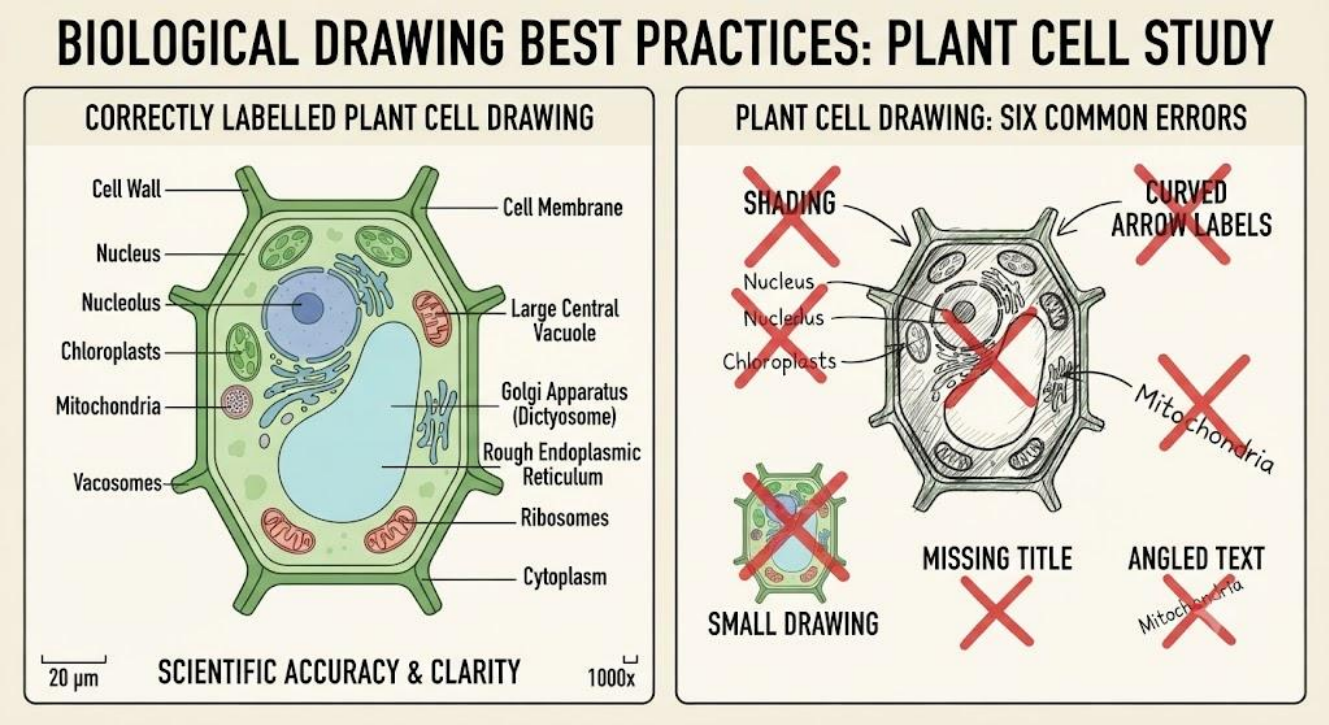

Figure 4.4: Labelling and presenting biological drawings

Pilot questions 4.4

1. Describe the correct type of line used to connect labels to structures in a biological drawing.
2. Explain how label text should be positioned and oriented.
3. State the information that must be included in the title of a biological drawing.
4. Name three common errors made in biological drawings.
5. Explain how to correct the error of sketchy, overlapping lines in a biological drawing.

Series Summary

This Series examined **the principles and techniques of biological drawing as a scientific method of recording observations**. Biological drawings should provide **accurate, well-labelled records** that promote careful observation and must be produced using **a sharp HB/H pencil, clean single lines, no shading, and only visible structures**. Standard equipment includes a **pencil, eraser, ruler, and unlined paper**. The Series emphasised **accuracy**, ensuring that shapes and structures match the specimen, **proportion**, ensuring that relative sizes are maintained, and the use of a **scale bar or magnification statement** to show the relationship between the drawing and the actual specimen.

The Series also covered **drawing techniques and presentation standards**. When drawing whole organisms, students should begin with a light outline before adding firm outlines and visible details without shading. Cell drawings should include **only clearly visible structures**, be drawn large enough for clarity, and use clean continuous lines. Drawings of dissected specimens should accurately represent the observed arrangement and spatial relationships of structures. Proper presentation requires **straight, horizontal label lines drawn with a ruler**, labels written horizontally, an informative title, and a **magnification statement or scale bar**. Common mistakes include **shading, sketchy lines, curved or crossing label lines, drawings that are too small, and missing titles**. By completing this Series, students should achieve SLOs **4.1–4.4**.

Glossary of Terms

- **Accuracy:** in biological drawing, the faithful representation of what was actually observed in the specimen.
- **Label line:** a thin, straight, horizontal line drawn with a ruler connecting a label to the structure it identifies.
- **Magnification statement:** a notation on a drawing indicating the ratio of drawing size to actual specimen size.

- **Proportion:** the correct maintenance of relative sizes among structures in a biological drawing.
- **Scale bar:** a line of stated actual length drawn on a biological drawing to allow calculation of actual specimen dimensions.
- **Shading:** the use of tonal variation to suggest depth or surface, specifically excluded from biological drawings.
- **Wet mount:** a microscope preparation in which a specimen is placed in water on a slide under a cover slip, the most common preparation for compound microscopy.

Concept Check Questions [Series 4]

Objective Questions

1. Biological drawings are always made in _____ rather than pen or colour. (Linked to SLO 4.1)
2. In biological drawing, draw only what is actually _____ in the specimen. (Linked to SLO 4.1)
3. A scale _____ is a line of stated actual length drawn on a drawing to allow size calculation. (Linked to SLO 4.2)
4. Label lines must be straight, drawn with a ruler, and must not _____ one another. (Linked to SLO 4.4)
5. Every biological drawing must have a _____ stating what the drawing shows. (Linked to SLO 4.4)

Short-Answer Questions

1. State three general rules for biological drawing. (Linked to SLO 4.1)
2. Distinguish between accuracy and proportion in biological drawing. (Linked to SLO 4.2)
3. Describe the correct first step when drawing a whole organism. (Linked to SLO 4.3)
4. Describe the correct type of line used to label a biological drawing. (Linked to SLO 4.4)
5. Name three common errors in biological drawing. (Linked to SLO 4.4)

Long-Answer Questions

1. Explain the purpose and general rules of biological drawing, including equipment needed. (Linked to SLO 4.1)
2. Explain accuracy, proportion, and scale and describe drawing techniques for different specimen types. (Linked to SLOs 4.2, 4.3)
3. Describe correct labelling, titling, and presentation of biological drawings and how to avoid common errors. (Linked to SLO 4.4)

Answers to Concept Check Questions [Series 4]

Objective Questions

1. Pencil.
2. Visible.
3. Bar.
4. Cross.
5. Title.

Short-Answer Questions

1. Draw only what is visible; use clean single pencil lines without shading; make the drawing large enough to show detail clearly.
2. Accuracy means shapes and arrangements match the specimen; proportion means relative sizes in the drawing match relative sizes in the specimen.
3. Lightly sketch the overall outline and major proportional relationships before adding any detail.
4. A thin, straight, horizontal line drawn with a ruler, without an arrowhead, pointing clearly to the structure.
5. Shading, sketchy overlapping lines, and curved or crossed label lines (or missing title/scale bar, drawing too small).

Long-Answer Questions

1. Biological drawings produce accurate labelled scientific records and promote careful observation. Rules: pencil only, clean single lines, no shading, draw only what is visible, drawing large enough for detail. Equipment: sharp HB or H pencil, eraser, ruler, unlined white paper.
2. Accuracy means shapes match the specimen; proportion means relative sizes match; scale bar or magnification statement conveys size relationship. Whole organisms:

light outline first, then firm, then detail. Cells: draw only clearly visible structures, large, no shading. Dissected specimens: show actual observed arrangement.

3. Label lines: straight, ruled, horizontal, no arrowheads, non-crossing; label text horizontal and outside the drawing. Title must state organism, view type, and stain. Magnification or scale bar required. Common errors: shading, sketchy lines, curved labels, drawing too small, missing title. All corrected by deliberate pencil technique, ruler use, and habit formation.

Answers to Pilot Questions [Series 4]

Part 4.1

1. Biological drawings promote close, careful observation of specimens and produce a permanent, annotated scientific record.
2. Pencil allows clean correction and produces the accepted convention for biological drawings without shading.
3. Draw only what is actually visible in the specimen; never add structures from memory or expectation.
4. Lines should be clear, single, and confident; not fuzzy, overlapping, or multi-stroke.
5. Sharp HB or H pencil, good quality eraser, ruler, and unlined white drawing paper.

Part 4.2

1. Accuracy means the shapes, boundaries, and relative arrangements of drawn structures faithfully represent what was observed.
2. Drawing structures with incorrect shapes, and omitting visible structures or including non-visible ones.
3. Proportion means the relative sizes of different structures in the drawing match their relative sizes in the actual specimen.
4. Estimate the relative sizes of major structures before drawing, set proportions at the start, and compare drawing with specimen periodically.

5. A magnification statement is a stated ratio (e.g. x5); a scale bar is a line of stated actual length drawn on the illustration.

Part 4.3

1. Lightly sketch the overall outline and major proportional relationships before adding any internal or detailed structures.
2. Use overlapping lines to show which structure is in front, or slight curves to suggest rounded surfaces, without artistic shading.
3. Only structures actually clearly visible in the field of view; no structures added from prior knowledge if not clearly seen.
4. A large drawing allows adequate space to show all visible detail and to add labels without obscuring the drawing.
5. A drawing should represent the actual observation; prior knowledge can cause the observer to draw what is expected rather than what is seen.

Part 4.4

1. A thin, straight, horizontal line drawn with a ruler, ending at the structure and without an arrowhead.
2. Label text should be written horizontally, outside the drawing boundary, and consistently styled throughout.
3. The organism or specimen name, the type of section or view, and the stain used if any.
4. Shading, sketchy overlapping lines, and curved label lines with arrowheads.
5. Erase the sketchy lines completely and redraw each line slowly and deliberately as a single clean stroke.

References and Attributions

Textual References (Books and External Sources)

- Campbell, N. A., & Reece, J. B. (2018). Biology (11th ed.). Pearson.
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Figures, Plates, Tables, and Boxes

- Figure 4.1: Purpose and rules of biological drawing Attribution: AI generated. Suggested OER search string: "biological drawing rules correct incorrect comparison equipment pencil unlined paper biology OER".
- Figure 4.2: Accuracy, proportion, and scale in biological drawings Attribution: AI generated. Suggested OER search string: "biological drawing accuracy proportion scale bar magnification label diagram biology OER".
- Figure 4.3: Drawing techniques for different specimen types Attribution: AI generated. Suggested OER search string: "biological drawing whole organism cell microscope dissection technique examples biology OER".
- Figure 4.4: Labelling and presenting biological drawings Attribution: AI generated. Suggested OER search string: "biological drawing labelling conventions title scale bar magnification common errors diagram biology OER".

Course code: BIO 107

Course title: General Biology Practical I

Course credit load: 1 Unit

Series 5: Laboratory Apparatus and Experiments

- **Part 5.1: Common Laboratory Glassware**
    - Sub Part 5.1.1: Beakers, flasks, and test tubes
    - Sub Part 5.1.2: Volumetric and graduated glassware
    - Sub Part 5.1.3: Slides, cover slips, and Petri dishes
- **Part 5.2: Other Laboratory Apparatus**
    - Sub Part 5.2.1: Heating apparatus
    - Sub Part 5.2.2: Separation and support apparatus
    - Sub Part 5.2.3: Dissecting instruments
- **Part 5.3: Designing and Conducting a Biology Experiment**
    - Sub Part 5.3.1: Variables and controls
    - Sub Part 5.3.2: Writing a method
    - Sub Part 5.3.3: Collecting and recording results
- **Part 5.4: Selected Experiments Illustrating Core Biology Topics**
    - Sub Part 5.4.1: Testing for biological molecules
    - Sub Part 5.4.2: Observing osmosis and diffusion
    - Sub Part 5.4.3: Investigating enzyme activity

Introduction

A biology laboratory contains a wide range of apparatus, each with a specific purpose and correct method of use; knowing the function and proper handling of common laboratory equipment is essential both for practical efficiency and for safety. This Series also introduces the principles of experimental design and presents three representative experiments that illustrate core topics in cell biology, allowing students to link practical technique with biological concepts.

This Series covers common laboratory glassware and its correct uses; heating, separation, support, and dissecting apparatus; the principles of experimental design including variables, controls, and method writing; and three illustrative practical experiments covering food molecule testing, osmosis and diffusion, and enzyme activity investigation, applying the measurement, microscopy, and drawing skills developed throughout this course.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 5.1** identify and describe the correct use of common laboratory glassware,
- **SLO 5.2** identify and describe the correct use of heating, separation, support, and dissecting apparatus,
- **SLO 5.3** design a simple biology experiment by identifying variables, controls, writing a method, and recording results, and
- **SLO 5.4** describe the procedure and expected outcomes of food molecule testing, osmosis/diffusion, and enzyme activity experiments.

5.1 Common Laboratory Glassware

5.1.1 Beakers, flasks, and test tubes

A beaker is a flat-bottomed, open-topped cylindrical glass or plastic container used for mixing, heating (on a suitable heat-resistant mat or tripod and gauze), and temporary storage of solutions; it has a graduation for approximate volume reading but is not sufficiently accurate for precise volume measurement, for which volumetric glassware (Part 5.1.2) should be used; beakers are available in a wide range of sizes from a few millilitres to several litres.

A conical (Erlenmeyer) flask has a wide flat base narrowing to a cylindrical neck, making it stable and resistant to spilling, and suitable for mixing, heating, and holding liquids during titrations or reactions where the contents must be swirled; a test tube is a small, narrow, cylindrical glass or plastic tube used for holding small volumes of liquid, performing chemical tests, and culturing microorganisms, and is held in a test tube rack when not in hand use.

Fill in the blank: A conical flask is suitable for mixing, heating, and holding liquids during reactions where the contents must be _____ without spilling.

5.1.2 Volumetric and graduated glassware

A graduated (measuring) cylinder is used for approximate volume measurement of liquids, read at the bottom of the meniscus at eye level as described when measuring volume; a burette is a long, graduated tube with a tap at the bottom, used for delivering precise, variable volumes of liquid, read by noting the difference between the initial and final scale readings; a pipette delivers a fixed, precise volume and is available in several sizes, always used with a pipette filler rather than by mouth.

A volumetric flask has a single calibration mark at the neck indicating an exact volume (typically 100 mL, 250 mL, or 1000 mL) and is used for preparing solutions of accurately known concentration, filled to the mark with solvent added after dissolving the solute; volumetric glassware should be cleaned thoroughly before use and inspected for chips or cracks in the graduation marks, since damaged volumetric glassware cannot be relied upon for accurate volume measurement.

Fill in the blank: A volumetric flask has a single _____ mark at the neck indicating an exact volume, used for preparing solutions of accurately known concentration.

5.1.3 Slides, cover slips, and Petri dishes

Glass microscope slides (75 mm by 25 mm flat glass rectangles) provide the platform on which specimens are mounted for compound microscopy; cover slips (thin, small squares or circles of glass placed over the specimen to protect the objective lens and flatten the specimen) are fragile and must be handled carefully by the edges to avoid breakage and fingerprint contamination of the optical surfaces; both slides and cover slips must be clean and unscratched before use.

Petri dishes (shallow, flat-lidded circular glass or plastic dishes) are used in microbiology for growing cultures of microorganisms on solid growth medium (agar), and in other contexts for dissection of small specimens, holding specimens under a dissecting microscope, or temporarily holding specimens and reagents during practical work; used Petri dishes containing microorganism cultures must be treated as biological hazardous waste and disposed of appropriately.

Fill in the blank: Cover slips must be handled carefully by the _____ to avoid breakage and fingerprint contamination of the optical surfaces.

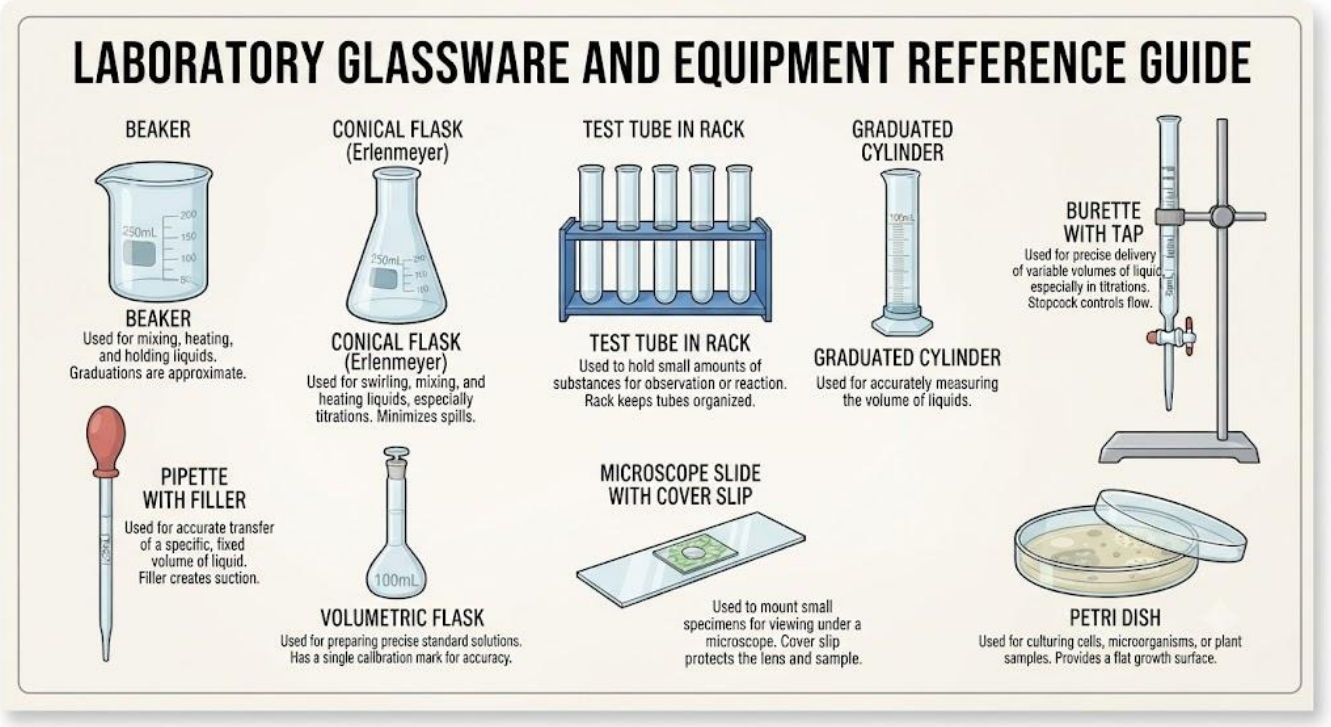

Figure 5.1: Common laboratory glassware

Pilot questions 5.1

1. Distinguish between a beaker and a volumetric flask in terms of the accuracy of their volume measurement.
2. State the correct tool to use alongside a pipette and explain why.
3. Describe the use of a burette and explain how volume delivered is determined.
4. Explain why microscope slides and cover slips must be clean and unscratched before use.
5. Describe the correct disposal procedure for a Petri dish containing a microorganism culture.

5.2 Other Laboratory Apparatus

5.2.1 Heating apparatus

A Bunsen burner is a gas burner connected to a laboratory gas supply, providing an adjustable flame used for heating liquids, sterilising wire loops, and other tasks requiring a direct flame; the air hole at the base controls the air-to-gas ratio and therefore the flame type: the roaring blue flame (air hole fully open) is hotter and suitable for most heating tasks, while the safety yellow luminous flame (air hole closed or partly closed) is cooler and suitable for low-temperature heating and for use as a standby flame when the burner is not actively in use.

A hot plate or electric heating mantle provides heat without an open flame and is therefore safer for use with flammable solvents; a water bath (a temperature-controlled container of water) provides gentler, more even heating at a controlled temperature, essential for experiments requiring precise temperature conditions such as enzyme activity investigations; liquids heated in a test tube must always be pointed away from the operator and others to prevent spraying if the liquid boils suddenly.

Fill in the blank: The _____ blue flame of a Bunsen burner, produced when the air hole is fully open, is hotter and suitable for most heating tasks.

5.2.2 Separation and support apparatus

A tripod and gauze (wire gauze placed on a tripod stand) support a beaker or flask above a Bunsen burner flame for even heating; retort stands with clamps and bosses support burettes, condensers, and other apparatus at a required height and angle; filter funnels and filter paper are used to separate insoluble solids from liquids by filtration, with the liquid (filtrate) passing through the paper and the solid (residue) retained on the paper.

A centrifuge spins samples at high speed to separate components by density (denser particles settling at the bottom of the tube), used in biology to separate cells from growth medium, organelles from cell homogenate, or precipitates from solutions; centrifuge tubes must always be balanced (opposite tubes loaded with equal mass) before a centrifuge run to prevent dangerous vibration and potential instrument damage or injury.

Fill in the blank: Centrifuge tubes must always be _____ before a centrifuge run, with opposite tubes loaded with equal mass, to prevent dangerous vibration.

5.2.3 Dissecting instruments

Dissecting scissors (sharp, straight-bladed scissors used for cutting tissues) and dissecting scalpels (short, replaceable-blade knives used for making precise incisions) are the primary cutting instruments in a dissection; blades must always be sharp (blunt blades require greater force and increase the risk of slipping), and scalpel blades must be changed using forceps or a blade-changing tool, never fingers, to avoid accidental cuts.

Dissecting needles (stiff, mounted needles used for probing, separating, and holding tissues) and forceps (tweezers-like instruments used for holding and manipulating small structures) complete the basic dissecting instrument set; all dissecting instruments should be cleaned after use, with blades and needles treated as sharp biological waste, and stored safely with blade guards or protective covers in place to protect both the instruments and any person handling them after use.

Fill in the blank: Scalpel blades must be changed using _____ or a blade-changing tool, never fingers, to avoid accidental cuts from the sharp edge.

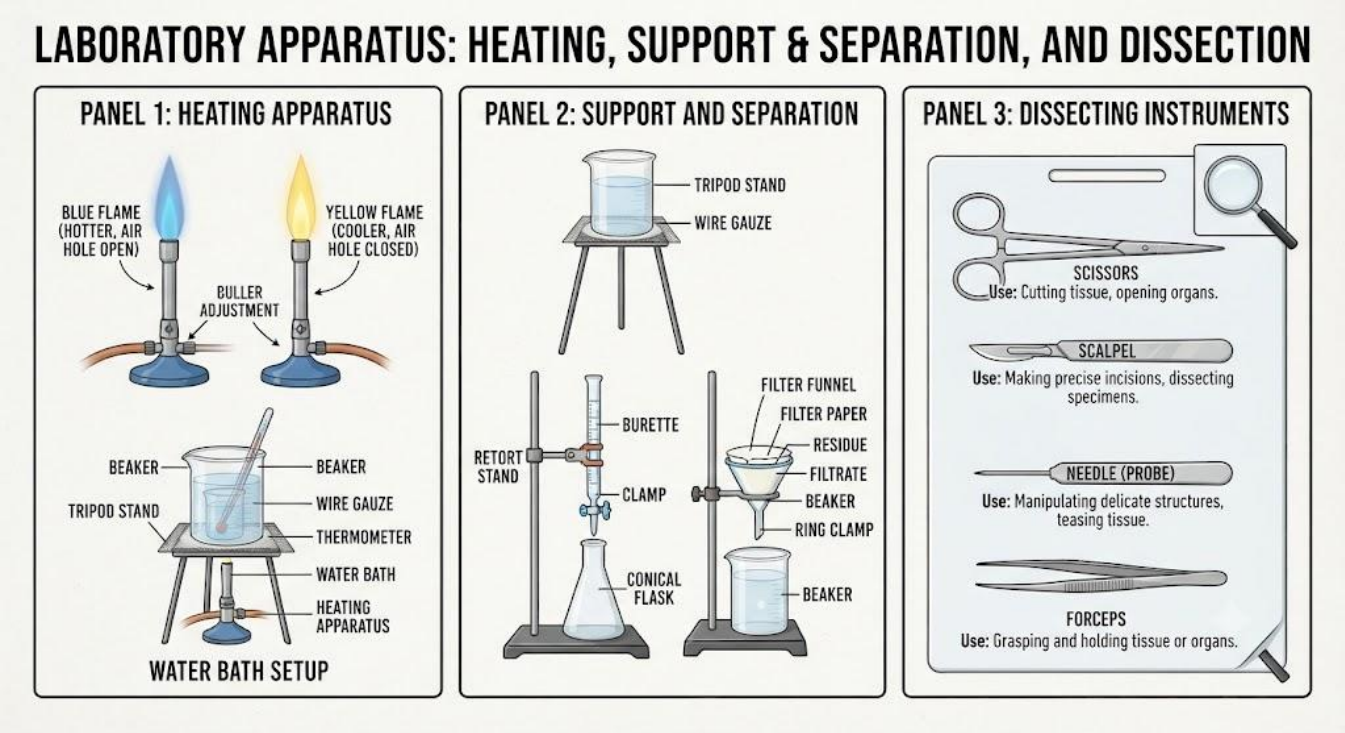

Figure 5.2: Other laboratory apparatus

Pilot questions 5.2

1. Distinguish between the roaring blue flame and the safety yellow flame of a Bunsen burner.
2. Explain why a water bath is used instead of a Bunsen burner for some heating experiments.
3. Describe the function of a tripod and gauze in a heating setup.
4. Explain why centrifuge tubes must be balanced before a centrifuge run.
5. Explain why scalpel blades should be changed with forceps rather than fingers.

5.3 Designing and Conducting a Biology Experiment

5.3.1 Variables and controls

An independent variable is the factor deliberately changed by the experimenter between experimental groups (for example, temperature in an enzyme activity investigation); a dependent

variable is the outcome measured in response to the change in the independent variable (for example, the rate of enzyme activity at each temperature); controlled variables are all other factors kept constant throughout the experiment to ensure that any observed change in the dependent variable can be attributed to the independent variable alone.

A control group or control treatment is a version of the experiment in which the independent variable is set to a reference level (often zero or the natural/standard condition) and no experimental treatment is applied, providing a baseline against which the experimental results can be compared; without a control, it is impossible to determine whether any observed change is actually caused by the experimental treatment or would have occurred anyway under the same conditions.

Fill in the blank: A _____ group provides a baseline reference by setting the independent variable to a reference level and applying no experimental treatment.

5.3.2 Writing a method

A well-written laboratory method describes every step of the experimental procedure in sufficient detail that another competent person could repeat the experiment exactly without additional guidance, producing a reproducible set of results; it should specify the exact quantities of materials used, the sequence of steps, the timing where relevant, the measurement methods and instruments used, and how results are to be recorded, using numbered sequential steps rather than continuous prose.

The method should also state the range and number of values of the independent variable tested (for example, five temperatures from 20 to 60 degrees C in steps of 10 degrees), the number of replicates at each value, and any specific safety precautions required by the materials or procedures involved; writing the method before conducting the experiment (not as a retrospective description of what was actually done) supports both clearer experimental thinking and a more reliable, reproducible procedure.

Fill in the blank: A well-written method describes every step in sufficient detail that another competent person could _____ the experiment exactly without additional guidance.

5.3.3 Collecting and recording results

Results should be recorded in a prepared data table (with column headings including variable names and units, as described when discussing data recording) during the experiment rather than after it, since recording as you go prevents errors from memory and ensures that any unusual observation is noted at the time it occurs rather than forgotten; raw data values should be recorded exactly as measured, before any calculations or averaging.

After data collection, calculations (means, rates, concentrations) are performed and recorded in additional table columns, and appropriate graphs are constructed to identify and display trends in the data; any anomalous results (values that differ markedly from the pattern of other results) should be noted and investigated rather than silently omitted, since they may reflect a genuine biological phenomenon, a measurement error, or a procedural problem, each of which has different implications for the interpretation of the experiment.

Fill in the blank: Results should be recorded in a prepared data table _____ the experiment, not after it, to prevent errors from memory and ensure unusual observations are noted at the time.

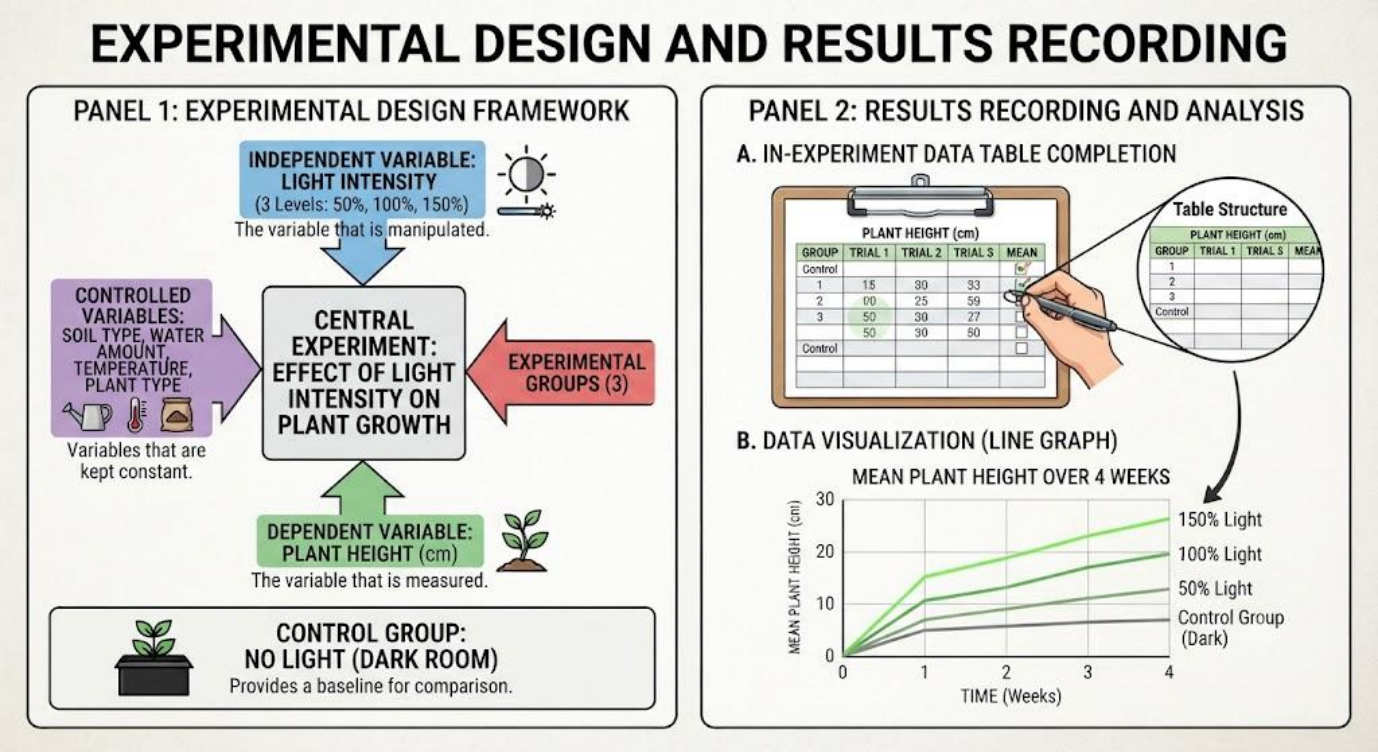

Figure 5.3: Experimental design and data collection

Pilot questions 5.3

1. Define independent variable, dependent variable, and controlled variable.
2. Explain the purpose of a control group in an experiment.
3. State two pieces of information that must be specified when writing the range of an independent variable.
4. Explain why results should be recorded during an experiment rather than afterwards.
5. Explain what should be done when an anomalous result is observed.

5.4 Selected Experiments Illustrating Core Biology Topics

5.4.1 Testing for biological molecules

Food molecule tests allow the identification of specific biological molecules in a sample using chemical reagents that produce a characteristic colour change in the presence of the target

molecule: the iodine test (iodine solution, which is brown/orange, turns blue-black in the presence of starch); the Benedicts test (blue Benedict reagent turns brick-red/orange precipitate when heated in the presence of reducing sugars such as glucose); and the Biuret test (blue Biuret reagent turns purple/lilac in the presence of protein).

For each test, a positive control (a sample known to contain the target molecule) and a negative control (a sample known to lack the target molecule) should be set up alongside the unknown sample, allowing the colour change of the unknown to be compared against confirmed positive and negative results; the tests can be performed on food extracts, plant tissue extracts, or prepared solutions to investigate whether a given sample contains starch, reducing sugar, or protein.

Fill in the blank: In the Benedict test, the blue reagent turns brick-red/orange precipitate when heated in the presence of _____ sugars such as glucose.

5.4.2 Observing osmosis and diffusion

Osmosis can be demonstrated using pieces of plant tissue (such as potato or carrot strips) placed in solutions of different concentrations (for example, distilled water and several concentrations of sucrose solution): strips placed in distilled water gain mass and become firm (turgid) as water enters by osmosis, while strips placed in concentrated solution lose mass and become soft (plasmolysed) as water leaves by osmosis; strips placed in an intermediate solution that matches cell solute concentration change little in mass.

Diffusion can be demonstrated by adding a crystal of coloured dye (such as potassium permanganate) to a beaker of still water and observing the gradual spread of colour through the water over time without stirring, illustrating net movement of particles from a high concentration region (where the crystal dissolves) to lower concentration regions throughout the surrounding water; the rate of diffusion increases at higher temperatures, which can be demonstrated by comparing diffusion rates in water at different temperatures.

Fill in the blank: In an osmosis investigation, plant strips placed in distilled water gain mass and become _____ as water enters the cells by osmosis.

5.4.3 Investigating enzyme activity

Enzyme activity can be investigated by measuring the rate at which an enzyme catalyses a reaction under different conditions (temperature, pH, or substrate concentration); a common accessible experiment uses amylase enzyme and starch solution: starch solution is mixed with amylase, and at regular time intervals a small sample is removed and tested with iodine solution (iodine turns blue-black in the presence of starch; no colour change indicates starch has been digested), with the time at which the iodine test no longer turns blue-black indicating the time taken for complete starch digestion at that condition.

The effect of temperature on enzyme activity follows a characteristic pattern: activity increases with temperature up to an optimum (the temperature at which the enzyme works fastest), then decreases sharply above the optimum as the enzyme begins to denature (unfold, losing its specific three-dimensional shape and therefore its catalytic ability); this pattern is demonstrated by repeating the amylase-starch experiment at several temperatures and comparing the time to complete digestion at each.

Fill in the blank: Above the enzyme temperature optimum, activity decreases sharply as the enzyme begins to _____ , losing its specific three-dimensional shape and catalytic ability.

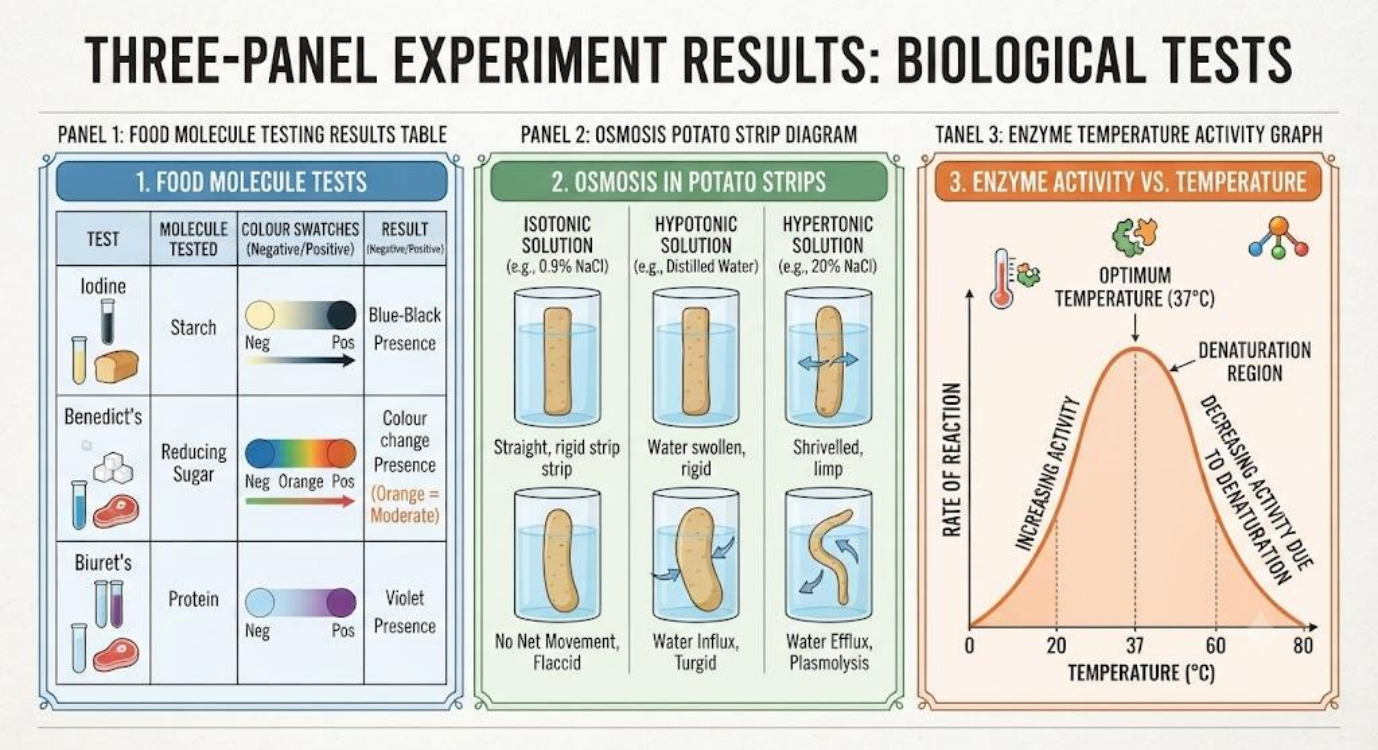

Figure 5.4: Selected biology experiments

Pilot questions 5.4

1. Name three food molecule tests and the colour change each produces when the target molecule is present.
2. Explain why a positive and negative control should be set up alongside an unknown sample in food testing.
3. Describe what happens to a potato strip placed in concentrated sucrose solution and explain why.
4. Describe how diffusion can be demonstrated using a coloured dye in still water.
5. Describe the characteristic pattern of enzyme activity as temperature increases from below to above the optimum.

Series Summary

This Series examined **common laboratory apparatus and experimental methods used in biology**. It covered the functions of **laboratory glassware**, including **beakers, conical flasks, and test tubes** for general use; **measuring cylinders, burettes, and pipettes** for measuring volumes; **volumetric flasks** for preparing solutions of exact concentration; and **slides, cover slips, and Petri dishes** for microscopy and specimen handling. Other essential equipment included the **Bunsen burner** (blue roaring flame for heating and yellow luminous flame for standby), **hot plates, water baths, tripod and wire gauze, retort stands, filter funnels, centrifuges** (with balanced tubes), and dissecting instruments such as **scissors, scalpels, needles, and forceps**, with emphasis on safe handling.

The Series also covered **experimental design and selected biological experiments**. Students learned to identify the **independent variable** (manipulated), **dependent variable** (measured), **controlled variables** (kept constant), and the **control group** (baseline for comparison). Experimental methods should be written as **clear, numbered, reproducible steps** specifying quantities, timing, and safety precautions. Results should be recorded in **data tables**, analysed using means where appropriate, and presented with suitable graphs. Practical experiments included **iodine testing for starch (blue-black colour), Benedict's test for reducing sugars (brick-red precipitate), Biuret test for proteins (purple colour), osmosis in potato strips (mass changes with solution concentration), and enzyme activity investigations showing increased activity up to an optimum temperature followed by a decline due to denaturation**. By completing this Series, students should achieve all SLOs and the overall course outcomes.

Glossary of Terms

- **Burette:** a long graduated tube with a tap used for delivering precise, variable volumes of liquid.
- **Control group:** an experimental group in which the independent variable is set to a reference level, providing a baseline for comparison.

- **Denaturation:** the irreversible loss of an enzyme three-dimensional shape, destroying its catalytic activity.
- **Independent variable:** the factor deliberately changed by the experimenter between experimental groups.
- **Optimum temperature:** the temperature at which an enzyme achieves its maximum catalytic activity.
- **Pipette filler:** a device used to draw liquid into a pipette, replacing the unsafe practice of mouth pipetting.
- **Volumetric flask:** a flask with a single calibration mark used for preparing solutions of accurately known concentration.

Concept Check Questions [Series 5]

Objective Questions

1. A volumetric flask has a single _____ mark at the neck for preparing solutions of known concentration. (Linked to SLO 5.1)
2. The roaring _____ flame of a Bunsen burner is produced when the air hole is fully open. (Linked to SLO 5.2)
3. A _____ group provides a baseline reference by receiving no experimental treatment. (Linked to SLO 5.3)
4. In the Benedict test, blue reagent turns brick-red in the presence of _____ sugars. (Linked to SLO 5.4)
5. Above the optimum temperature, enzyme activity decreases as the enzyme begins to _____ . (Linked to SLO 5.4)

Short-Answer Questions

1. Distinguish between a burette and a pipette in terms of use. (Linked to SLO 5.1)
2. Explain why centrifuge tubes must be balanced before use. (Linked to SLO 5.2)
3. Define independent and dependent variable. (Linked to SLO 5.3)
4. Name three food molecule tests and the colour change each produces. (Linked to SLO 5.4)
5. Describe what happens to a potato strip placed in distilled water and explain why. (Linked to SLO 5.4)

Long-Answer Questions

1. Identify and describe the correct use of common laboratory glassware and other apparatus. (Linked to SLOs 5.1, 5.2)
2. Explain how to design a simple biology experiment including variables, controls, method, and result recording. (Linked to SLO 5.3)
3. Describe the procedure and expected outcomes of food molecule testing, osmosis, and enzyme activity experiments. (Linked to SLO 5.4)

Answers to Concept Check Questions [Series 5]

Objective Questions

1. Calibration.
2. Blue.
3. Control.
4. Reducing.
5. Denature.

Short-Answer Questions

1. A burette delivers precise, variable volumes by noting the difference between initial and final readings; a pipette delivers a single fixed precise volume.
2. Unbalanced tubes cause dangerous vibration that could damage the centrifuge or cause injury.
3. The independent variable is deliberately changed by the experimenter; the dependent variable is the measured outcome.
4. Iodine/starch (blue-black), Benedict/reducing sugar (brick-red), Biuret/protein (purple).
5. The strip gains mass and becomes turgid as water enters the cells by osmosis from the higher water concentration outside.

Long-Answer Questions

1. Beaker and conical flask are for mixing/heating (approximate volumes); burette, pipette, and volumetric flask for precise volumes; slides/cover slips for microscopy; Petri dishes for cultures. Bunsen burner provides direct flame; water bath provides controlled temperature; tripod/gauze supports heating; centrifuge separates by density; dissecting instruments (scissors, scalpel, needles, forceps) for dissection.

2. Identify independent (changed), dependent (measured), and controlled (constant) variables, and set up a control group as baseline. Write numbered steps specifying quantities, timing, and safety. Record results in a prepared data table during the experiment, calculate means, plot graphs, and note anomalies.
3. Food testing: iodine (blue-black for starch), Benedict heated (brick-red for reducing sugar), Biuret (purple for protein), with positive and negative controls. Osmosis: potato strips gain mass in distilled water, lose mass in concentrated solution. Enzyme activity: amylase-starch rate increases to temperature optimum then falls sharply as enzyme denatures.

Answers to Pilot Questions [Series 5]

Part 5.1

1. A beaker provides only approximate volume; a volumetric flask has a single precise calibration mark for accurate volume.
2. A pipette filler; mouth pipetting is unsafe and must never be done.
3. A burette delivers variable volumes; volume delivered equals the initial reading minus the final reading.
4. Dirty or scratched slides and cover slips impair image quality and contaminate specimens.
5. Used microorganism culture dishes must be autoclaved or placed in labelled biohazard waste bags for proper biological waste disposal.

Part 5.2

1. The roaring blue flame is hotter, used for most heating tasks; the yellow luminous flame is cooler, used as a standby.
2. A water bath provides gentler, more even heating at a controlled temperature, essential when precise temperature conditions are needed.

3. A tripod and gauze support a container above a Bunsen flame and distribute heat more evenly than direct contact with the flame.
4. Unbalanced tubes cause dangerous vibration, potentially damaging the centrifuge or causing injury.
5. Scalpel blades are extremely sharp; using fingers to change them risks serious cuts.

Part 5.3

1. Independent variable: the factor deliberately changed. Dependent variable: the outcome measured. Controlled variable: a factor kept constant throughout.
2. A control group provides a baseline with no treatment applied, allowing the experimenter to determine whether any observed change is caused by the experimental treatment.
3. The range of values tested and the number of steps or values within that range.
4. Recording during the experiment prevents memory errors and ensures unusual observations are noted at the time they occur.
5. An anomalous result should be noted and investigated, since it may reflect a genuine biological phenomenon, a measurement error, or a procedural problem.

Part 5.4

1. Iodine/starch (brown to blue-black), Benedict/reducing sugar (blue to brick-red precipitate on heating), Biuret/protein (blue to purple).
2. Positive and negative controls confirm the expected colour changes for a definite positive and negative result, allowing the unknown to be compared against confirmed references.
3. The strip loses mass and becomes soft as water leaves the cells by osmosis into the surrounding concentrated solution.
4. Add a coloured dye crystal to still water and observe the gradual spread of colour through the water over time without stirring.

5. Activity increases with temperature up to the optimum, then decreases sharply above the optimum as the enzyme denatures.

References and Attribution

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Figures, Plates, Tables, and Boxes

- Figure 5.1: Common laboratory glassware Attribution: AI generated. Suggested OER search string: "laboratory glassware beaker flask test tube burette pipette volumetric flask slide Petri dish diagram biology OER".
- Figure 5.2: Other laboratory apparatus Attribution: AI generated. Suggested OER search string: "laboratory apparatus Bunsen burner water bath tripod filter funnel centrifuge dissecting instruments diagram biology OER".
- Figure 5.3: Experimental design and data collection Attribution: AI generated. Suggested OER search string: "experimental design variables control group method results recording data table graph biology OER".
- Figure 5.4: Selected biology experiments Attribution: AI generated. Suggested OER search string: "food molecule test iodine Benedict Biuret osmosis potato enzyme temperature activity curve biology OER".