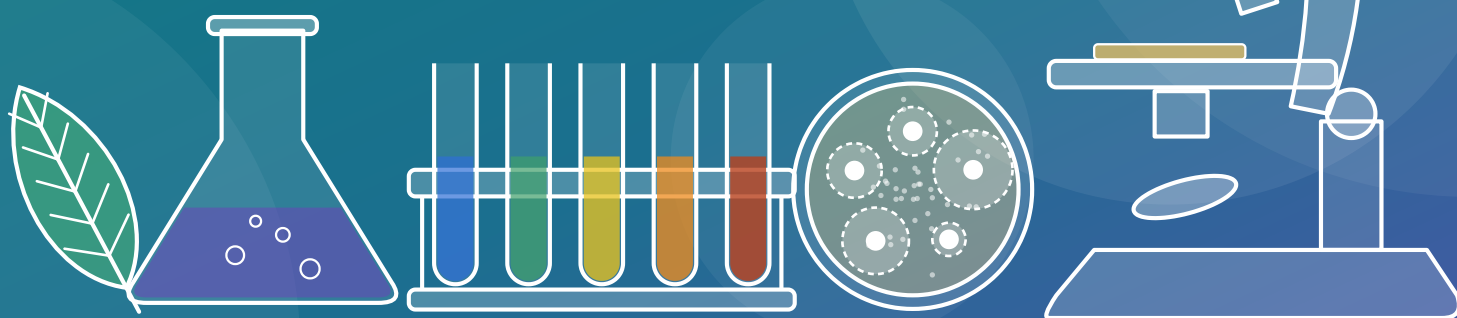


PRACTICAL BASED ASSESSMENT

Biology Practical Book

**All 19 PBA Practicals with
Related Theory, Labelled
Diagrams & Answers**

Based on the National Curriculum of Pakistan 2022-23 and the FBISE Assessment Framework for PBA.
Linked with the NBF Textbooks of Biology, Grade 11 and Grade 12.



AUTHOR

Muhammad Adeel Farooq

Lecturer Biology
FG Inter College, Jhelum Cantt

ABOUT THE AUTHOR

Muhammad Adeel Farooq

Lecturer Biology, FG Inter College, Jhelum Cantt
Founder, EduNova Academy PK
(an online learning platform)



Muhammad Adeel Farooq is a lecturer, researcher and educator with more than five years of teaching experience. He teaches Biology at FG Inter College, Jhelum Cantt, and has served as a visiting lecturer at Government College University, Lahore, and at the University of Education, Township Campus, Lahore.

With a strong research background, he has contributed to more than 18 research publications, which have earned over 650 citations on Google Scholar. His M.Phil. research has been published in the **Journal of Burn Care & Research**, published by **Oxford University Press**.

5+

YEARS OF TEACHING

18+

RESEARCH PUBLICATIONS

650+

GOOGLE SCHOLAR CITATIONS

Education

B.Sc. (Hons.) Zoology
GC University, Lahore

M.Phil. Zoology
GC University, Lahore

B.Ed.
Bachelor of Education

Mission — Through **EduNova Academy PK**, an online learning platform, he aims to make quality academic education and modern Bioinformatics skills more accessible to students.

● About this Book

This book has been written for students of HSSC (Class XI and XII) who are preparing for the **Practical Based Assessment (PBA)** of Biology conducted by the Federal Board of Intermediate and Secondary Education, Islamabad. It covers **all nineteen practicals** listed in the FBISE Assessment Framework — eight major practicals of Section A and eleven minor practicals of Section B.

Every practical opens with a **Related Theory** box that names the chapter and topics of the NBF Model Textbook of Biology (Grade 11 or Grade 12) on which the practical is based, followed by the key concepts a student must know. Then come the object, apparatus, labelled diagrams, procedure, sample observations and calculations, precautions and, finally, **answers to short questions** of the kind asked in the PBA paper.

Students are advised to perform every practical in the laboratory, because only those who have done so are allowed to attempt the PBA paper. Record your own procedure, observations and calculations on worksheets and compare them with the sample data given here.

Scheme of the PBA Paper (Composite, HSSC)

Section A — Major Practical		Section B — Minor Practical
Practicals	1 – 8	9 – 19
Marks	24 (60%)	16 (40%)
Nature	Performance, calculation, procedure and observation based; each question on a single practical	Each question may be based on one or more practicals

- Total marks: **40**; time: **2 hours 30 minutes**.
- No marks for practical notebooks, and MCQs are not included.
- Questions of 0.5 marks are not asked as single parts.
- Only students who have performed all prescribed practicals can attempt the PBA.

● Contents

SECTION A — MAJOR PRACTICALS (24 marks)

Practical 01	Effect of Temperature, pH and Enzyme Concentration on Enzyme Activity	G-11 Ch 3	1
Practical 02	Preparation of % and Molar Solutions; Simple and Serial Dilutions	G-12 Ch 11	9
Practical 03	Concentration of Reducing Sugar by Benedict's Test using Colorimeter	G-11 Ch 2	15
Practical 04	Measuring Cell Size with Eyepiece Graticule and Stage Micrometer	G-11 Ch 1	20
Practical 05	Actual Size, Image Size and Magnification from Photomicrographs	G-11 Ch 1	26
Practical 06	Antibiotic Sensitivity by Disc Diffusion (Kirby-Bauer) Method	G-12 Ch 15	32
Practical 07	Analysis of Use and Misuse of Antibiotics through Data	G-12 Ch 15	37
Practical 08	Measuring Variability, Statistics and Experimental Design	G-12 Ch 11	43

SECTION B — MINOR PRACTICALS (16 marks)

Practical 09	Setting up a Light Microscope to View Specimens	G-11 Ch 1	51
Practical 10	Plant Tissues: T.S. of Monocot & Dicot Root, Stem and Bifacial Leaf	G-11 Ch 9	59
Practical 11	Animal Tissues: Testis, Ovary, Blood Vessels and Pancreas	G-11 Ch 11; G-12 Ch 2, 6	73
Practical 12	Temporary Slides of Animal Cells (Epithelium, Blood, Cheek Cells)	G-11 Ch 1; G-12 Ch 2	80
Practical 13	Temporary Slides of Plant Cells (Leaf Epidermis, Onion Peel)	G-11 Ch 1, 9	86
Practical 14	ABO and Rh Blood Groups; Inheritance of Blood Groups	G-11 Ch 12	91
Practical 15	Sporophyte and Gametophyte of Fern (<i>Adiantum</i>)	G-11 Ch 8	96
Practical 16	Male and Female Cones of <i>Pinus</i>	G-11 Ch 8	102
Practical 17	Representative Vertebrates: Amphibians, Reptiles, Birds, Mammals	G-11 Ch 10	108
Practical 18	Kingdom Protista: Protozoa, Algae, Myxomycota, Oomycota	G-11 Ch 7	113
Practical 19	Kingdom Fungi: Zygo-, Asco-, Deutero- and Basidiomycota	G-11 Ch 7	119

G-11 = NBF Model Textbook of Biology Grade 11; G-12 = NBF Textbook of Biology Grade 12.

PRACTICAL BASED ASSESSMENT

Section A Major Practicals

24 marks • 60%

01	Effect of Temperature, pH and Enzyme Concentration on Enzyme Activity	p. 1
02	Preparation of % and Molar Solutions; Simple and Serial Dilutions	p. 9
03	Concentration of Reducing Sugar by Benedict's Test using Colorimeter	p. 15
04	Measuring Cell Size with Eyepiece Graticule and Stage Micrometer	p. 20
05	Actual Size, Image Size and Magnification from Photomicrographs	p. 26
06	Antibiotic Sensitivity by Disc Diffusion (Kirby-Bauer) Method	p. 32
07	Analysis of Use and Misuse of Antibiotics through Data	p. 37
08	Measuring Variability, Statistics and Experimental Design	p. 43

PRACTICAL

01

Section A • Major Practical

Effect of Temperature, pH and Enzyme Concentration on the Rate of Enzyme Activity

Related Theory from Textbook

Biology Grade 11 > Chapter 3: Enzymes

- 3.1 Enzyme structure; 3.1.1 components of active site
- 3.2 Mechanism of enzyme action; 3.2.1 models; 3.2.2 energy of activation
- 3.3 Factors affecting the rate of enzymatic action: 3.3.1 temperature, 3.3.2 pH, 3.3.3 enzyme concentration
- 3.4 Enzyme inhibition

Biology Grade 12 > Chapter 11: Biostatistics and Data Analysis

- 11.4–11.5 Charts and graphs; designing experiments with variables and controls

Enzymes are **globular proteins** that act as **biological catalysts**. They speed up chemical reactions by **lowering the activation energy**, without being used up. The substrate binds to a specific region of the enzyme called the **active site**, forming an **enzyme-substrate (ES) complex**, which then gives products (lock-and-key and induced-fit models). Because the shape of the active site depends on the enzyme's 3-D structure, anything that changes this shape — such as temperature or pH — changes the rate of reaction.

Optimum temperature — temperature at which an enzyme works fastest; about 37 °C for most human enzymes.

Denaturation — permanent loss of the 3-D shape (and active site) of an enzyme, e.g. by high heat or extreme pH.

Optimum pH — pH at which an enzyme works fastest, e.g. pepsin ≈ 2, papain ≈ 6.5, trypsin ≈ 8.

Rate of reaction — amount of product formed (or substrate used) per unit time, e.g. mL of O₂ per minute.

Choice of Experiment (PBA)

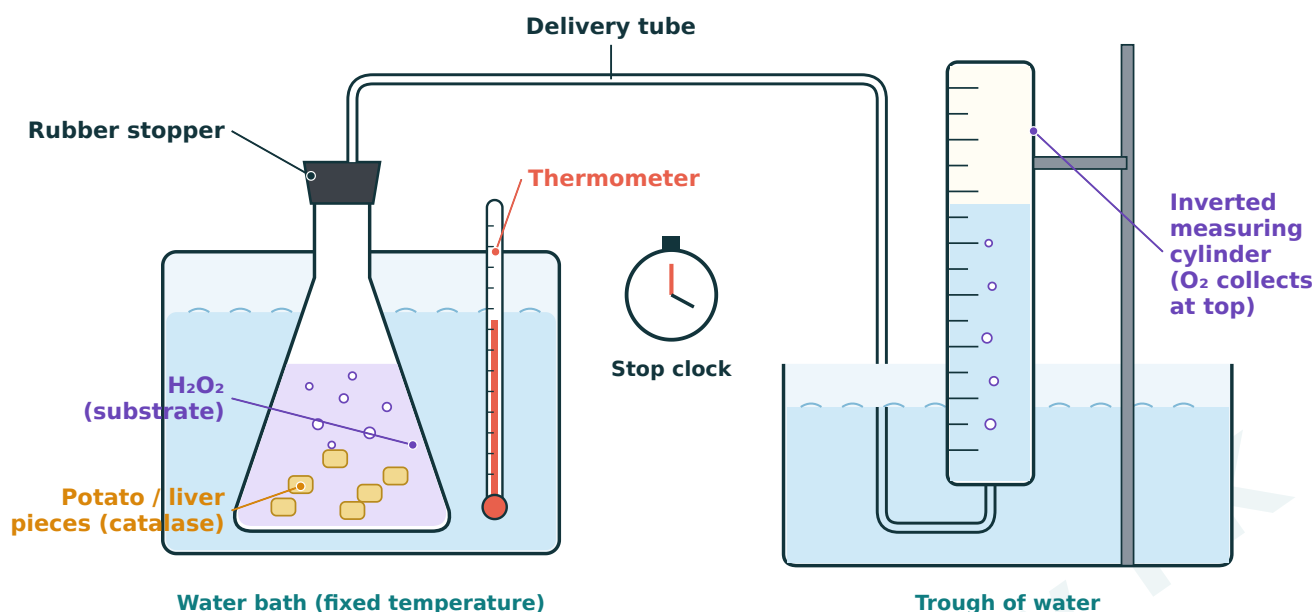
According to the FBISE list, a student performs **any one** of the following three experiments. All three use the same apparatus: the enzyme **catalase** (from potato or liver) breaks down hydrogen peroxide into water and oxygen. The volume of oxygen collected in a fixed time tells us the rate of reaction.



Rate of reaction = volume of O₂ collected ÷ time taken

• Apparatus and Materials

Fresh potato (or liver) extract as source of catalase, hydrogen peroxide solution (e.g. 3% or 1 M), buffer solutions of different pH, conical flask with rubber stopper and delivery tube, trough of water, 50 mL measuring cylinder, water bath (or beakers of water at different temperatures), thermometer, stop clock, syringes / pipettes, clamp stand, knife and cutting board.

Fig. 1.1: Apparatus to study the activity of catalase

● Experiment A: Effect of Temperature on the Rate of Enzyme Activity

Object: To study the effect of temperature on the rate of catalase activity.

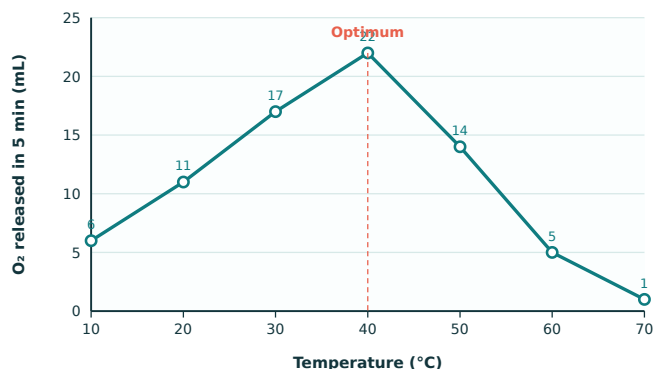
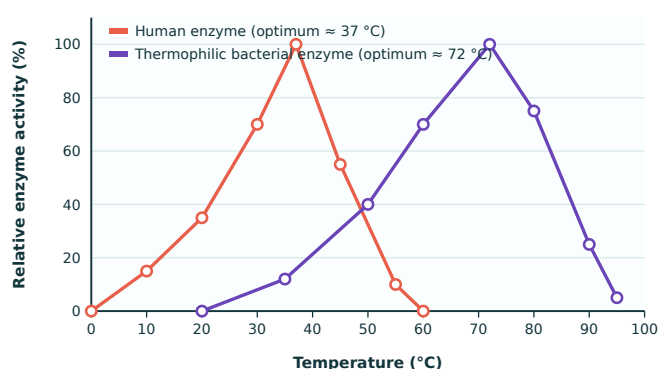
Independent variable: temperature. **Dependent variable:** volume of O_2 released in 5 minutes. **Controlled variables:** volume and concentration of H_2O_2 , amount of potato extract, pH, time.

Procedure

1. Set up water baths at 10, 20, 30, 40, 50, 60 and 70 °C.
2. Put 10 mL of H_2O_2 in the flask and 5 g of potato pieces (or 5 mL extract) in a separate tube. Keep both in the water bath for 5 minutes so they reach the required temperature.
3. Fill the measuring cylinder with water and invert it in the trough over the end of the delivery tube.
4. Add the potato to the H_2O_2 , close the flask with the stopper at once and start the stop clock.
5. After 5 minutes, read the volume of O_2 collected in the cylinder.
6. Repeat at each temperature (take three readings at each and find the mean). Plot a graph of rate against temperature.

Observations (sample readings)

Temperature (°C)	10	20	30	40	50	60	70
O_2 in 5 min (mL)	6	11	17	22	14	5	1
Rate (mL min ⁻¹)	1.2	2.2	3.4	4.4	2.8	1.0	0.2

Fig. 1.2: Rate of catalase activity vs temperature**Fig. 1.3: Human enzyme vs thermophilic bacterial enzyme****Result and Explanation**

The rate increases from 10 °C to about **40 °C** (optimum) and then falls sharply. At low temperature, molecules have little kinetic energy, so fewer enzyme–substrate collisions occur; the enzyme is **inactive but not destroyed**. Above the optimum, hydrogen bonds holding the 3-D shape break, the active site changes shape and the enzyme is **denatured**. Enzymes of human body work best at about 37 °C, while enzymes of **thermophilic bacteria** (e.g. *Thermus aquaticus*, living in hot springs) have optimum temperatures of about 70–80 °C; *Taq* DNA polymerase from this bacterium is used in PCR.

● Experiment B: Effect of pH on the Rate of Enzyme Activity

Object: To investigate the effect of pH on catalase activity and compare the optimum pH of different enzymes.

Independent variable: pH (buffer solutions). **Dependent variable:** volume of O₂ in 5 minutes.

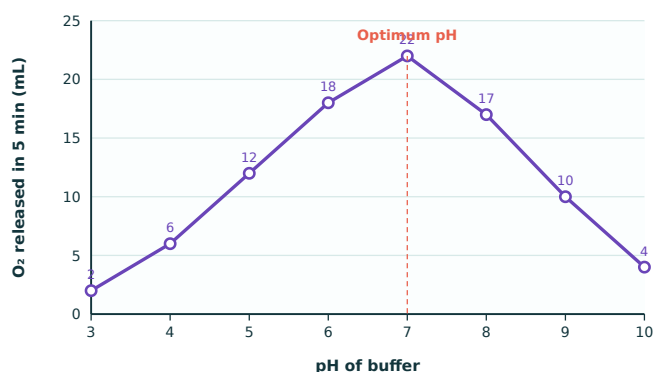
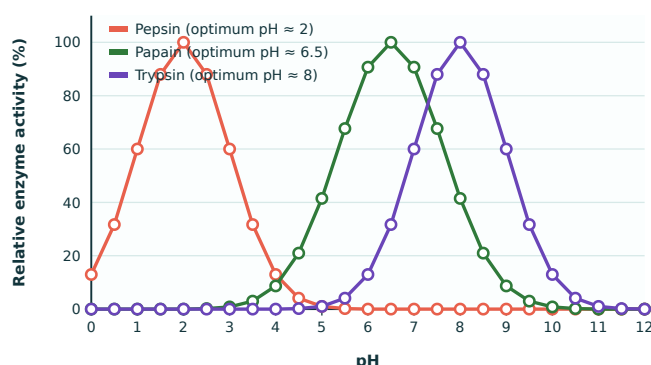
Controlled variables: temperature (30–35 °C water bath), volume and concentration of H₂O₂, amount of enzyme.

Procedure

1. Take seven flasks; to each add 10 mL of H₂O₂ and 5 mL of a buffer of pH 3, 4, 5, 6, 7, 8, 9 or 10 respectively.
2. Keep all flasks at the same temperature in a water bath.
3. Add the same amount of potato extract to the first flask, close it and collect the O₂ for 5 minutes.
4. Repeat for each pH and record the volume of O₂. Plot volume (or rate) against pH.

Observations (sample readings)

pH	3	4	5	6	7	8	9	10
O ₂ in 5 min (mL)	2	6	12	18	22	17	10	4

Fig. 1.4: Catalase activity vs pH**Fig. 1.5: Optimum pH of pepsin, papain and trypsin**

Result and Explanation

Catalase works best at about **pH 7**. On either side of the optimum, the change in H^+ ion concentration alters the **ionic charges on the R-groups** of amino acids at the active site, so the substrate cannot bind properly; at extreme pH the enzyme is denatured. Every enzyme has its own optimum pH: **pepsin** (stomach) ≈ 2 , **papain** (papaya, used as meat tenderiser) $\approx 6-7$, **trypsin** (small intestine) ≈ 8 .

● Experiment C: Effect of Enzyme Concentration on the Rate of Reaction

Object: To show that the concentration of enzyme affects the rate of enzyme action.

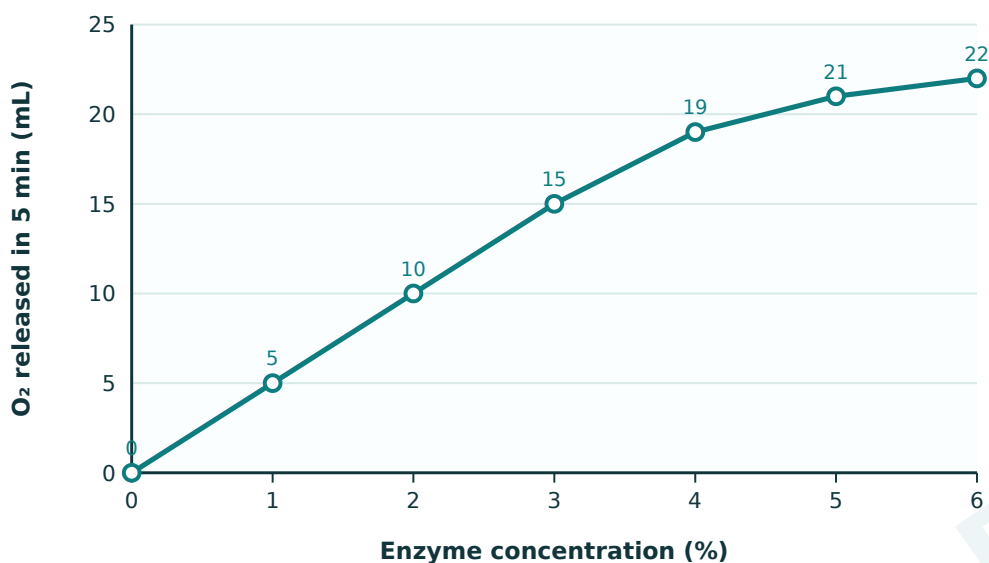
Independent variable: enzyme concentration. **Dependent variable:** volume of O_2 in 5 minutes. **Controlled variables:** temperature, pH, volume and concentration of H_2O_2 .

Procedure

1. Prepare potato extract of 1%, 2%, 3%, 4%, 5% and 6% by dilution (see Practical 2).
2. Add 5 mL of the 1% extract to 10 mL of H_2O_2 , close the flask and collect O_2 for 5 minutes.
3. Repeat with each concentration, keeping everything else the same.
4. Plot the volume of O_2 against enzyme concentration.

Observations (sample readings)

Enzyme concentration (%)	1	2	3	4	5	6
O_2 in 5 min (mL)	5	10	15	19	21	22

Fig. 1.6: Rate of reaction vs enzyme concentration

Result and Explanation

As enzyme concentration increases, more active sites are available, so the rate rises in direct proportion. At high enzyme concentration the curve levels off because the **substrate becomes the limiting factor**: all substrate molecules are already occupied. If more substrate is added, the rate rises again.

• Precautions

- Cut potato pieces of the same size (same surface area) in every trial.
- Close the flask immediately after adding the enzyme so that no oxygen escapes.
- Let the enzyme and substrate reach the bath temperature before mixing.
- Make sure there are no air bubbles in the measuring cylinder at the start.
- Handle hydrogen peroxide carefully — it irritates skin and eyes; wear goggles and gloves.

● Answers to Short Questions

Enzymes: Basic Concepts

Q1. What is an enzyme? Why is it called a biological catalyst?

Ans. An enzyme is a globular protein that speeds up biochemical reactions in living cells. It is called a biological catalyst because it increases the rate of reaction by lowering the activation energy and remains unchanged at the end of the reaction.

Q2. What is an active site?

Ans. It is a small pocket or groove on the enzyme surface, made of a few amino acids, where the substrate binds and the reaction takes place.

Q3. Differentiate between the lock-and-key and induced-fit models.

Ans. In the **lock-and-key** model the active site has a rigid shape exactly complementary to the substrate. In the **induced-fit** model the active site is flexible and changes its shape slightly to fit the substrate when it binds.

Q4. Which enzyme is used in this experiment, and what reaction does it catalyse?

Ans. Catalase. It breaks down toxic hydrogen peroxide into water and oxygen: $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$.

Q5. Why are potato and liver used as a source of catalase?

Ans. Their cells contain a large amount of catalase (in peroxisomes), which protects cells from hydrogen peroxide produced during metabolism.

Variables and Design

Q6. In the temperature experiment, name the independent, dependent and controlled variables.

Ans. Independent: temperature. Dependent: volume of oxygen released (rate of reaction). Controlled: volume and concentration of H_2O_2 , amount of enzyme, pH and time.

Q7. If the effect of substrate concentration is to be investigated, what would be the independent and dependent variables?

Ans. Independent variable: concentration of H_2O_2 (substrate). Dependent variable: volume of oxygen collected per unit time.

Q8. What would be a suitable control for this experiment?

Ans. A flask with H_2O_2 and **boiled** (denatured) potato extract. No oxygen should be produced, which shows that the oxygen comes from enzyme activity.

Q9. Which apparatus is used to keep the temperature constant?

Ans. A thermostatically controlled water bath (or a beaker of water with a thermometer).

Q10. Why are three readings taken at each temperature?

Ans. To check repeatability, find a reliable mean and identify any anomalous reading.

Effect of Temperature

Q11. Why is the rate of reaction slow at low temperature?

Ans. Molecules have less kinetic energy, so enzyme and substrate molecules collide less often and fewer ES complexes are formed. The enzyme is only inactivated, not destroyed.

Q12. What happens to an enzyme above its optimum temperature?

Ans. Hydrogen and other weak bonds holding its 3-D shape break, the active site loses its shape and the enzyme is denatured; the rate falls rapidly.

Q13. What is the optimum temperature of most human enzymes?

Ans. About 37 °C (body temperature).

Q14. Why can bacteria of hot springs survive at 70-80 °C?

Ans. They are thermophilic; their enzymes have extra bonds (e.g. more disulphide and ionic bonds) that keep the shape stable at high temperature, so their optimum is around 70-80 °C.

Q15. Name one useful enzyme obtained from thermophilic bacteria.

Ans. *Taq* DNA polymerase from *Thermus aquaticus*, used in PCR.

Effect of pH

Q16. How does pH affect enzyme activity?

Ans. A change in pH alters the ionic charges of the amino acids at the active site and may break ionic and hydrogen bonds, so the substrate cannot bind; at extreme pH the enzyme is denatured.

Q17. Give the optimum pH of pepsin, papain and trypsin.

Ans. Pepsin $\approx$ 2 (acidic), papain $\approx$ 6.5 (nearly neutral), trypsin $\approx$ 8 (alkaline).

Q18. Why are buffer solutions used in this experiment?

Ans. A buffer resists changes in pH and keeps the pH constant during the reaction.

Q19. Why does pepsin stop working when food passes into the small intestine?

Ans. The small intestine is alkaline (pH about 8), far from pepsin's optimum pH of 2, so pepsin becomes inactive.

Enzyme Concentration and Calculations

Q20. Why does the graph of rate against enzyme concentration level off?

Ans. At high enzyme concentration, substrate becomes the limiting factor; all substrate molecules are already bound, so adding more enzyme has no further effect.

Q21. 10 mL of O₂ is collected in the first 5 minutes. Predict the volume at 15 minutes if conditions stay constant.

Ans. If the rate remains constant: $10 \text{ mL} \times 3 = 30 \text{ mL}$. In practice it may be slightly less because the substrate is used up with time.

Q22. 22 mL of O₂ was released in 5 minutes. Calculate the rate of reaction.

Ans. Rate = $22 \div 5 = 4.4 \text{ mL min}^{-1}$.

Q23. How will you prepare 1 molar H_2O_2 solution?

Ans. Molar mass of $\text{H}_2\text{O}_2 = (2 \times 1) + (2 \times 16) = 34 \text{ g mol}^{-1}$. Dissolve 34 g of pure H_2O_2 in distilled water and make the volume up to 1 dm^3 (1000 mL). (Equivalent volume of a concentrated stock solution is diluted in practice.)

PRACTICAL
02

Section A · Major Practical

Preparation of Weight/Volume (%) and Molar Solutions; Simple and Serial Dilutions from Stock Solution**Related Theory from Textbook****Biology Grade 12 > Chapter 11: Biostatistics and Data Handling**

- Describing volumes and concentrations of reagents (% w/v, mol dm⁻³)
- Preparing concentrations by serial or proportional dilution
- 11.3 Presenting data in tables and charts

Biology Grade 11 > Chapter 2: Molecular Biology / Chapter 3: Enzymes

- Glucose and other biomolecules in solution
- Enzyme and substrate concentration (use of dilutions in Practicals 1 and 3)

A **solution** is a uniform mixture of a **solute** dissolved in a **solvent** (usually water). In biology practicals we often need solutions of exact strength — for example glucose standards for Benedict's test, enzyme extracts of different concentration, or buffers. The strength (concentration) of a solution may be expressed as **percentage (w/v)** or as **molarity (mol dm⁻³)**. A **dilution** lowers the concentration by adding more solvent; the amount of solute stays the same.

% (w/v) — grams of solute in 100 mL of solution; 5% glucose = 5 g in 100 mL.

Mole — amount of a substance equal to its molar mass (relative formula mass) in grams.

Molarity (M) — moles of solute per dm³ (1000 mL) of solution.

Stock solution — a concentrated solution from which weaker solutions are made by dilution.

Simple (proportional) dilution — stock and water mixed in different proportions to give a range of concentrations.

Serial dilution — a stepwise dilution in which each solution is diluted by the same factor (e.g. 10 times) to make the next.

● Object

(i) To prepare solutions of known percentage (w/v) and molarity. (ii) To make simple (proportional) and serial dilutions from a stock solution.

● Apparatus and Materials

Electronic balance, weighing boat / butter paper, spatula, beakers, glass rod, funnel, volumetric flasks (100 mL and 250 mL), measuring cylinders, graduated pipettes or syringes, test tubes and rack, wash bottle with distilled water, labels / marker, glucose, sodium chloride (NaCl), sucrose.

● Key Formulae

$$\% \text{ (w/v)} = (\text{mass of solute in g} \div \text{volume of solution in mL}) \times 100$$

$$\text{Mass of solute needed (g)} = \% \text{ required} \times \text{volume required (mL)} \div 100$$

$$\text{Number of moles} = \text{mass (g)} \div \text{molar mass (g mol}^{-1}\text{)}$$

$$\text{Mass needed (g)} = \text{Molarity (mol dm}^{-3}\text{)} \times \text{Molar mass} \times \text{Volume (dm}^3\text{)}$$

$$\text{Dilution: } C_1V_1 = C_2V_2$$

C_1, V_1 = concentration and volume of stock; C_2, V_2 = concentration and volume of diluted solution

Substance	Formula	Molar mass (g mol ⁻¹)
Glucose	C ₆ H ₁₂ O ₆	(6×12)+(12×1)+(6×16) = 180
Sucrose	C ₁₂ H ₂₂ O ₁₁	342
Sodium chloride	NaCl	23 + 35.5 = 58.5
Hydrogen peroxide	H ₂ O ₂	34

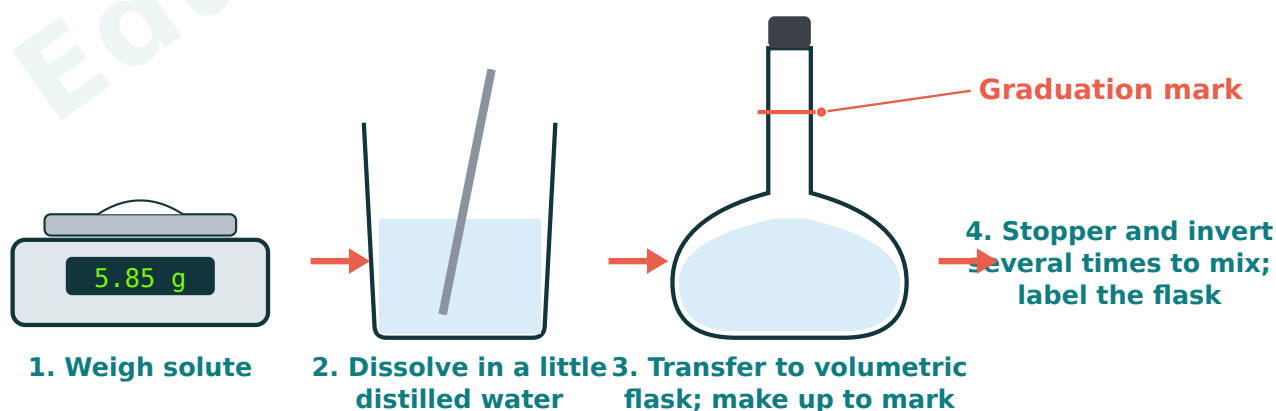
• Part A: Preparation of a Percentage (w/v) Solution

Example: Prepare 100 mL of 5% glucose solution

Mass of glucose = $5 \times 100 \div 100 = 5 \text{ g}$.

1. Weigh 5 g of glucose on the balance using a weighing boat.
2. Dissolve it in about 60 mL of distilled water in a beaker; stir with a glass rod.
3. Pour the solution into a 100 mL volumetric flask through a funnel. Rinse the beaker and rod with a little water and add the rinsings to the flask.
4. Add distilled water until the bottom of the meniscus touches the graduation mark (use a dropper for the last few drops).
5. Stopper, invert several times to mix, and label: "5% (w/v) glucose, date".

Fig. 2.1: Steps in preparing a solution of known concentration



● Part B: Preparation of a Molar Solution

Example 1: Prepare 100 mL of 1 M NaCl solution

Mass = $M \times M_r \times V(\text{dm}^3) = 1 \times 58.5 \times 0.1 = 5.85 \text{ g}$. Dissolve 5.85 g NaCl and make the volume up to 100 mL in a volumetric flask.

Example 2: Prepare 250 mL of 0.5 M glucose solution

Mass = $0.5 \times 180 \times 0.25 = 22.5 \text{ g}$ glucose, made up to 250 mL.

● Part C: Simple (Proportional) Dilution

A range of glucose standards is made from a 1% stock by mixing stock and distilled water in different proportions so that the total volume is always 10 mL. (These standards are used in Practical 3.)

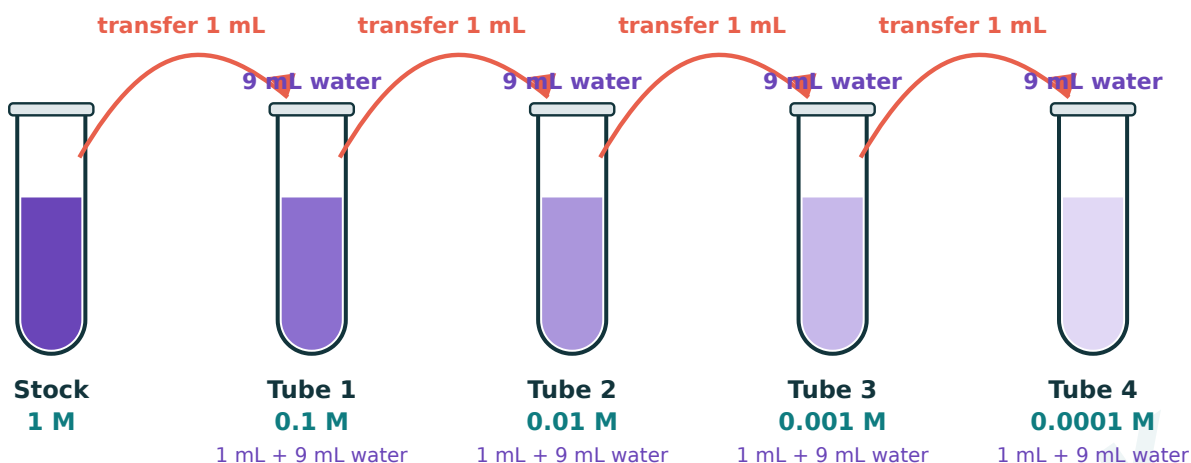
Concentration required (%)	Volume of 1% stock (mL)	Volume of distilled water (mL)	Total volume (mL)
1.0	10	0	10
0.8	8	2	10
0.6	6	4	10
0.4	4	6	10
0.2	2	8	10
0.0 (blank)	0	10	10

Using $C_1V_1 = C_2V_2$: make 50 mL of 2% sucrose from 10% stock

$V_1 = C_2V_2 \div C_1 = (2 \times 50) \div 10 = 10 \text{ mL}$ of stock + **40 mL** distilled water.

● Part D: Serial Dilution

To make a ten-fold serial dilution of 1 M glucose: put 9 mL distilled water in each of four labelled tubes. Transfer 1 mL of stock to tube 1 and mix well — this is 0.1 M. Using a clean pipette, transfer 1 mL of tube 1 to tube 2 (0.01 M), and so on.

Fig. 2.2: Ten-fold serial dilution of a 1 M stock solution

Each step dilutes the solution 10 times (dilution factor = 10). Mix well before each transfer.

Tube	Stock	1	2	3	4
Concentration (mol dm^{-3})	1	0.1	0.01	0.001	0.0001
Dilution factor from stock	1	10	100	1000	10 000

Where are serial dilutions used?

- To make very dilute solutions accurately (weighing tiny masses is not accurate).
- To make standards for colorimetry and calibration curves.
- To count bacteria (viable plate count) in microbiology.
- To test the effect of concentration of enzyme, substrate, hormones or antibiotics.

• Precautions

- Use a clean, dry weighing boat and zero (tare) the balance before weighing.
- Read the meniscus at eye level; the bottom of the curve must touch the mark.
- Always use distilled water, never tap water.
- Use a clean pipette for each transfer in serial dilution and mix thoroughly before each transfer.
- Label every flask and tube immediately with concentration and date.

● Answers to Short Questions

Solutions and Units

Q1. What is meant by a 10% (w/v) glucose solution?

Ans. 10 g of glucose dissolved in water and the volume made up to 100 mL of solution.

Q2. Define molarity. Give its unit.

Ans. Molarity is the number of moles of solute dissolved per dm^3 (1000 mL) of solution. Unit: mol dm^{-3} (M).

Q3. Calculate the molar mass of glucose.

Ans. $\text{C}_6\text{H}_{12}\text{O}_6 = (6 \times 12) + (12 \times 1) + (6 \times 16) = 72 + 12 + 96 = 180 \text{ g mol}^{-1}$.

Q4. Why is a volumetric flask used instead of a beaker to prepare a standard solution?

Ans. A volumetric flask has one accurate graduation mark for a fixed volume, so the final volume, and hence the concentration, is exact. Beaker markings are only approximate.

Q5. Why is the solute first dissolved in a smaller volume of water?

Ans. So that it dissolves completely before the volume is made up to the mark; otherwise undissolved solid would give a wrong final volume.

Calculations

Q6. How much NaCl is needed to make 500 mL of 0.9% (w/v) saline?

Ans. Mass = $0.9 \times 500 \div 100 = 4.5 \text{ g}$.

Q7. How much glucose is needed to make 200 mL of 0.1 M glucose?

Ans. Mass = $0.1 \times 180 \times 0.2 = 3.6 \text{ g}$.

Q8. How will you prepare 1 M hydrogen peroxide?

Ans. Molar mass of $\text{H}_2\text{O}_2 = 34 \text{ g mol}^{-1}$; dissolve 34 g H_2O_2 (or an equivalent volume of concentrated stock) and make up to 1 dm^3 with distilled water.

Q9. What volume of 20% stock is needed to make 100 mL of 5% solution?

Ans. $V_1 = (5 \times 100) \div 20 = 25 \text{ mL}$ of stock + 75 mL water.

Q10. A 1 M solution is serially diluted 10-fold four times. What is the final concentration?

Ans. $1 \div 10^4 = 0.0001 \text{ M}$ (10^{-4} M).

Dilutions

Q11. Differentiate between simple (proportional) dilution and serial dilution.

Ans. In **proportional** dilution each solution is made directly from the stock by mixing different volumes of stock and water. In **serial** dilution each new solution is made from the previous one by the same dilution factor.

Q12. Why is serial dilution preferred for making very dilute solutions?

Ans. Very small masses or volumes cannot be measured accurately; stepwise dilution gives accurate low concentrations.

Q13. Why must the solution be mixed before each transfer in serial dilution?

Ans. So that the solute is evenly spread and the 1 mL transferred has the correct concentration; otherwise errors multiply at each step.

Q14. What is a blank, and why is it needed?

Ans. A blank contains everything except the substance being tested (e.g. distilled water with reagent). It is used to set the colorimeter to zero and as a control.

Q15. State one source of error in preparing solutions and how to reduce it.

Ans. Parallax error when reading the meniscus — read with the eye level with the mark. (Also: weighing error — tare the balance and avoid spilling.)

PRACTICAL
03

Section A · Major Practical

To Investigate the Concentration of Reducing Sugar (Glucose) by Benedict's Test using the Colorimeter

Related Theory from Textbook

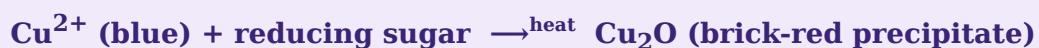
Biology Grade 11 > Chapter 2: Molecular Biology

- 2.6 Carbohydrates; 2.7 Monosaccharides (glucose)
- 2.9 Properties and roles of disaccharides: sucrose, maltose, lactose
- Reducing and non-reducing sugars (Benedict's test)

Biology Grade 12 > Chapter 11: Biostatistics and Data Handling

- Preparing concentrations by proportional / serial dilution
- Drawing graphs and reading values from a calibration curve

Reducing sugars are sugars with a free aldehyde ($-\text{CHO}$) or ketone ($\text{C}=\text{O}$) group that can reduce other substances. All **monosaccharides** (glucose, fructose, galactose) and some **disaccharides** (maltose, lactose) are reducing sugars; **sucrose** is non-reducing. **Benedict's reagent** is a blue alkaline solution of copper(II) sulphate (with sodium citrate and sodium carbonate). When heated with a reducing sugar, blue Cu^{2+} ions are reduced to **brick-red copper(I) oxide (Cu_2O)** precipitate. The colour obtained depends on how much reducing sugar is present, so the test is **semi-quantitative**. A **colorimeter** makes it **quantitative**.



Colorimeter — instrument that measures how much light of a particular colour (wavelength) is absorbed by a coloured solution.

Absorbance — amount of light absorbed by the sample; higher for a more concentrated coloured solution.

Calibration curve — graph of absorbance against known concentrations (standards), used to find an unknown concentration.

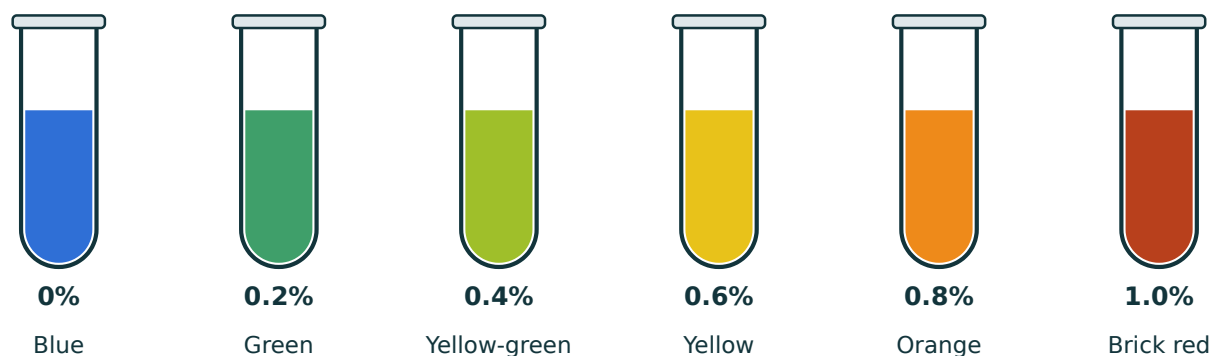
Blank — tube with distilled water + reagent, used to set the colorimeter to zero absorbance.

● Object

To find the concentration of glucose in an unknown solution by Benedict's test, using a colorimeter and a calibration curve prepared from glucose standards.

● Apparatus and Materials

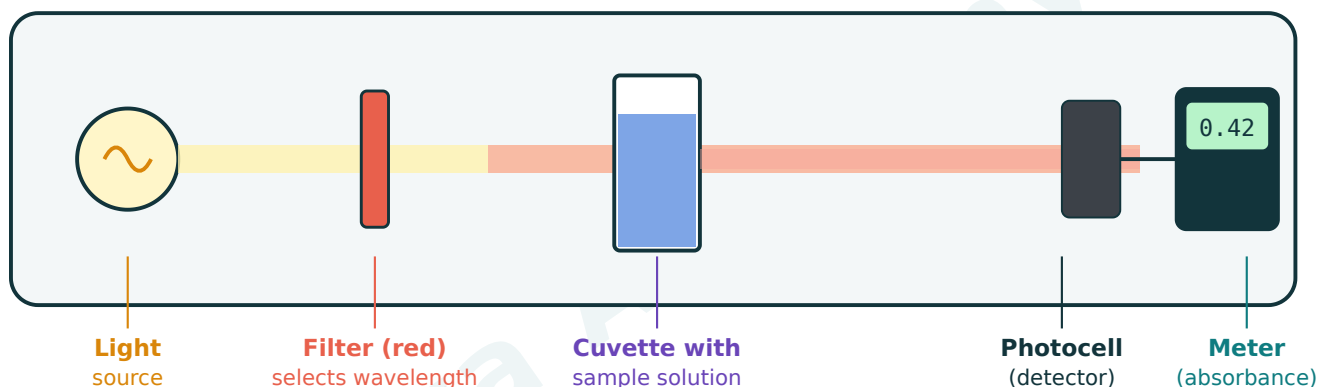
Colorimeter with red (or orange) filter, cuvettes, Benedict's reagent, 1% glucose stock solution, unknown glucose solution (e.g. fruit juice or "solution X"), distilled water, test tubes and rack, graduated pipettes/syringes, boiling water bath, test-tube holder, centrifuge or filter paper and funnel, stop clock, marker.

Fig. 3.1: Colour change in Benedict's test with increasing glucose concentration

Increasing concentration of reducing sugar → more Cu_2O (brick-red) precipitate

Fig. 3.2: Working principle of a colorimeter

Light of a selected colour passes through the sample; a more coloured sample absorbs more light



● Procedure

1. Prepare glucose standards of 0, 0.2, 0.4, 0.6, 0.8 and 1.0% from the 1% stock by proportional dilution (Practical 2, Part C). Label the tubes.
2. Put 2 mL of each standard and 2 mL of the unknown solution into separate labelled test tubes.
3. Add 2 mL of Benedict's reagent to every tube and mix.
4. Place all tubes together in a boiling water bath for exactly 5 minutes. Note the colours.
5. Cool the tubes. Centrifuge (or filter) to remove the red precipitate; the remaining **supernatant** is blue — the less sugar, the bluer it is.
6. Switch on the colorimeter, fit the red filter and set absorbance to zero using a cuvette of distilled water (blank).
7. Pour each supernatant into a clean cuvette, wipe the clear sides, place it in the colorimeter and record the absorbance.
8. Plot a calibration curve of absorbance (y-axis) against glucose concentration (x-axis). Read the concentration of the unknown from the curve.

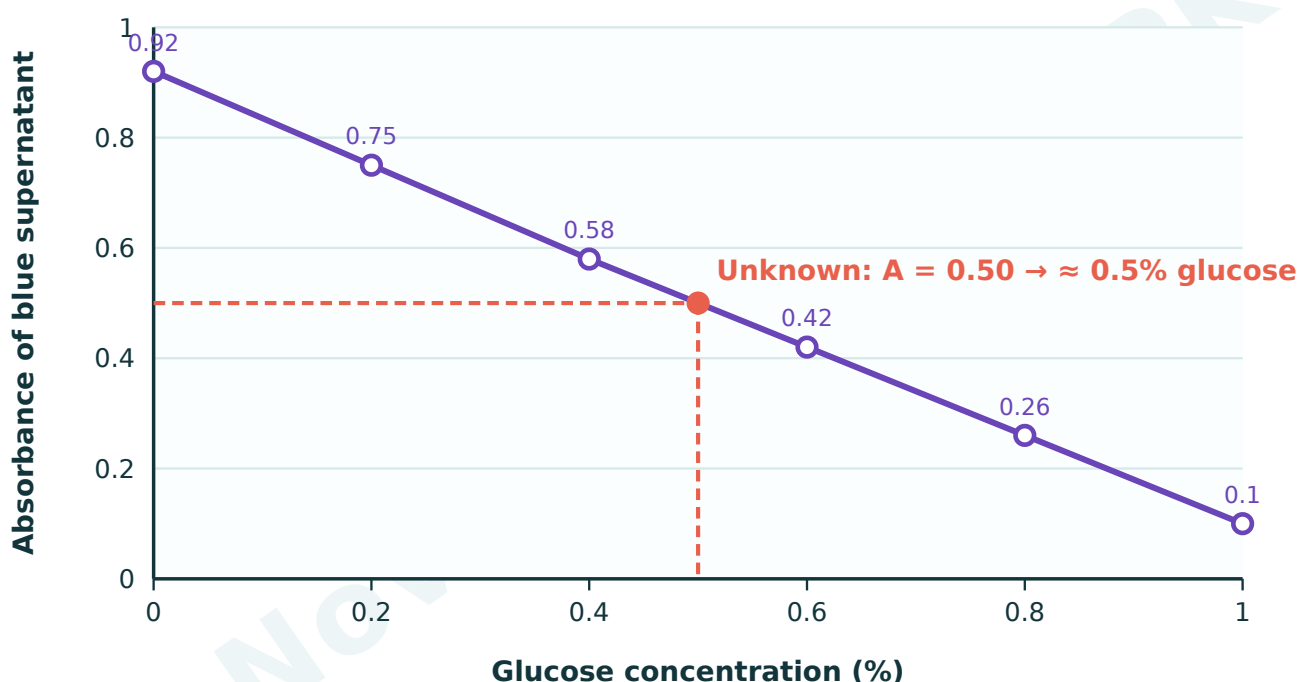
Why a red filter?

The blue supernatant absorbs red/orange light most strongly (red is the complementary colour of blue). Using a red filter makes the colorimeter most sensitive to changes in the blue colour.

• Observations (sample readings)

Glucose (%)	0	0.2	0.4	0.6	0.8	1.0	Unknown
Colour after heating	Blue	Green	Yellow-green	Yellow	Orange	Brick red	Yellow-green
Absorbance of supernatant	0.92	0.75	0.58	0.42	0.26	0.10	0.50

Fig. 3.3: Calibration curve for glucose standards



Result

The absorbance of the unknown (0.50) corresponds to about **0.5% glucose** on the calibration curve. Absorbance of the supernatant decreases as glucose concentration increases, because more blue Cu^{2+} is used up to form the red precipitate.

• Precautions

- Use the same volume of sample and reagent and the same heating time for every tube.
- Heat all tubes together so they get identical conditions.
- Hold cuvettes by the frosted/ribbed sides; clean fingerprints from the clear sides.
- Re-zero the colorimeter with the blank before each set of readings.
- Keep the unknown within the range of the standards; dilute it if it is more concentrated than 1%.
- Use a test-tube holder and goggles when handling the boiling water bath.

● Answers to Short Questions

Reducing Sugars and Benedict's Test

Q1. What is a reducing sugar? Give two examples.

Ans. A sugar with a free aldehyde or ketone group that can reduce Cu^{2+} ions, e.g. glucose and maltose (also fructose, lactose).

Q2. Is sucrose a reducing sugar? How can it be tested?

Ans. No. Sucrose is first hydrolysed by boiling with dilute HCl, neutralised with NaHCO_3 , and then tested with Benedict's reagent; glucose and fructose formed give a positive result.

Q3. What are the components of Benedict's reagent?

Ans. Copper(II) sulphate, sodium citrate and sodium carbonate (alkaline).

Q4. What causes the brick-red colour?

Ans. Reduction of blue Cu^{2+} ions to insoluble red copper(I) oxide (Cu_2O).

Q5. Why is Benedict's test called semi-quantitative?

Ans. The colour (green, yellow, orange, red) only gives a rough idea of the amount of sugar; it does not give an exact value.

Colorimetry

Q6. What is a colorimeter?

Ans. An instrument that measures the absorbance or transmission of light of a selected wavelength through a coloured solution.

Q7. What is the relationship between absorbance and transmission?

Ans. They are opposite: when a solution absorbs more light, less light passes through (transmission decreases).

Q8. Why is the precipitate removed before using the colorimeter?

Ans. Solid particles scatter light and give false readings; only the clear supernatant should be measured.

Q9. What is the purpose of the blank?

Ans. To set the colorimeter to zero absorbance so that readings show only the absorbance due to the sample colour.

Q10. Why is the absorbance of the supernatant lower for higher glucose concentration?

Ans. More glucose reduces more Cu^{2+} ions, leaving fewer blue ions in the solution; so it absorbs less red light.

Variables and Calibration

Q11. Name the independent and dependent variables in making the calibration curve.

Ans. Independent: glucose concentration of standards. Dependent: absorbance (or % transmission) of the supernatant.

Q12. Name three variables that must be kept constant.

Ans. Volume of sample and of Benedict's reagent, heating time and temperature, and the filter/wavelength used.

Q13. How is the concentration of the unknown found from the calibration curve?

Ans. Draw a horizontal line from its absorbance on the y-axis to the curve, then a vertical line down to the x-axis and read the concentration.

Q14. If the unknown gives an absorbance lower than all the standards, what should you do?

Ans. It is more concentrated than the highest standard; dilute it by a known factor, test again, and multiply the result by the dilution factor.

Q15. Give one advantage of using a colorimeter rather than judging colours by eye.

Ans. It gives objective, numerical and repeatable results; judging colour by eye is subjective.

PRACTICAL

04

Section A • Major Practical

To Measure the Size of a Tissue or Cell using Eyepiece Graticule (Ocular Micrometer) and Stage Micrometer

Related Theory from Textbook

Biology Grade 11 > Chapter 1: Cells and Sub-Cellular Organelles

- 1.3 Microscopy — light microscope, magnification and resolution
- Units of measurement of cells (mm, μm , nm)
- Measuring cells: eyepiece graticule and stage micrometer; estimating cell number in a field of view

Cells and tissues are measured in **micrometres (μm)**. The **eyepiece graticule** is a small glass disc fitted inside the eyepiece; it carries a scale (usually 0–100) whose divisions have **no fixed value**, because the size of the image changes with the objective lens. It is therefore **calibrated** against a **stage micrometer** — a slide carrying an accurate scale (usually 1 mm divided into 100 divisions, so 1 division = $10\text{ }\mu\text{m}$). Once the value of one eyepiece unit (epu) is known for a given objective, any cell under that objective can be measured.

$$1\text{ mm} = 1000\text{ }\mu\text{m} \quad \bullet \quad 1\text{ }\mu\text{m} = 1000\text{ nm}$$

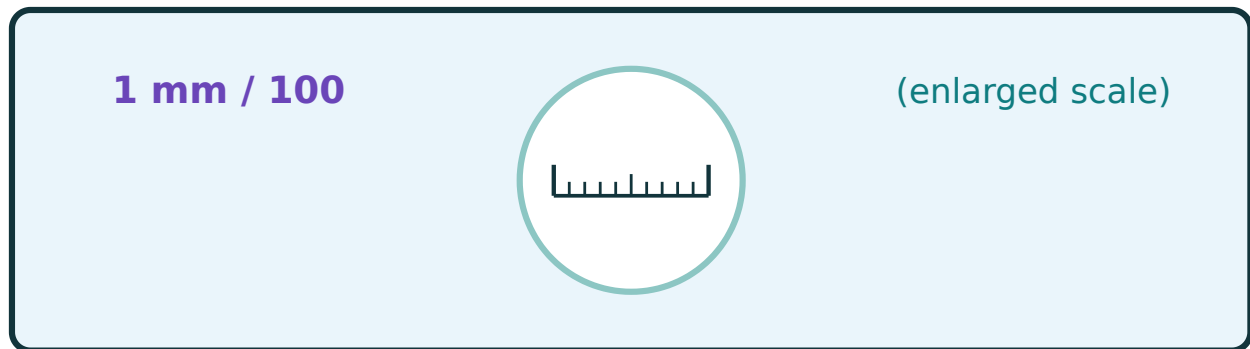
$$\text{Value of 1 epu} = (\text{number of stage divisions} \times 10\text{ }\mu\text{m}) \div \text{number of eyepiece units that coincide}$$

• Object

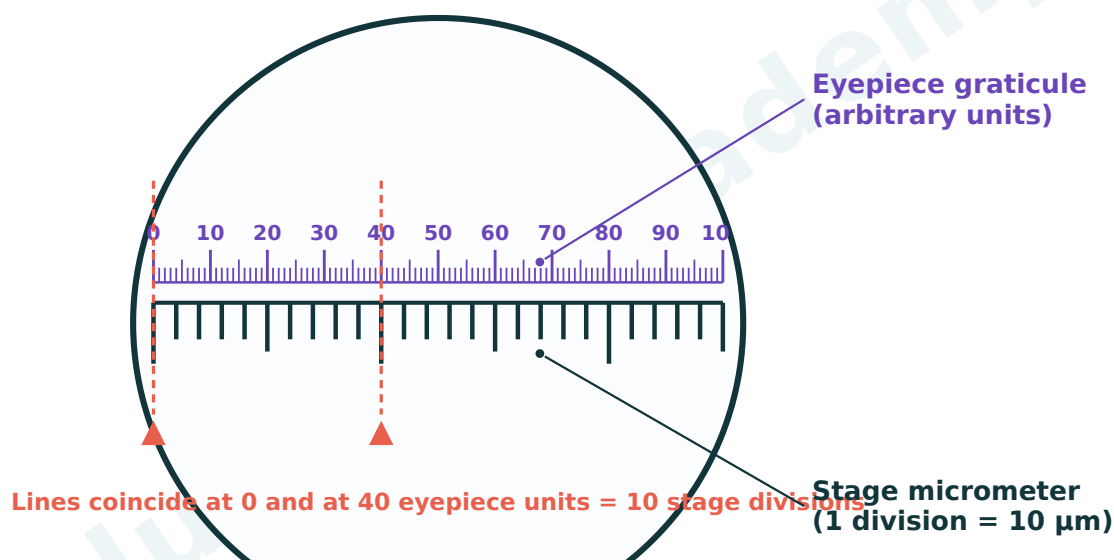
(i) To calibrate an eyepiece graticule using a stage micrometer. (ii) To measure the actual size of cells (e.g. onion epidermal cells or cheek cells). (iii) To estimate the number of cells in a given area using the field of view.

• Apparatus and Materials

Compound microscope, eyepiece fitted with graticule, stage micrometer slide, prepared slide or temporary mount of onion epidermis / cheek cells, lens paper, calculator.

Fig. 4.1: Stage micrometer slide

micrometer slide: 1 mm scale divided into 100 divisions (1 division = 0.01 mm)

Fig. 4.2: Calibration — the two scales superimposed

● Procedure

A. Calibrating the eyepiece graticule

1. Put the eyepiece graticule in the eyepiece (scale facing down) and place the stage micrometer on the stage.
2. Focus the micrometer scale under the low power ($\times 10$) objective.
3. Rotate the eyepiece and move the slide so that the two scales lie parallel and their zero lines coincide.
4. Look along the scales for the next point where a line of the graticule coincides exactly with a line of the micrometer. Note both readings.
5. Calculate the value of one eyepiece unit. Repeat for the $\times 40$ objective.

Calculation (×40 objective)

40 eyepiece units coincide with 10 stage divisions.

10 stage divisions = $10 \times 10 \mu\text{m} = 100 \mu\text{m}$

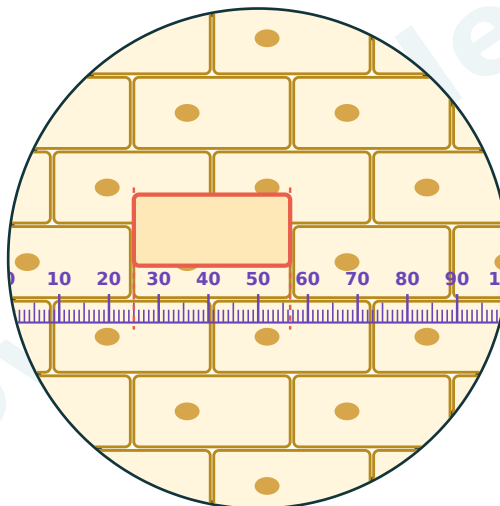
So, 1 eyepiece unit = $100 \mu\text{m} \div 40 = 2.5 \mu\text{m}$

Objective	Eyepiece units	Stage divisions	Actual length (μm)	Value of 1 epu (μm)
×10	10	10	100	10
×40	40	10	100	2.5

B. Measuring cells

1. Remove the stage micrometer and place the slide of onion epidermis (or cheek cells).
2. Focus the cells with the objective you calibrated.
3. Rotate the eyepiece so the graticule lies along the length of a cell; count the eyepiece units it covers.
4. Measure 5–10 cells, find the mean, and convert to μm using the calibration.

Fig. 4.3: Measuring an onion epidermal cell with the eyepiece graticule



Cell spans from 25 to 56 units = 31 eyepiece units

Cell	1	2	3	4	5	Mean
Length in epu (×10 objective)	31	28	33	30	28	30
Actual length (μm) = epu × 10	310	280	330	300	280	300

Result

Mean length of onion epidermal cells = $30 \text{ epu} \times 10 \mu\text{m} = 300 \mu\text{m} (0.3 \text{ mm})$.

C. Estimating the number of cells in a given area

The diameter of the field of view can be found with the stage micrometer. Count the cells (e.g. stomata) in several fields, find the mean, and divide by the area of the field.

Example: stomatal density

Field diameter ($\times 40$) = 0.4 mm, so radius $r = 0.2$ mm.

Area of field = $\pi r^2 = 3.14 \times 0.2 \times 0.2 = 0.126 \text{ mm}^2$

Mean number of stomata in 5 fields = 8

Stomatal density = $8 \div 0.126 = \approx \mathbf{64 \text{ stomata per mm}^2}$

Grid method: if a counting grid is used, count cells in several squares of known area, find the mean per square and divide by the area of one square.

• Precautions

- Calibrate separately for every objective; never use the $\times 10$ value for $\times 40$.
- Make sure the zero lines coincide exactly before counting.
- Choose a point far along the scale where lines coincide exactly, to reduce error.
- Measure several cells and take the mean.
- Handle the stage micrometer carefully; it is expensive and easily scratched.

● Answers to Short Questions

Basic Ideas

Q1. What is an eyepiece graticule?

Ans. A transparent glass disc with a scale (usually 0–100 divisions) fitted in the eyepiece; its divisions have no units until calibrated.

Q2. What is a stage micrometer?

Ans. A microscope slide with an accurate scale, commonly 1 mm divided into 100 divisions, each equal to 10 μm .

Q3. Why must the eyepiece graticule be calibrated?

Ans. Its scale stays the same size while the image of the specimen changes with the objective; so the actual value of one division is different for each objective.

Q4. Why is the graticule calibration different for $\times 10$ and $\times 40$ objectives?

Ans. At $\times 40$ the specimen and micrometer scale appear four times larger, so each eyepiece unit covers one-fourth of the length it covered at $\times 10$.

Q5. Convert 0.25 mm into μm and nm.

Ans. $0.25 \text{ mm} = 250 \mu\text{m} = 250\,000 \text{ nm}$.

Calculations

Q6. 25 eyepiece units coincide with 5 stage divisions. Find the value of 1 epu.

Ans. $5 \text{ divisions} = 50 \mu\text{m}$; $1 \text{ epu} = 50 \div 25 = 2 \mu\text{m}$.

Q7. A cheek cell measures 30 epu where $1 \text{ epu} = 2 \mu\text{m}$. What is its actual diameter?

Ans. $30 \times 2 = 60 \mu\text{m}$.

Q8. If $1 \text{ epu} = 10 \mu\text{m}$ at $\times 10$, what will it be at $\times 40$?

Ans. $10 \div 4 = 2.5 \mu\text{m}$.

Q9. The field of view at $\times 10$ is 1.6 mm wide. How many cells of 200 μm length fit across it?

Ans. $1.6 \text{ mm} = 1600 \mu\text{m}$; $1600 \div 200 = 8 \text{ cells}$.

Q10. How can the number of cells in a given area be estimated?

Ans. Count cells in several fields of view (or grid squares) of known area, take the mean, and divide by the area to get cells per mm^2 .

Accuracy

Q11. Why are several cells measured and a mean taken?

Ans. Cells vary in size; a mean of several measurements is more reliable and reduces the effect of an unusual cell.

Q12. Give two sources of error in this practical.

Ans. Scales not exactly aligned at zero; judging where lines coincide; cells not lying flat or cut obliquely.

Q13. Why should a coincidence point far along the scale be chosen?

Ans. The error of judging one line is spread over many divisions, giving a more accurate value per division.

PRACTICAL

05

Section A • Major Practical

To Measure the Actual Size, Image Size and Magnification of a Tissue or Cell from Photomicrographs using Scale Bar or Millimetre Ruler

Related Theory from Textbook

Biology Grade 11 > Chapter 1: Cells and Sub-Cellular Organelles

- 1.3 Microscopy — magnification and resolution
- Comparison of light and electron microscope; electron micrographs of organelles
- Calculating actual sizes from photomicrographs using magnification or scale bars

A **photomicrograph** is a photograph taken through a light microscope; an **electron micrograph** is taken with an electron microscope. The size of the object in the picture (**image size**) is bigger than its real (**actual**) size. **Magnification** tells how many times larger the image is than the object. Pictures are usually given with either a stated magnification (e.g. $\times 1500$) or a **scale bar** — a line whose length represents a known actual distance.

$$\text{Magnification (M)} = \text{Image size (I)} \div \text{Actual size (A)}$$

Both sizes must be in the SAME unit before dividing. Magnification has no unit (written as $\times$)

Image size — length of the object as measured on the photograph or drawing (with a ruler, in mm).

Actual size — real size of the object, usually in μm or nm.

Scale bar — a line on a micrograph labelled with the actual length it represents.

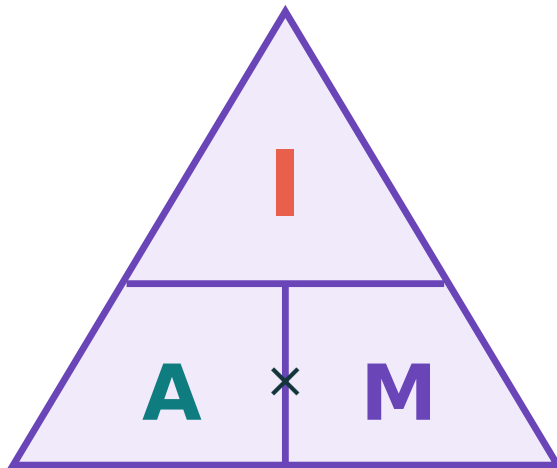
Resolution — ability to distinguish two close points as separate; light microscope ≈ 250 nm, electron microscope ≈ 0.2 nm (textbook values).

• Object

(a) To calculate the real size of an object from its magnification. (b) To calculate magnification from a scale bar. (c) To calculate the magnification of a photomicrograph or image.

• Apparatus and Materials

Printed photomicrographs / electron micrographs (with magnification or scale bar), transparent millimetre ruler, calculator, sharp pencil.

Fig. 5.1: The I-A-M triangle

I = image size, A = actual size, M = magnification

$$M = I \div A$$

$$A = I \div M$$

$$I = A \times M$$

Cover the quantity you want;
the other two show the formula

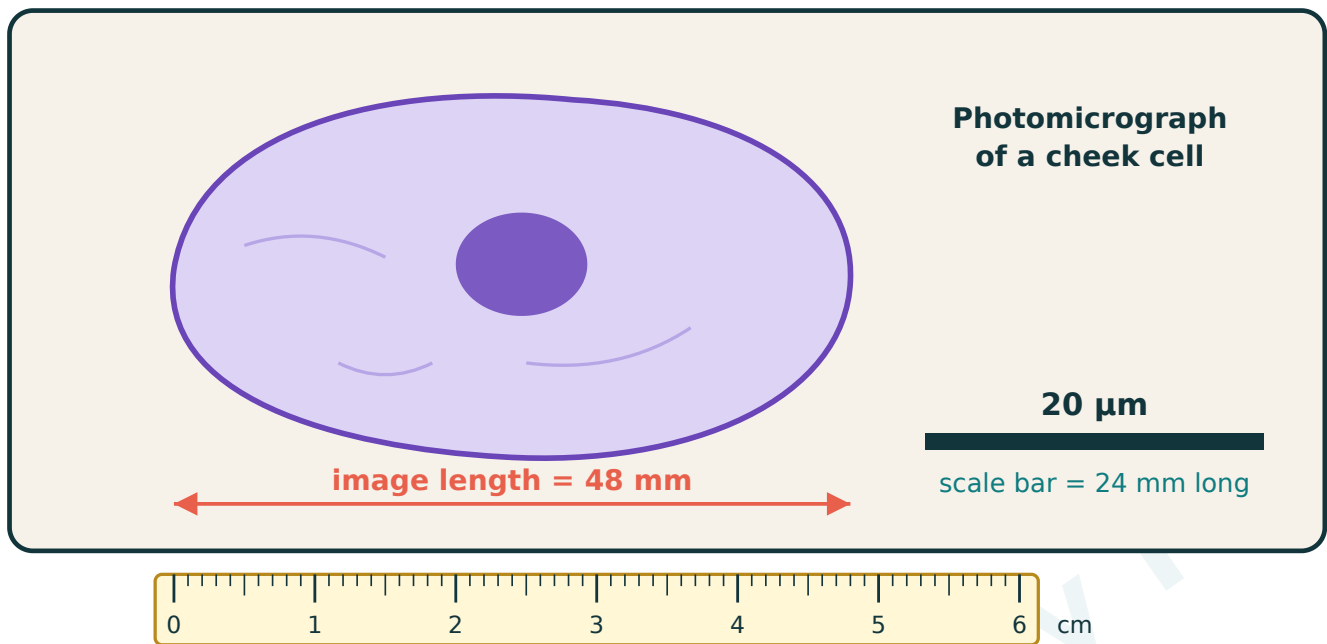
Unit conversions (always convert first!)

	mm	μm	nm
1 mm	1	1 000	1 000 000
1 μm	0.001	1	1 000
1 nm	0.000 001	0.001	1

To change mm to μm multiply by 1000; to change μm to nm multiply by 1000.

● Procedure

1. Place the ruler along the longest axis of the object in the picture (or across the tissue layer to be measured).
2. Read the length in millimetres, as accurately as possible (to 0.5 mm).
3. If a scale bar is given, measure the length of the scale bar with the ruler as well.
4. Convert all lengths to the same unit (usually μm).
5. Use the formula $M = I \div A$ and give the answer with correct units and sensible significant figures.

Fig. 5.2: Measuring the image of a cheek cell with a ruler; a scale bar is also given

• Worked Examples

(a) Calculating the real size of an object from its magnification

The image of the cell in Fig. 5.2 is 48 mm long. The magnification is $\times 1200$. Find its actual length.

$$I = 48 \text{ mm} = 48 \times 1000 = 48\,000 \text{ } \mu\text{m}$$

$$A = I \div M = 48\,000 \div 1200 = \mathbf{40 \text{ } \mu\text{m}}$$

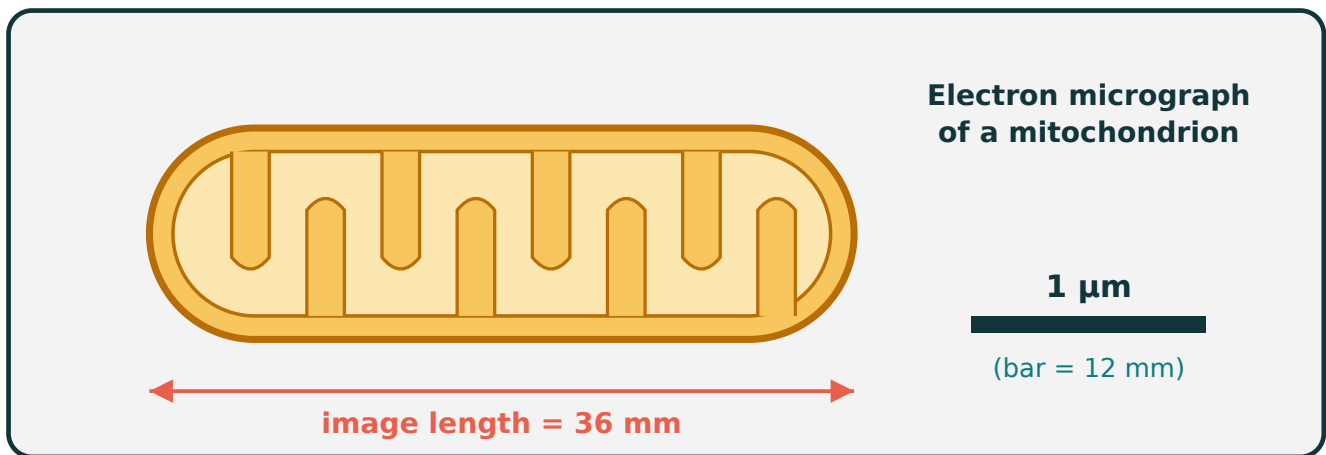
(b) Calculating magnification from a scale bar

The scale bar in Fig. 5.2 measures 24 mm and represents 20 μm.

$$\text{Length of bar} = 24 \text{ mm} = 24\,000 \text{ } \mu\text{m}$$

$$M = 24\,000 \div 20 = \mathbf{\times 1200}$$

Now the actual length of the cell = $48\,000 \text{ } \mu\text{m} \div 1200 = \mathbf{40 \text{ } \mu\text{m}}$ (same answer as (a)).

Fig. 5.3: Electron micrograph of a mitochondrion with scale bar**(c) Calculating the magnification of a photomicrograph / image**

In Fig. 5.3 the mitochondrion image is 36 mm long; the scale bar (12 mm) represents 1 μm .

$$M = 12\,000\ \mu\text{m} \div 1\ \mu\text{m} = \times 12\,000$$

$$\text{Actual length} = 36\,000\ \mu\text{m} \div 12\,000 = 3\ \mu\text{m}$$

If the actual length is known to be 3 μm , $M = I \div A = 36\,000 \div 3 = \times 12\,000$.

(d) Measuring a tissue layer

In a photomicrograph of a leaf ($\times 200$) the palisade layer is 18 mm thick. Actual thickness = $18\,000\ \mu\text{m} \div 200 = 90\ \mu\text{m}$.

• Precautions

- Measure from edge to edge along the same line each time; avoid parallax by looking straight down at the ruler.
- Convert units before calculating.
- Do not measure the magnification printed next to a picture that has been enlarged or reduced — use the scale bar instead.
- Give the answer in a suitable unit (μm for cells, nm for organelles).

● Answers to Short Questions

Concepts

Q1. Define magnification.

Ans. The number of times the image of an object is larger than the object itself: $M = \text{image size} \div \text{actual size}$.

Q2. Differentiate between magnification and resolution.

Ans. Magnification is how much larger the image is; resolution is the ability to show two close points as separate, i.e. how much detail is visible.

Q3. What is a scale bar and why is it useful?

Ans. A line on a micrograph labelled with the actual length it represents. It remains correct even when the picture is enlarged or reduced, because the bar changes size with the picture.

Q4. Why must the image size and actual size be in the same unit?

Ans. Magnification has no unit; dividing quantities in different units (e.g. mm by μm) gives a wrong answer by a factor of 1000.

Calculations

Q5. An image of a cell is 30 mm long at $\times 600$. Find the actual size.

Ans. $30 \text{ mm} = 30\,000 \mu\text{m}$; $A = 30\,000 \div 600 = 50 \mu\text{m}$.

Q6. A scale bar of 40 mm represents 10 μm . What is the magnification?

Ans. $M = 40\,000 \div 10 = \times 4000$.

Q7. A red blood cell is 7.5 μm in diameter. How long will its image be at $\times 2000$?

Ans. $I = A \times M = 7.5 \times 2000 = 15\,000 \mu\text{m} = 15 \text{ mm}$.

Q8. A chloroplast of actual length 5 μm appears 50 mm long in a micrograph. Find M.

Ans. $M = 50\,000 \div 5 = \times 10\,000$.

Q9. A nucleus measures 25 mm on a micrograph with magnification $\times 5000$. Give its actual diameter in μm and nm.

Ans. $25\,000 \div 5000 = 5 \mu\text{m} = 5000 \text{ nm}$.

Measurement Skills

Q10. Why is it better to measure the longest dimension of a cell?

Ans. It is easy to find and repeat; it reduces the percentage error of measurement.

Q11. Why can a light microscope not show ribosomes, even at high magnification?

Ans. Ribosomes (about 25 nm) are smaller than the resolving power of the light microscope (about 250 nm), so they cannot be distinguished.

Q12. What is the maximum useful magnification of a light microscope and of an electron microscope?

Ans. Light microscope about $\times 1500$ (useful range $\times 500$ – 1500). Electron microscope: direct magnification about $\times 16\,000$ and photographic magnification up to about $\times 1\,000\,000$ (Table 1.1 of the textbook).

PRACTICAL

06

Section A · Major Practical

To Investigate how much a Bacterial Pathogen shows Sensitivity or Resistance to a particular Antibiotic by Disc Diffusion Method (Kirby-Bauer Test)

Related Theory from Textbook

Biology Grade 12 > Chapter 15: Pharmacological Drugs

- 15.2 Antibiotics and their mode of action
- Types of antibiotics: penicillins, tetracyclines, fluoroquinolones, sulfonamides
- Antibiotic resistance and “superbugs”

Biology Grade 11 > Chapter 6: Prokaryotes

- Structure of bacterial cell: cell wall (peptidoglycan), ribosomes (70S), DNA
- Culturing bacteria; importance of bacteria

Antibiotics are chemical substances, produced by micro-organisms (or made synthetically), that kill bacteria (**bactericidal**) or stop their growth (**bacteriostatic**) without harming the host much. Each class acts on a different target in the bacterial cell. Bacteria that are not affected by an antibiotic are **resistant**. The **Kirby-Bauer disc diffusion test** tells which antibiotic will work best against a particular bacterium: the antibiotic diffuses out of a paper disc into the agar, and a clear **zone of inhibition** forms where bacteria cannot grow. The larger the zone, the more sensitive the bacterium.

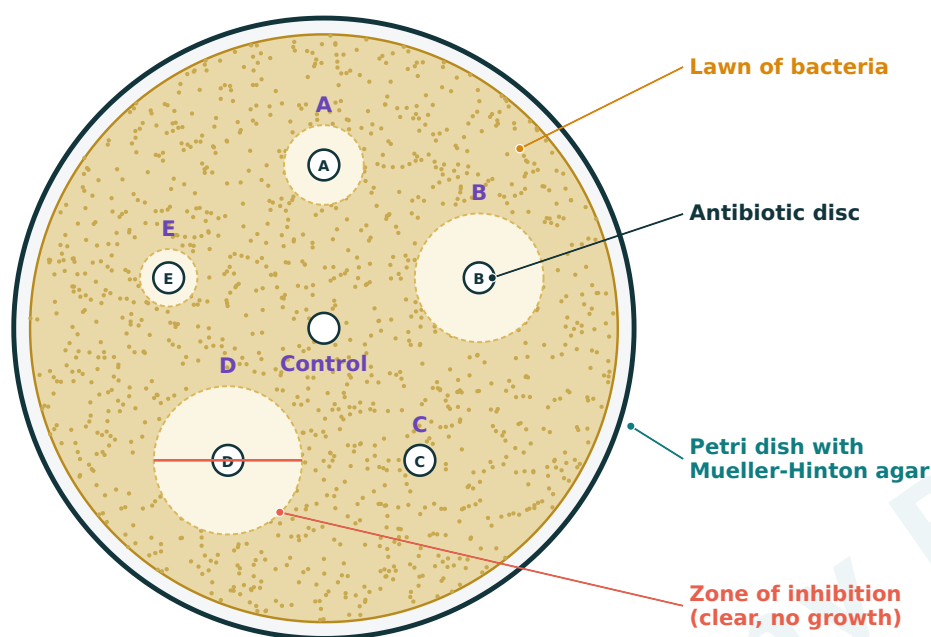
Class (example)	Mode of action	Effect
Penicillins (penicillin, amoxicillin) — β -lactams	Block the enzyme (transpeptidase) that cross-links peptidoglycan; the weak cell wall bursts by osmosis	Bactericidal
Tetracyclines (tetracycline, doxycycline)	Bind the 30S ribosomal subunit and stop tRNA attaching — protein synthesis is blocked	Bacteriostatic
Fluoroquinolones (ciprofloxacin, levofloxacin)	Inhibit DNA gyrase (topoisomerase II) and topoisomerase IV — DNA replication stops	Bactericidal
Sulfonamides (sulfamethoxazole)	Resemble PABA and competitively inhibit an enzyme of folic acid synthesis; no nucleotides can be made	Bacteriostatic

● Object

To test the sensitivity of a bacterium (e.g. *E. coli* or *Staphylococcus*) to different antibiotics by measuring the zones of inhibition.

● Apparatus and Materials

Sterile Petri dishes with Mueller-Hinton agar, broth culture of bacteria (adjusted to 0.5 McFarland standard), sterile cotton swabs, antibiotic discs (and plain sterile paper discs for control), sterile forceps, spirit lamp / Bunsen burner, incubator at 37 °C, ruler or vernier callipers, marker, disinfectant (70% alcohol), gloves.

Fig. 6.1: Kirby-Bauer plate after incubation (sample result)

● Procedure

1. Wash hands, wipe the bench with disinfectant and work near a flame (aseptic technique).
2. Dip a sterile swab into the bacterial broth, press out the excess on the side of the tube, and swab the entire agar surface in three directions to make an even **lawn**.
3. Leave the plate for 3–5 minutes to dry. Mark the bottom of the plate into sectors and label each sector.
4. Flame the forceps, let them cool, and place one antibiotic disc in each sector, about 2 cm from the edge and from other discs. Press gently. Place a plain sterile disc as a control.
5. Tape the lid at two points (do not seal completely), invert the plate and incubate at 37 °C for 18–24 hours.
6. Measure the diameter of each clear zone (including the disc) in mm across the bottom of the plate. Take readings from replicate plates.
7. Compare with the standard chart to classify the bacterium as **Sensitive (S)**, **Intermediate (I)** or **Resistant (R)** to each antibiotic.
8. Autoclave or soak all plates in disinfectant before disposal.

● Observations and Data Analysis

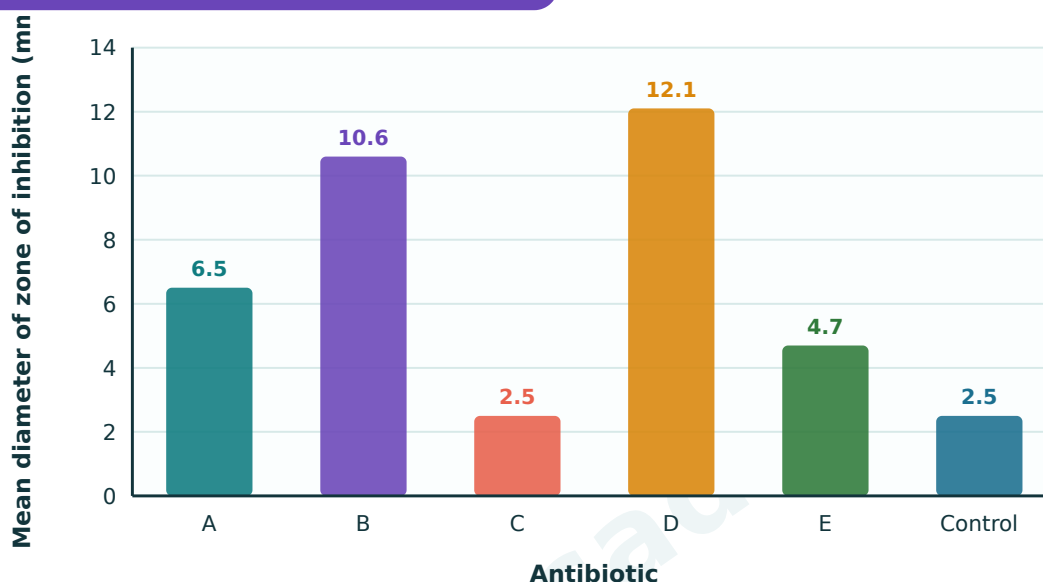
Table 6.1 (from the FBISE model paper) gives the diameters of zones of inhibition for antibiotics A–E in five replicates. The diameter of each disc was 2.5 mm.

Replicate	A	B	C	D	E	Control
R1	6.0	10.0	2.5	12.5	4.5	2.5
R2	7.0	10.1	2.5	11.0	5.0	2.5
R3	6.5	12.0	2.5	12.5	5.0	2.5

Replicate	A	B	C	D	E	Control
R4	7.0	10.2	2.5	12.0	4.0	2.5
R5	6.0	2.5*	2.5	12.5	5.0	2.5
Mean	6.5	10.6†	2.5	12.1	4.7	2.5

* Anomalous reading. † Mean of B recalculated without the anomaly = $(10.0 + 10.1 + 12.0 + 10.2) \div 4 = 10.6$ mm (the paper shows 10.5).

Fig. 6.2: Bar chart of mean zone diameters



Interpretation

- **Anomalous reading:** B in R5 (2.5 mm) — far below the other readings of B (10–12 mm); probably the disc was faulty, not pressed onto the agar, or had lost its antibiotic. It is left out when calculating the mean.
- **Most effective:** D (largest mean zone, 12.1 mm) — the bacterium is most sensitive to D.
- **Least effective:** C (2.5 mm = disc diameter only, no inhibition) — the bacterium is **resistant** to C.
- Order of effectiveness: D > B > A > E > C.
- **Control:** a plain disc gives no zone (2.5 mm), proving that the clear zones are due to the antibiotics and not to the paper disc or handling.

• Precautions and Safety

- Treat all cultures as potential pathogens; never open incubated plates, and wear gloves and a lab coat.
- Keep the lid on the plate as much as possible; work near a flame.
- Use a standard amount of inoculum so that the lawn is even.
- Place discs well apart so that zones do not overlap.
- Do not seal plates completely — this can encourage growth of anaerobic pathogens.
- Sterilise all used material before disposal; wash hands afterwards.

● Answers to Short Questions

Antibiotics

Q1. What is an antibiotic?

Ans. A chemical substance produced by micro-organisms (or synthesised) that kills or inhibits the growth of bacteria.

Q2. Differentiate between bactericidal and bacteriostatic antibiotics. Give an example of each.

Ans. Bactericidal antibiotics kill bacteria (e.g. penicillin, ciprofloxacin); bacteriostatic antibiotics only stop their growth and multiplication (e.g. tetracycline, sulfonamides).

Q3. How does penicillin kill bacteria?

Ans. It inhibits the enzyme that forms cross-links in peptidoglycan of the cell wall. The weakened wall cannot resist osmotic pressure and the bacterium bursts.

Q4. Why does penicillin not harm human cells?

Ans. Human cells have no cell wall and no peptidoglycan, so the target of penicillin is absent.

Q5. How do tetracyclines act?

Ans. They bind to the 30S subunit of bacterial (70S) ribosomes and prevent tRNA from attaching, so protein synthesis stops.

Q6. What is the target of fluoroquinolones?

Ans. The enzymes DNA gyrase and topoisomerase IV, which are needed for DNA replication.

Q7. Why are sulfonamides called competitive inhibitors?

Ans. They resemble PABA (para-aminobenzoic acid) and compete with it for the active site of the enzyme that makes folic acid.

Kirby-Bauer Test

Q8. What is a zone of inhibition?

Ans. The clear area around an antibiotic disc where bacteria could not grow because the antibiotic diffused into the agar.

Q9. What does a large zone of inhibition indicate?

Ans. The bacterium is highly sensitive to that antibiotic (it also depends on how fast the antibiotic diffuses).

Q10. What is the purpose of the control disc?

Ans. To show that the paper disc or handling alone does not stop bacterial growth; any zone is due to the antibiotic.

Q11. Why is Mueller-Hinton agar used?

Ans. It is a standard medium that supports growth of most bacteria and allows antibiotics to diffuse evenly, so results can be compared with standard charts.

Q12. Why are plates incubated at 37 °C?

Ans. It is the optimum temperature for growth of most human pathogens.

Q13. Why are plates incubated upside down?

Ans. To stop drops of condensed water falling on the agar surface and spreading the bacteria.

Q14. Why are replicates used?

Ans. To identify anomalous readings and to calculate a reliable mean.

Data Handling**Q15. Identify the anomalous reading in Table 6.1 and suggest a reason.**

Ans. B in R5 (2.5 mm). The disc may have been defective, not in contact with the agar, or contaminated with resistant bacteria.

Q16. Which antibiotic is most effective and which is least effective? Give reasons.

Ans. D is most effective (largest mean zone, 12.1 mm). C is least effective (zone equal to disc size, 2.5 mm, i.e. no inhibition; the bacterium is resistant).

Q17. Calculate the mean zone of A.

Ans. $(6.0 + 7.0 + 6.5 + 7.0 + 6.0) \div 5 = 32.5 \div 5 = 6.5 \text{ mm}$.

Q18. What type of graph is suitable for Table 6.1 and why?

Ans. A bar chart, because the independent variable (type of antibiotic) is categorical (discontinuous).

PRACTICAL

07

Section A • Major Practical

Analysis of Use and Misuse of Specific Antibiotics through Provided Data

Related Theory from Textbook

**Biology Grade 12 > Chapter 15:
Pharmacological Drugs**

- 15.2 Antibiotics and their mode of action
- Antibiotic resistance: overuse, mutations and natural selection (superbugs)
- 15.1 Drug discovery and post-marketing surveillance

**Biology Grade 12 > Chapter 11:
Biostatistics and Data Handling**

- 11.3 Graphic presentation of data: bar chart, pie chart (angles = $\% \times 3.6$)
- Percentages and rates of change

Antimicrobial resistance (AMR) is the ability of micro-organisms to survive drugs that once killed them. Resistance arises by **mutation** or by receiving resistance genes from other bacteria (on **plasmids**, by conjugation, transformation or transduction). When antibiotics are used, sensitive bacteria die but resistant ones survive and multiply — this is **natural selection**. **Misuse** of antibiotics speeds up this process.

Mechanisms of resistance — enzymes that destroy the drug (e.g. β -lactamase breaks penicillin), altered target site, efflux pumps that throw the drug out, reduced entry through the wall.

Superbugs — bacteria resistant to many antibiotics, e.g. MRSA, and XDR *Salmonella* Typhi (extensively drug-resistant typhoid) reported in Sindh, Pakistan, since 2016.

Correct use — only on a qualified doctor's prescription, at the right dose, for the full course, and never for viral infections.

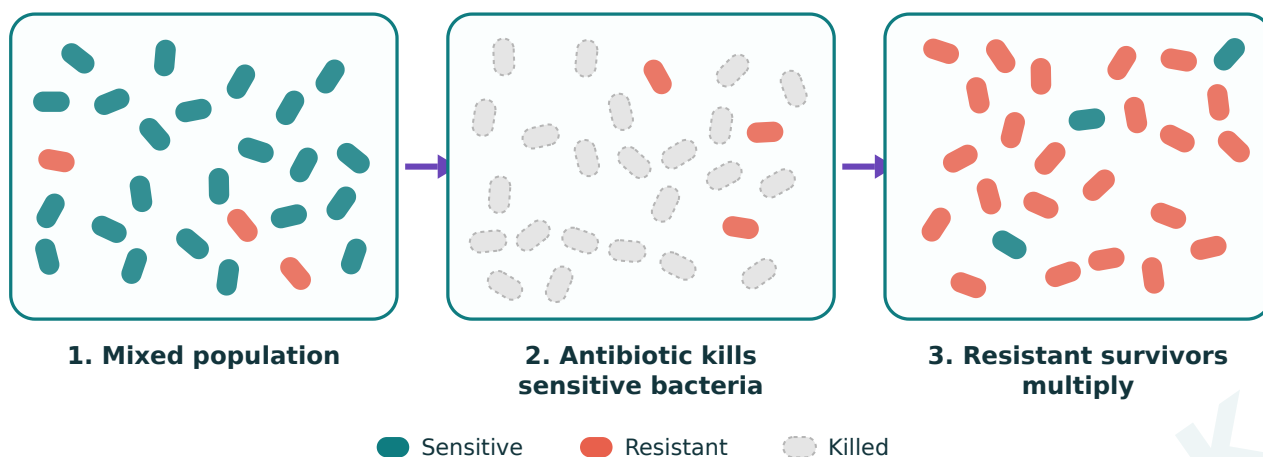
WHO AWaRe — WHO groups antibiotics into Access, Watch and Reserve to guide careful prescribing.

• Object

To analyse given data on the use of antibiotics and on antibiotic resistance, present it in suitable charts, and draw conclusions about misuse of antibiotics.

• Materials

Data tables (survey / hospital records), graph paper, ruler, protractor, pencil, calculator.

Fig. 7.1: How misuse of antibiotics selects resistant bacteria

• Data Set 1: Pattern of Antibiotic Use (sample survey of 200 people)

The data sets in this practical are sample data prepared for practice in analysis.

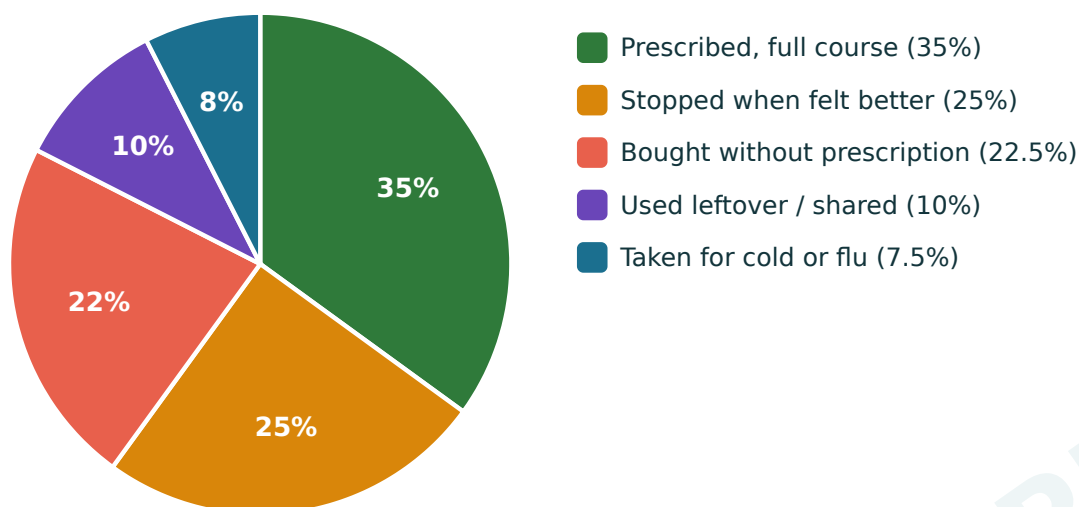
Pattern of use	Number of people	Percentage	Angle for pie chart
Prescribed by doctor, full course completed	70	35%	126°
Prescribed, but stopped when felt better	50	25%	90°
Bought from pharmacy without prescription	45	22.5%	81°
Used leftover or shared antibiotics	20	10%	36°
Taken for cold / flu (viral infection)	15	7.5%	27°
Total	200	100%	360°

Calculations

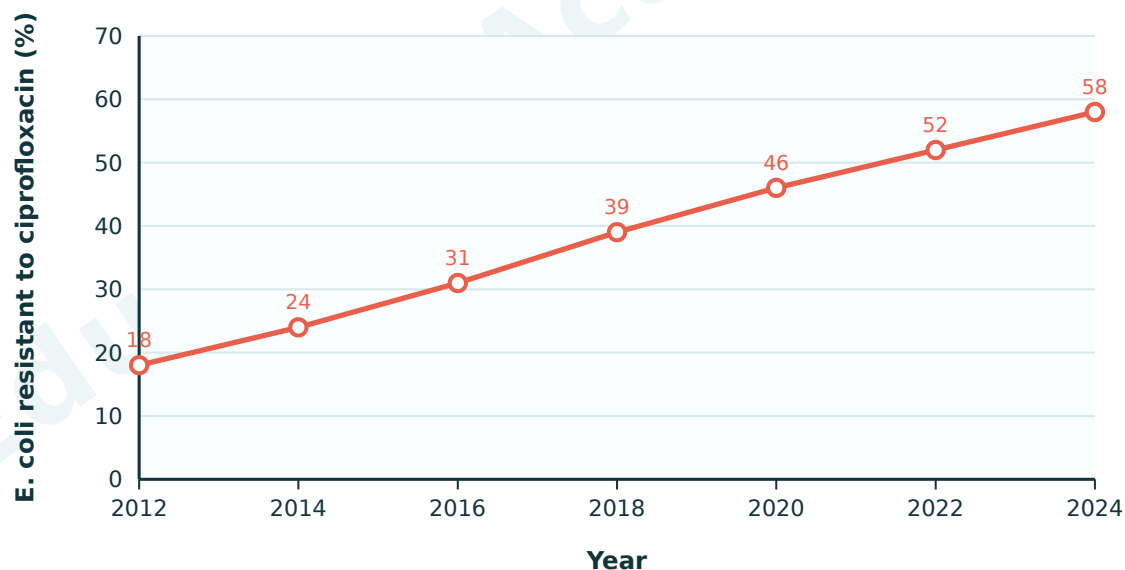
Percentage = (number ÷ total) × 100; e.g. $50 \div 200 \times 100 = 25\%$.

Angle = (number ÷ total) × 360°; e.g. $50 \div 200 \times 360 = 90^\circ$.

People who misused antibiotics = $50 + 45 + 20 + 15 = 130 = 65\%$.

Fig. 7.2: Pie chart of antibiotic use pattern**• Data Set 2: Resistance of *E. coli* to Ciprofloxacin in a Hospital**

Year	2012	2014	2016	2018	2020	2022	2024
Resistant isolates (%)	18	24	31	39	46	52	58

Fig. 7.3: Trend of ciprofloxacin resistance**Calculations**

Increase from 2012 to 2024 = $58 - 18 = 40$ percentage points.

Percentage increase = $(40 \div 18) \times 100 = 222\%$.

Mean rate of change = $40 \div 12$ years = **3.3 percentage points per year.**

Conclusions

- Two-thirds (65%) of users misused antibiotics — stopping early and self-medication are the most common forms.
- Resistance of *E. coli* to ciprofloxacin more than tripled in 12 years; the steady rise matches increasing misuse.
- Antibiotics are useless against viruses (cold, flu); using them only selects resistant bacteria in the body.
- If the trend continues, common infections may become untreatable, so correct use must be promoted.

• Forms of Misuse and their Prevention

Misuse	Why it is harmful	Prevention
Self-medication / buying without prescription	Wrong drug or dose; partly sensitive bacteria survive	Sell antibiotics only on prescription
Stopping the course early	Surviving, partly resistant bacteria multiply	Always complete the full course
Using antibiotics for viral infections	No benefit; kills normal flora and selects resistant bacteria	Public awareness; doctors avoid unnecessary prescriptions
Using leftover / shared medicine	Wrong antibiotic and incomplete dose	Dispose of leftovers safely
Use as growth promoters in poultry / livestock	Resistant bacteria and genes reach humans through food and environment	Restrict non-medical use in animals

• Precautions in Data Analysis

- Check that percentages add up to 100% and angles to 360°.
- Label pie chart sectors and give a title and key.
- Use a line graph only for continuous data (e.g. years); use a bar or pie chart for categories.
- Do not draw conclusions that the data do not show (correlation is not always cause).

● Answers to Short Questions

Resistance

Q1. What is antibiotic resistance?

Ans. The ability of bacteria to survive and multiply in the presence of an antibiotic that normally kills them or stops their growth.

Q2. How does misuse of antibiotics lead to resistance?

Ans. Antibiotics kill sensitive bacteria, while the few resistant ones survive (natural selection) and multiply, so the whole population becomes resistant.

Q3. Name two ways by which bacteria become resistant.

Ans. Mutation in their own genes, and receiving resistance genes from other bacteria on plasmids (conjugation), or by transformation/transduction.

Q4. Give two mechanisms of resistance.

Ans. Production of enzymes (e.g. β -lactamase) that destroy the antibiotic; efflux pumps that pump the drug out; alteration of the target site.

Q5. What is a superbug? Give an example.

Ans. A bacterium resistant to several antibiotics, e.g. MRSA (methicillin-resistant *Staphylococcus aureus*) or XDR typhoid bacteria.

Use and Misuse

Q6. Why should antibiotics not be used for colds and flu?

Ans. Colds and flu are caused by viruses; antibiotics act on bacterial structures and have no effect on viruses, but they promote resistance.

Q7. Why is it important to complete the course of antibiotics?

Ans. Stopping early leaves some bacteria alive; the tougher, partly resistant ones survive and multiply.

Q8. Give three steps to reduce antibiotic resistance.

Ans. Use antibiotics only on prescription; complete the full course; avoid use in viral infections and as growth promoters in animals (also: hygiene and vaccination).

Data Analysis

Q9. From Data Set 1, what percentage of people used antibiotics correctly?

Ans. 35% (70 out of 200).

Q10. Calculate the angle for “bought without prescription” on the pie chart.

Ans. $45 \div 200 \times 360^\circ = 81^\circ$.

Q11. Why is a pie chart suitable for Data Set 1 and a line graph for Data Set 2?

Ans. Data Set 1 shows parts of a whole (categories adding to 100%), so a pie chart fits. Data Set 2 shows change over continuous time, so a line graph fits.

Q12. Calculate the percentage increase in resistance from 2016 to 2024.

Ans. $(58 - 31) \div 31 \times 100 = 87\%$.

Q13. Predict the resistance in 2026 if the trend continues.

Ans. About 3 percentage points per year: $58 + (2 \times 3.3) \approx 65\%$.

PRACTICAL

08

Section A · Major Practical

Measuring Variability: Statistics, Charts and Design of Experiments

Related Theory from Textbook

Biology Grade 12 > Chapter 11:
Biostatistics and Data Handling

- 11.1 Biostatistics and its uses
- 11.2 Mean, median, mode, standard deviation, range and percentile
- 11.3 Sketching a bar chart; choosing the appropriate chart
- 11.5 Sketching error bars based on range or standard deviation
- Designing experiments with control group and variables

Biology Grade 11 > Chapters 3, 4 and 9

- Ch 3: factors affecting enzyme activity (option e)
- Ch 4: Bioenergetics — factors affecting photosynthesis (option g)
- Ch 9: 9.1 Nutrition in plants (N, P, K); 9.6 Growth and development (options c, d, f, h)

Biology is full of **variation**: no two leaves or two students are exactly alike. To study variation and to test hypotheses we must **design fair experiments**, collect **reliable data**, summarise it with **statistics** and present it in suitable **charts**.

Independent variable (IV) — the factor the investigator changes (plotted on x-axis).

Dependent variable (DV) — the factor measured, which changes because of the IV (y-axis).

Controlled (standardised) variables — all other factors kept the same so the test is fair.

Control group / experiment — a set-up without the IV (or at normal level) used for comparison.

Qualitative data — categoric: nominal (e.g. flower colour) or ordinal (ranked order).

Quantitative data — numerical: discrete (counts) or continuous (e.g. height, mass, leaf length).

Options given in the FBISE list (any one is performed)

1. (a) Measuring variability in leaf surface area by graph paper method using different plant species.
2. (b) Height or weight variability among students of the same age group.
3. (c) Increase in plant height in different soil types (different N, P, K).
4. (d) Effect of amount of fertilizer on plant growth (height and number of leaves).
5. (e) Effect of temperature / pH on enzyme activity (see Practical 1).
6. (f) Effect of light intensity on plant growth.
7. (g) Effect of light intensity on the rate of photosynthesis.
8. (h) Effect of different amounts of water in soil on plant growth.

● Statistical Formulae

Quantity	How to find it	Tells us
Mean ($\bar{x}$)	$\Sigma x \div n$	average value
Median	middle value when data are arranged in order (average of two middle values if n is even)	central value, not affected by extremes
Mode	most frequent value	commonest value
Range	largest – smallest value	simple spread of data
Percentile	value below which a given % of data lie (50th percentile = median)	position of a value in the data
Standard deviation (s)	$s = \sqrt{[\Sigma(x - \bar{x})^2 \div (n - 1)]}$	spread of data around the mean
Standard error (SE)	$SE = s \div \sqrt{n}$	how reliable the mean is
95% confidence interval	$\bar{x} \pm 2 \times SE$	range in which the true mean lies with 95% confidence

● Option (b): Height Variability among Students of the Same Age Group

Method: Measure the height of 10 students of class 12 without shoes, standing straight against a wall with a metre rod; read to the nearest cm. **IV:** individual student (categorical). **DV:** height (continuous).

Student	A	B	C	D	E	F	G	H	I	J
Height (cm)	180	182	175	171	160	172	170	158	165	168

Worked solution

Mean = $\Sigma x \div n = 1701 \div 10 = \mathbf{170.1 \text{ cm}}$

Arranged: 158, 160, 165, 168, 170, 171, 172, 175, 180, 182 $\Rightarrow$ **Median** = $(170 + 171) \div 2 = \mathbf{170.5 \text{ cm}}$; **Mode:** none (no value repeats); **Range** = $182 - 158 = \mathbf{24 \text{ cm}}$

x (cm)	180	182	175	171	160	172	170	158	165	168
$x - \bar{x}$	9.9	11.9	4.9	0.9	-10.1	1.9	-0.1	-12.1	-5.1	-2.1
$(x - \bar{x})^2$	98.01	141.61	24.01	0.81	102.01	3.61	0.01	146.41	26.01	4.41

$$\Sigma(x - \bar{x})^2 = 546.9$$

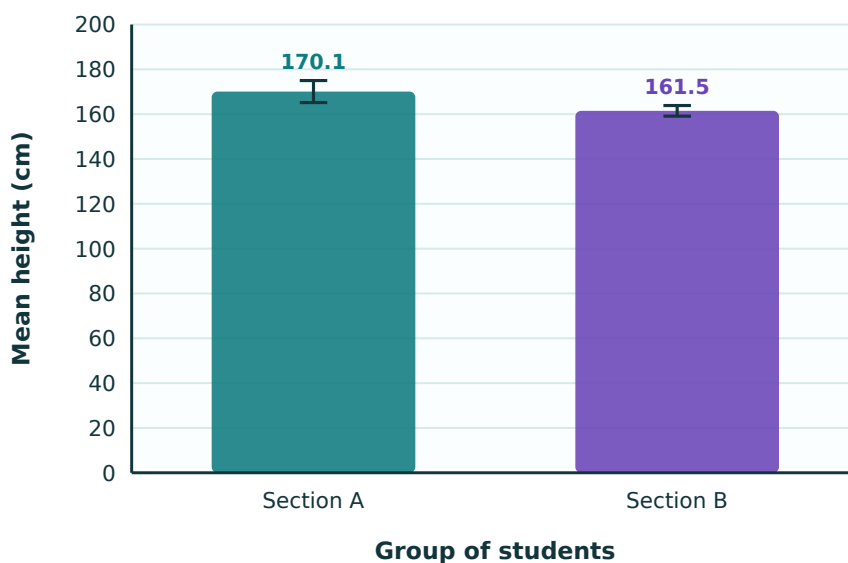
Standard deviation $s = \sqrt{(546.9 \div 9)} = \sqrt{60.77} = \mathbf{7.80 \text{ cm}}$

(If divided by n instead of $n - 1$ — the “biased” SD mentioned in the textbook — $s = \sqrt{(546.9 \div 10)} = 7.40 \text{ cm}$. For a sample, $n - 1$ is preferred.)

Standard error $SE = 7.80 \div \sqrt{10} = 7.80 \div 3.16 = \mathbf{2.47 \text{ cm}}$

95% confidence interval = $170.1 \pm (2 \times 2.47) = 170.1 \pm 4.9 = \mathbf{165.2 \text{ to } 175.0 \text{ cm}}$

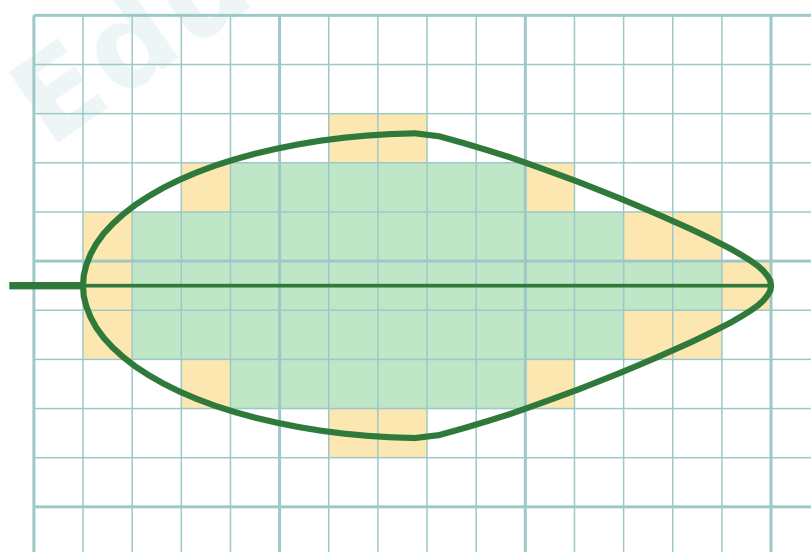
For comparison, a second group (Section B) gave a mean of 161.5 cm with $SE = 1.19 \text{ cm}$ (95% CI: 159.1–163.9 cm). The bar chart shows the means with error bars of $\pm 2SE$.

Fig. 8.1: Mean height of two groups with error bars (± 2 SE)**Using error bars**

The error bars of the two groups **do not overlap**, so the difference in mean height is **likely to be significant**. If error bars overlap a lot, the difference is probably due to chance. The **null hypothesis** here is: "There is no difference between the mean heights of the two groups."

• Option (a): Variability in Leaf Surface Area by Graph Paper Method

Method: Collect 5 mature leaves each of three species. Place each leaf on 1 cm graph paper and trace its outline. Count all full squares and those more than half covered; ignore squares less than half covered. The total gives the area in cm^2 .

Fig. 8.2: Finding leaf area on graph paper (this leaf: 44 full + 16 more-than-half squares $\approx 60 \text{ cm}^2$)

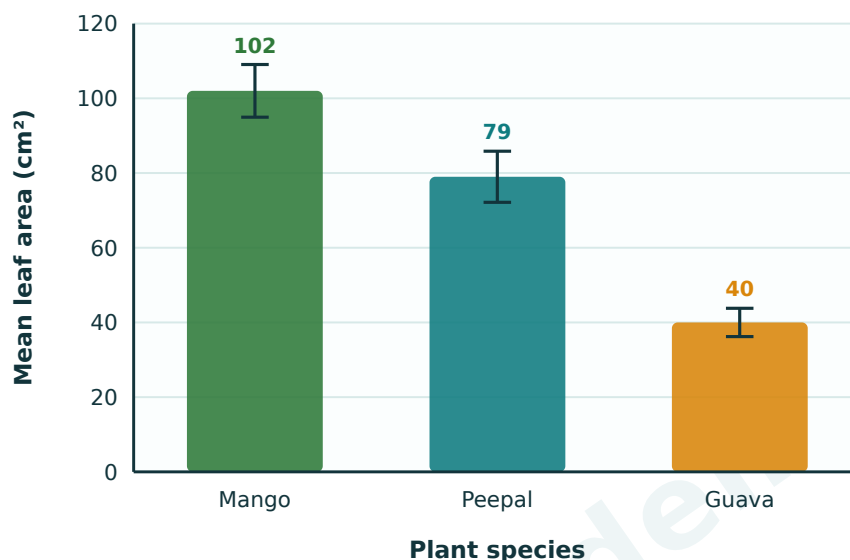
- Full squares
- More than half covered (count as 1)

1 square = 1 cm^2

Area $\approx$ full squares + squares more than half covered (ignore the rest)

Species	Leaf 1	Leaf 2	Leaf 3	Leaf 4	Leaf 5	Mean (cm ²)	SD (cm ²)
Mango	98	110	104	92	106	102	7.07
Peepal	75	82	70	88	80	79	6.86
Guava	42	38	45	40	35	40	3.81

Fig. 8.3: Mean leaf area of three species (error bars = ± 1 SD)



● Option (g): Effect of Light Intensity on the Rate of Photosynthesis

Method: Place a fresh shoot of *Elodea* / *Hydrilla* under an inverted funnel in a beaker of water containing a little sodium hydrogen carbonate (source of CO₂). Place a lamp at 10 cm and, after 5 minutes to adjust, count the bubbles released per minute. Repeat at 20, 30, 40 and 50 cm. Light intensity $\propto 1/d^2$. Keep a glass tank of water between lamp and beaker to absorb heat so temperature stays constant.

Fig. 8.4: Apparatus

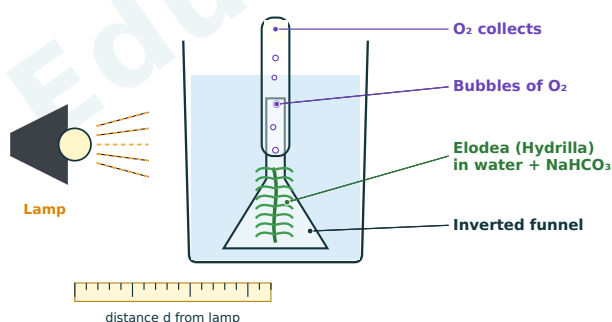
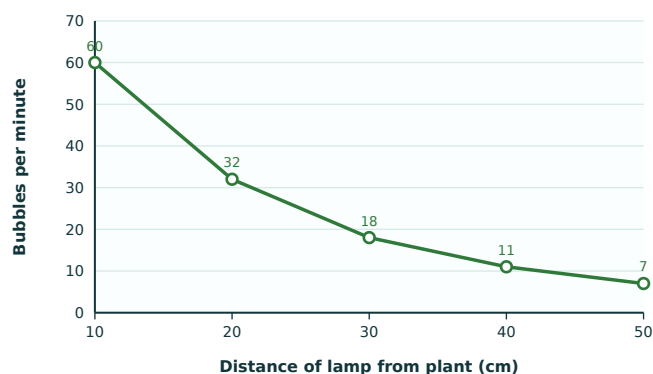


Fig. 8.5: Bubbles per minute vs distance



Distance d (cm)	10	20	30	40	50
Relative light intensity ($1/d^2 \times 10\,000$)	100	25	11.1	6.3	4
Bubbles per minute (mean of 3)	60	32	18	11	7

Conclusion: As light intensity increases (lamp closer), the rate of photosynthesis increases, because light is the limiting factor. At very high intensity the rate levels off as CO₂ or temperature becomes limiting.

● Design of the Other Options

Option	Independent variable	Dependent variable	Key controlled variables	Control
(c) Soil types	Soil type (sandy, loamy, clay, or N/P/K-rich)	Increase in plant height (cm) after 3 weeks	Species, seed/seedling size, water, light, temperature, pot size	Plants in ordinary garden soil
(d) Fertilizer	Amount of fertilizer (0, 1, 2, 3, 4 g per pot)	Plant height and number of leaves	Type of fertilizer, species, water, light, soil volume	Pot with 0 g fertilizer
(e) Temperature / pH on enzyme	Temperature or pH	Rate (volume of O ₂ / time)	Enzyme and substrate amount, time	Boiled enzyme
(f) Light intensity on growth	Light intensity (distance from lamp / layers of shade net)	Plant height and number of leaves	Species, water, soil, temperature, duration	Plants in normal daylight
(h) Water in soil	Volume of water per day (0, 25, 50, 75, 100 mL)	Plant height and number of leaves	Species, soil type, pot size, light, temperature	Pot given normal watering

● Risk Assessment (example for Option g)

Hazard	Risk	Severity / probability	Precaution
Electric lamp near water	Electric shock	High / low	Keep wires dry; switch off before moving
Hot bulb	Burns	Medium / medium	Do not touch bulb; let it cool
Glassware	Cuts if broken	Medium / low	Handle carefully; report breakages

● Dealing with Anomalies and Evaluating Results

- An **anomalous result** is one that does not fit the pattern; circle it, suggest a reason, repeat the reading and leave it out of the mean.
- **Reliability / repeatability:** take at least three replicates; similar replicates and small SD mean reliable data.
- **Validity:** the experiment measures what it claims to; all key variables are controlled.
- **Accuracy:** closeness to the true value; improve with better instruments (e.g. digital balance, data logger).
- Check whether the range and intervals of the IV were suitable (e.g. at least 5 values).

● Rules for Drawing Charts

- Give a clear title; label both axes with quantity and unit, e.g. “Height / cm”.
- IV on the x-axis, DV on the y-axis; use a sensible linear scale using more than half the grid.
- Use a **bar chart** for categoric IV (bars separate), a **histogram** for continuous frequency data (bars touching), a **line graph** for continuous IV, a **pie chart** for parts of a whole.
- Plot points with small crosses or dots in circles; join points with straight lines or a smooth best-fit curve; add a legend for more than one data set.
- Draw error bars as vertical lines with short caps showing $\pm$ SD, $\pm$ SE or $\pm$ 2SE (state which).

● Answers to Short Questions

Variables and Design

Q1. Differentiate between independent and dependent variables.

Ans. The independent variable is changed by the experimenter; the dependent variable is measured and changes as a result.

Q2. In an experiment on the effect of fertilizer on plant growth, name the IV, DV and two controlled variables.

Ans. IV: amount of fertilizer; DV: plant height / number of leaves; controlled: plant species, volume of water, light, soil type, pot size.

Q3. What is a control experiment? Why is it needed?

Ans. A set-up identical to the others but without the independent factor (or at a standard level). It shows that the change in DV is due to the IV alone.

Q4. What is a null hypothesis? Give an example.

Ans. A statement that there is no difference or no relationship between variables, e.g. "Fertilizer has no effect on plant height".

Q5. Why are replicates used in an investigation?

Ans. To calculate a reliable mean, check repeatability and identify anomalies.

Statistics

Q6. Find the mean, median, mode and range of: 4, 7, 7, 9, 13.

Ans. Mean = $40 \div 5 = 8$; median = 7; mode = 7; range = $13 - 4 = 9$.

Q7. What does standard deviation tell us?

Ans. How widely the data are spread around the mean; a small SD means values are close to the mean.

Q8. How is standard error calculated and what does it show?

Ans. $SE = SD \div \sqrt{n}$. It shows how precisely the sample mean estimates the true population mean.

Q9. The heights of 10 students have SD = 7.8 cm. Calculate SE.

Ans. $SE = 7.8 \div \sqrt{10} = 7.8 \div 3.16 = 2.47 \text{ cm}$.

Q10. What is the 50th percentile of a data set?

Ans. It is the median — half of the values lie below it.

Q11. Two means have 95% confidence intervals that do not overlap. What can you conclude?

Ans. The difference between the means is likely to be statistically significant, i.e. not due to chance.

Charts

Q12. Which chart would you use for (i) blood groups of a class, (ii) change in height of a plant over 6 weeks, (iii) percentage of land use?

Ans. (i) Bar chart (categorical data); (ii) line graph (continuous time); (iii) pie chart (parts of a whole).

Q13. Differentiate between a bar chart and a histogram.

Ans. A bar chart shows categorical data with separate bars; a histogram shows frequency of continuous data grouped into classes, with bars touching.

Q14. What are error bars?

Ans. Lines drawn above and below the mean on a bar chart or graph to show the spread (SD) or reliability (SE / 95% CI) of the data.

Specific Experiments

Q15. How is leaf area found by the graph paper method?

Ans. Trace the leaf on 1 cm graph paper and count full squares plus squares more than half covered; each square = 1 cm².

Q16. Why is sodium hydrogen carbonate added to water in the *Elodea* experiment?

Ans. It releases CO₂, so that carbon dioxide does not become a limiting factor.

Q17. Why is a tank of water placed between the lamp and the plant?

Ans. To absorb heat from the lamp so that temperature stays constant (controlled variable).

Q18. What is the relationship between light intensity and distance from the lamp?

Ans. Light intensity is inversely proportional to the square of distance ($I \propto 1/d^2$).

Q19. Why does the rate of photosynthesis level off at high light intensity?

Ans. Another factor, such as CO₂ concentration or temperature, becomes limiting.

PRACTICAL BASED ASSESSMENT

Section B

Minor Practicals

16 marks • 40%

09	Setting up a Light Microscope to View Specimens	p. 51
10	Plant Tissues: T.S. of Monocot & Dicot Root, Stem and Bifacial Leaf	p. 59
11	Animal Tissues: Testis, Ovary, Blood Vessels and Pancreas	p. 73
12	Temporary Slides of Animal Cells (Epithelium, Blood, Cheek Cells)	p. 80
13	Temporary Slides of Plant Cells (Leaf Epidermis, Onion Peel)	p. 86
14	ABO and Rh Blood Groups; Inheritance of Blood Groups	p. 91
15	Sporophyte and Gametophyte of Fern (<i>Adiantum</i>)	p. 96
16	Male and Female Cones of <i>Pinus</i>	p. 102
17	Representative Vertebrates: Amphibians, Reptiles, Birds, Mammals	p. 108
18	Kingdom Protista: Protozoa, Algae, Myxomycota, Oomycota	p. 113
19	Kingdom Fungi: Zygo-, Asco-, Deutero- and Basidiomycota	p. 119

PRACTICAL

09

Section B • Minor Practical

Set up a Light Microscope to View and Observe Specimens

Related Theory from Textbook

Biology Grade 11 > Chapter 1: Cells and Sub-Cellular Organelles

- 1.3 Microscopy: light microscope — parts and working principle (Fig. 1.2, 1.3)
- Magnification and resolution; difference between them
- 1.3.1 Electron microscopy; Table 1.1 comparison of light and electron microscope

A **compound light microscope** uses two lenses one after the other. The **objective lens** forms a real, inverted and magnified image of the specimen; the **ocular lens (eyepiece)** magnifies this image further to form a virtual image. Light from a mirror or lamp passes through the thin specimen, so the specimen must be thin and transparent.

Total magnification = magnification of objective × magnification of ocular (eyepiece)

e.g. 40× objective with 10× eyepiece = 400×; maximum ≈ 1500× (100× objective with 15× eyepiece)

Magnification — capacity of a lens to make an object look larger than its original size.

Resolution (resolving power) — ability to distinguish two close points as separate; naked eye 0.1 mm, light microscope ≈ 250 nm, electron microscope ≈ 0.2 nm.

Working distance — distance between the objective lens and the slide when the specimen is in focus.

Parfocal — objectives are set so that the specimen stays nearly in focus when the nosepiece is turned.

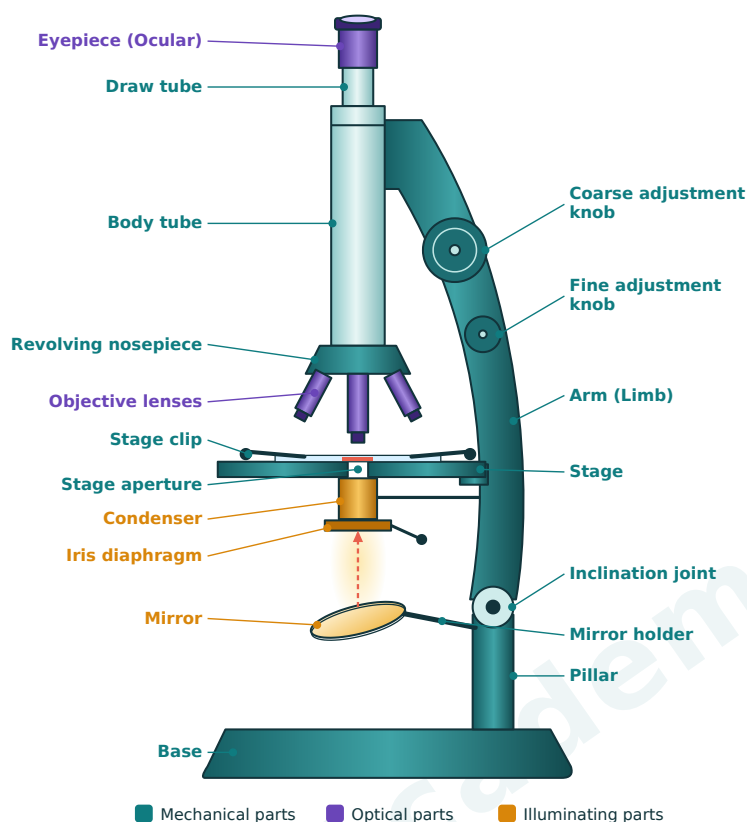
• Object

To identify the parts of a compound light microscope, understand their functions, and set it up correctly to view and observe a specimen.

• Apparatus

Compound light microscope, prepared slide (e.g. onion peel, blood smear), lens paper, dust cover.

Fig. 9.1: Compound light microscope (side view). The dotted arrow shows the path of light from the mirror.



● Parts and their Functions

Part	Structure and Function
A. MECHANICAL PARTS	
Base	Heavy, U-shaped (horseshoe) foot on which the whole microscope stands; keeps it stable.
Pillar	Short upright piece rising from the base; carries the inclination joint.
Inclination joint	Hinge between pillar and arm; allows the microscope to be tilted for comfortable viewing.
Arm (limb)	Curved handle that holds the body tube, stage and adjustment knobs; used to carry the microscope.
Body tube	Hollow tube that holds the eyepiece at the top and nosepiece at the bottom; keeps lenses at the correct distance.
Draw tube	Narrow upper tube holding the eyepiece; slides in the body tube to set the tube length.
Revolving nosepiece	Rotating disc carrying the objectives; brings the required objective into position.
Coarse adjustment knob	Large knob that moves the tube (or stage) quickly through a large distance for rough focusing.

Part	Structure and Function
Fine adjustment knob	Small knob that moves the tube (or stage) very slowly for sharp focusing, especially under high power.
Stage	Flat platform on which the slide is placed.
Stage clips	Hold the slide firmly on the stage.
Stage aperture	Hole in the centre of the stage through which light passes to the specimen.
B. OPTICAL PARTS	
Eyepiece (ocular lens)	Lens through which we look; magnifies the image formed by the objective (5×, 10× or 15×).
Objective lenses	Lenses near the specimen that form the first magnified image: scanning 4×, low power 10×, high power 40× and oil-immersion 100×.
C. ILLUMINATING PARTS	
Mirror / lamp	Mirror (plane and concave sides) reflects light into the microscope; modern microscopes have a built-in lamp.
Condenser	Lens system below the stage that collects light and focuses it on the specimen.
Iris diaphragm	Adjustable opening below the condenser that controls the amount of light.

● Procedure: Setting up the Microscope

1. Carry the microscope with one hand on the arm and the other under the base; place it on the table about 10 cm from the edge.
2. Turn the nosepiece until the low-power (10×) objective clicks into place.
3. Adjust the mirror (or switch on the lamp) and open the iris diaphragm until the field of view is evenly bright.
4. Place the slide on the stage with the specimen over the aperture; fix it with the stage clips.
5. Looking from the side, lower the objective with the coarse knob until it is just above the slide.
6. Look through the eyepiece and raise the objective slowly with the coarse knob until the object appears.
7. Sharpen the image with the fine adjustment knob; adjust the light with the diaphragm.
8. For high power, turn the 40× objective into place and focus with the **fine knob only**.
9. Draw what you see and write the total magnification under the drawing.

● Light Microscope vs Electron Microscope (Textbook Table 1.1)

Feature	Light Microscope	Electron Microscope
Source of illumination	Visible light (about 400–700 nm)	Beam of electrons (wavelength about 1 nm)
Lenses	Glass lenses	Electromagnetic lenses
Magnification	About 1500×	1 to 50 million times depending on type
Resolving power	About 250 nm (low)	About 0.2 nm (high)

Feature	Light Microscope	Electron Microscope
Specimen	Living or dead	Only dead, dried specimens; thin sections of 20–100 nm
Image	Usually coloured; formed by light absorption	Black and white; formed by electron scattering
Vacuum	Not required	Essential

● Precautions

- Clean lenses only with lens paper.
- Never use the coarse knob with the high-power objective.
- Keep both eyes open while observing.
- Do not tilt the microscope when a wet mount is on the stage.
- After use, bring the low-power objective into position, remove the slide and cover the microscope.

● Answers to Short Questions

Eyepiece

Q1. Why is the eyepiece also called the ocular lens?

Ans. Because it is the lens we put our eye to (Latin *oculus* = eye).

Q2. Look at your lab microscope. What magnification is written on its eyepiece?

Ans. Usually 10×. Some microscopes have 5× or 15× eyepieces.

Draw Tube and Body Tube

Q3. What is a draw tube, and why is it made so that it can slide in and out?

Ans. It is the upper, narrower tube that holds the eyepiece and fits inside the body tube. It slides so that the tube length can be set correctly (normally 160 mm).

Q4. What is the main job of the body tube?

Ans. It holds the eyepiece and the objectives in a straight line and at the correct distance from each other, so that a clear image is formed.

Q5. Why is the inside of the body tube painted black?

Ans. Black absorbs stray light and stops reflections inside the tube, so the image stays clear.

Revolving Nosepiece

Q6. Why is the nosepiece made to revolve instead of being fixed?

Ans. So that we can change quickly from one objective to another without removing any lens.

Q7. While rotating the nosepiece you hear a "click". What does this click tell you?

Ans. It tells us the objective is locked exactly in line with the body tube and the path of light.

Objective Lenses

Q8. Name the objective lenses found on a compound microscope and write their magnifying power.

Ans. Scanning 4×, low power 10×, high power 40× and oil-immersion 100×.

Q9. Which objective lens is the longest, and which one comes closest to the slide?

Ans. The 100× oil-immersion objective. It is the longest and comes closest to the slide (shortest working distance).

Q10. Why is a drop of immersion (cedarwood) oil placed on the slide when using the 100× objective?

Ans. The oil has almost the same refractive index as glass, so light does not bend away between the slide and the lens. The image becomes brighter and sharper.

Q11. Your eyepiece is 10× and you are using the 40× objective. What is the total magnification?

Ans. Total magnification = $10 \times 40 = 400\times$.

Coarse Adjustment Knob

Q12. What is the function of the coarse adjustment knob?

Ans. It moves the body tube (or stage) up and down quickly to bring the object roughly into focus.

Q13. Why must the coarse knob never be used when the high power objective is in place?

Ans. The high power objective is very close to the slide. A big movement can crush the slide and damage the lens.

Fine Adjustment Knob

Q14. When do we use the fine adjustment knob?

Ans. For sharp, final focusing, especially under high power.

Q15. How can you tell the fine knob from the coarse knob just by looking at them?

Ans. The coarse knob is larger; the fine knob is smaller.

Arm

Q16. What is the correct way to carry a microscope, and which part do you hold?

Ans. Hold the arm with one hand and support the base with the other hand, keeping the microscope upright.

Q17. Name any two parts that are attached to the arm.

Ans. Body tube, stage, and the coarse and fine adjustment knobs.

Stage, Stage Clips and Stage Aperture

Q18. What is the stage of a microscope?

Ans. The flat platform on which the slide is placed for observation.

Q19. What is a mechanical stage, and how is it better than a simple stage?

Ans. A stage fitted with knobs that move the slide forward, backward and sideways. It moves the slide smoothly and exactly without touching it by hand.

Q20. Why are stage clips needed on the stage?

Ans. To hold the slide firmly so that it does not move while we observe.

Q21. What is the stage aperture? What would happen if it was not there?

Ans. It is the hole in the centre of the stage. Without it, light from below could not reach the specimen.

Condenser

Q22. Where is the condenser located and what does it do?

Ans. It lies just below the stage. It collects light from the mirror and focuses it onto the specimen.

Q23. Why is the image dull and unclear under high power if the condenser is not adjusted properly?

Ans. Because enough light is not focused on the small area being viewed, so the image looks dim and blurred.

Iris Diaphragm

Q24. How does the iris diaphragm control the light reaching the specimen?

Ans. Its lever opens or closes the opening, letting more or less light pass to the condenser.

Q25. Why should the light be reduced when you look at an unstained, transparent specimen like cheek cells?

Ans. Too much light washes out transparent cells. Less light increases contrast, so the cells become visible.

Mirror

Q26. The mirror has two surfaces. Name them and tell when each one is used.

Ans. Plane surface: used when light is bright (or a condenser is present). **Concave surface:** used when light is dim, because it converges the light.

Q27. What is used instead of a mirror in modern microscopes?

Ans. A built-in electric lamp (illuminator).

Inclination Joint

Q28. What is the use of the inclination joint?

Ans. It allows the upper part of the microscope to be tilted for comfortable viewing.

Q29. Why should we avoid tilting the microscope when a wet mount is on the stage?

Ans. The water may run off the slide onto the stage and the specimen may slide away.

Pillar and Base

Q30. Which two parts are joined by the pillar?

Ans. The base and the arm (through the inclination joint).

Q31. Why is the base of a microscope made heavy and U-shaped?

Ans. To keep the centre of gravity low, so the microscope stays stable and does not fall.

General

Q32. Define resolution. What is the resolution of a light microscope?

Ans. Resolution is the ability of a microscope to show two very close points as two separate points. The resolution of a light microscope is about **250 nm (0.25 μm)**.

Q33. Differentiate between magnification and resolution.

Ans. Magnification tells how many times larger the image looks than the object. Resolution tells how much fine detail can be seen, i.e. how close two points can be and still look separate.

Q34. Divide the parts of a microscope into mechanical, optical and illuminating parts.

Ans. Mechanical: base, pillar, inclination joint, arm, draw tube, body tube, nosepiece, knobs, stage, clips. **Optical:** eyepiece, objectives. **Illuminating:** mirror (or lamp), condenser, iris diaphragm.

Q35. Why is the image seen through a compound microscope upside down and reversed?

Ans. The objective forms a real, inverted image. The eyepiece magnifies it without turning it back, so the final image stays inverted and laterally reversed.

Q36. Why do we always start focusing with the low power objective?

Ans. Low power has a wider field of view and more working distance, so the object is easy to find and the slide is less likely to be damaged.

Q37. Why should lenses be cleaned with lens paper and not with an ordinary cloth?

Ans. Lens paper is soft and lint-free; a cloth may scratch the lens or leave fibres on it.

PBA-type Questions

Q38. In a labelled figure of a light microscope, how will you recognise the objective lens and the source of illumination?

Ans. The objective lenses are the short tubes attached to the revolving nosepiece just above the stage; the source of illumination is the mirror (or lamp) at the bottom, below the condenser.

Q39. Why is the light microscope limited to about 1500× useful magnification?

Ans. Its resolution is limited by the wavelength of visible light (about 250 nm); magnifying further only makes the image larger and blurred, without new detail.

Q40. State two differences between the light microscope and the electron microscope.

Ans. Light microscope uses light and glass lenses and can view living specimens; the electron microscope uses electron beams and electromagnetic lenses, has far higher resolution, and views only dead specimens in a vacuum.

PRACTICAL
10

Section B • Minor Practical

To Find and Draw Particular Tissues in Plant Specimens: T.S. of Monocot & Dicot Root, Monocot & Dicot Stem and Bifacial Leaf**Related Theory from Textbook****Biology Grade 11 > Chapter 9: Diversity in Plant Functions**

- 9.2.1 Role of palisade and spongy mesophyll in gaseous exchange; 9.2.2 stomata
- 9.3.3 Structure and function of xylem and phloem
- 9.5.2 Mechanical tissues; 9.5.3 Arrangement of vascular bundles
- 9.6.1 Meristematic tissues; 9.6.3 Lateral meristems in secondary growth

Biology Grade 11 > Chapter 8: Kingdom Plantae

- 8.5.2 Angiosperms; 8.5.3 Classification of angiosperms: monocots and dicots

Plant organs are made of **tissues**. **Meristematic tissues** divide actively (apical meristems for primary growth, lateral meristems — vascular cambium and cork cambium — for secondary growth). **Permanent tissues** are **simple** (parenchyma, collenchyma, sclerenchyma) or **complex** (xylem and phloem). Every root, stem and leaf has three tissue systems: **dermal** (epidermis), **ground** (cortex, endodermis, pericycle, pith, mesophyll) and **vascular** (xylem and phloem). **Xylem** (tracheids, vessels, fibres, xylem parenchyma) conducts water and minerals and gives support; **phloem** (sieve tubes, companion cells, phloem parenchyma, fibres) translocates food.

Radial bundle — xylem and phloem on different radii, alternating (roots).

Conjoint bundle — xylem and phloem together on the same radius (stems, leaves).

Exarch — protoxylem towards the outside, metaxylem towards the centre (roots).

Endarch — protoxylem towards the centre (stems).

Open bundle — cambium between xylem and phloem (dicot stem).

Closed bundle — no cambium (monocot stem, leaf veins).

• Object

To study permanent slides (or freshly cut sections) of (a) monocot root, (b) dicot root, (c) monocot stem, (d) dicot stem and (e) bifacial leaf; to identify their tissues and draw labelled diagrams.

• Material and Apparatus

Permanent slides, or fresh young root and stem of maize (monocot), root of gram/sunflower and stem of sunflower (dicot), leaf of sunflower/mango; razor, potato or carrot piece, watch glass, brush, safranin, glycerine, slides, cover slips, compound microscope.

● Procedure (for fresh sections)

1. Hold the material (between potato pieces if thin). Keep material and razor wet and cut many thin transverse sections with quick, even strokes.
2. Transfer sections to water in a watch glass with a brush; select the thinnest complete section.
3. Stain with safranin for 2–3 minutes (lignified walls of xylem and sclerenchyma turn red); wash off extra stain.
4. Mount in a drop of glycerine; lower a cover slip gently at an angle to avoid air bubbles.
5. Observe under low power, then high power. Draw and label; note identification features.

• (a, b) T.S. of Monocot and Dicot Root

Fig. 10.1: T.S. of dicot root (gram / sunflower)

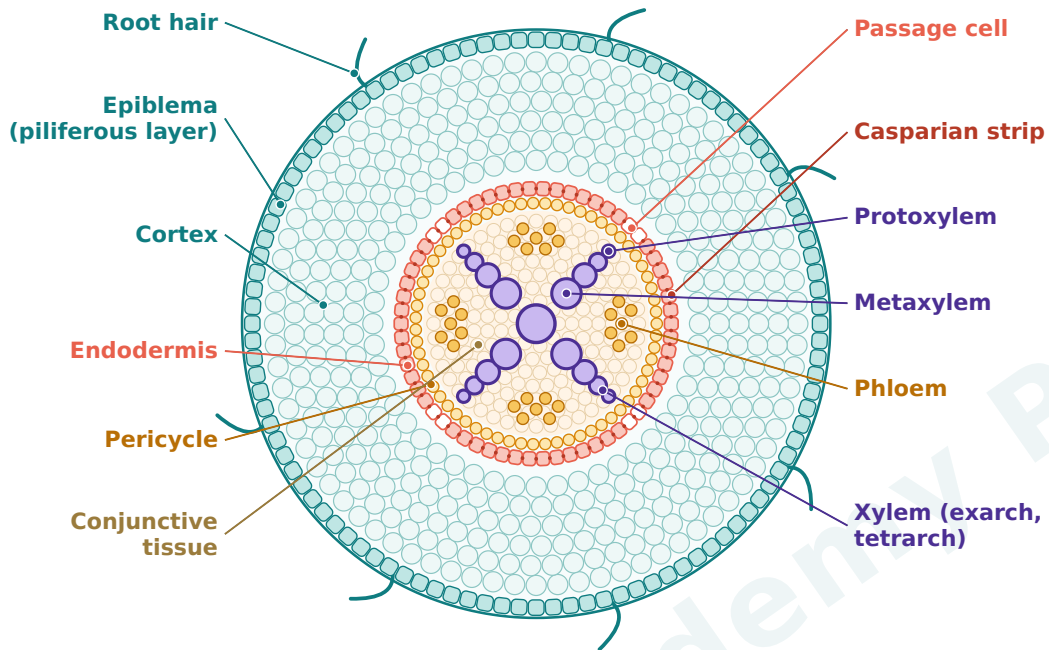
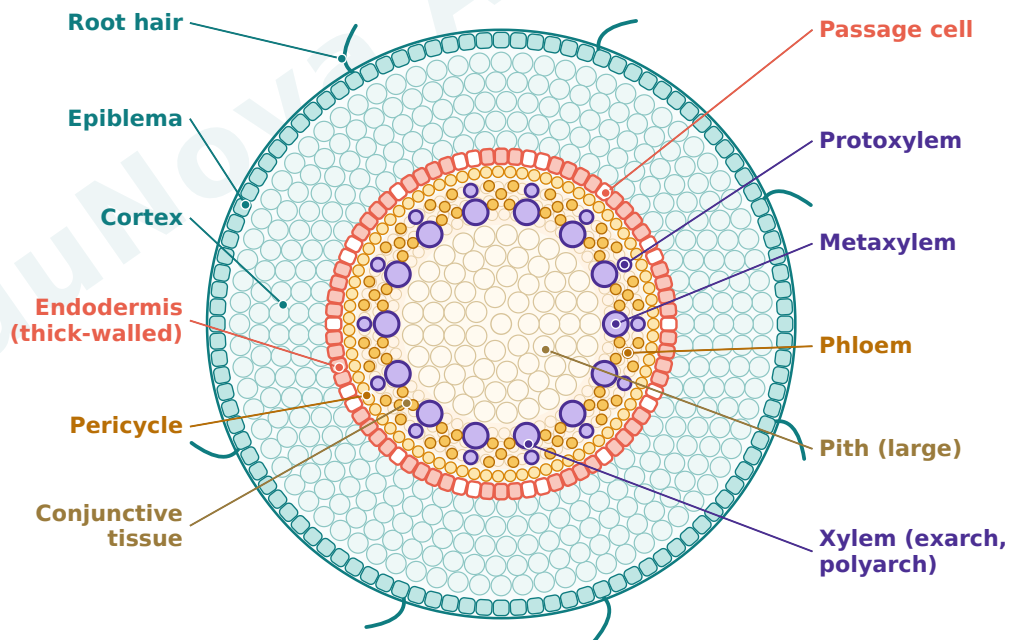


Fig. 10.2: T.S. of monocot root (maize)



Epidermis / Epiblema
 Cortex / Ground tissue
 Collenchyma
 Sclerenchyma
 Endodermis
 Pericycle
 Xylem
 Phloem
 Cambium
 Pith

Differences between Dicot Root and Monocot Root

Character	Dicot Root	Monocot Root
Examples	Gram, sunflower, bean	Maize, wheat, onion
Epiblema	Single layer of thin-walled cells, no cuticle; bears unicellular root hairs	Same as dicot root
Cortex	Wide, made of rounded parenchyma cells with intercellular spaces	Wide, parenchymatous; usually wider than in dicot root
Endodermis	Barrel-shaped cells with Casparian strips; passage cells opposite protoxylem	Cells with thick walls (U-shaped thickening); thin-walled passage cells opposite protoxylem
Pericycle	Single layer; forms lateral roots, and later part of vascular cambium and cork cambium	Single layer; forms lateral roots only
Vascular bundles	Radial (xylem and phloem on separate radii)	Radial
Number of xylem groups	2 to 6 (diarch to hexarch), usually tetrarch	Many, more than 6 — polyarch
Xylem	Exarch; metaxylem vessels meet at the centre, star-shaped	Exarch; metaxylem vessels do not meet at the centre
Shape of vessels	Angular / polygonal	Rounded or oval
Pith	Absent or very small	Large and well developed
Conjunctive tissue	Parenchymatous; later forms part of cambium	Parenchymatous or sclerenchymatous
Secondary growth	Present	Absent

• (c, d) T.S. of Monocot and Dicot Stem

Fig. 10.3: T.S. of dicot stem (sunflower)

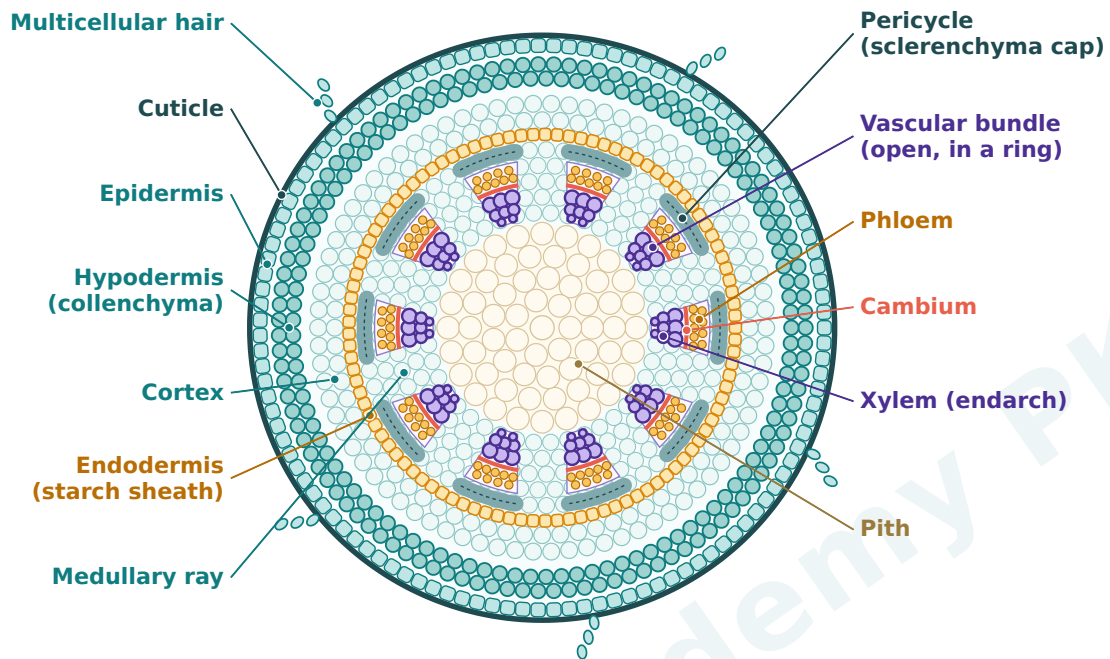
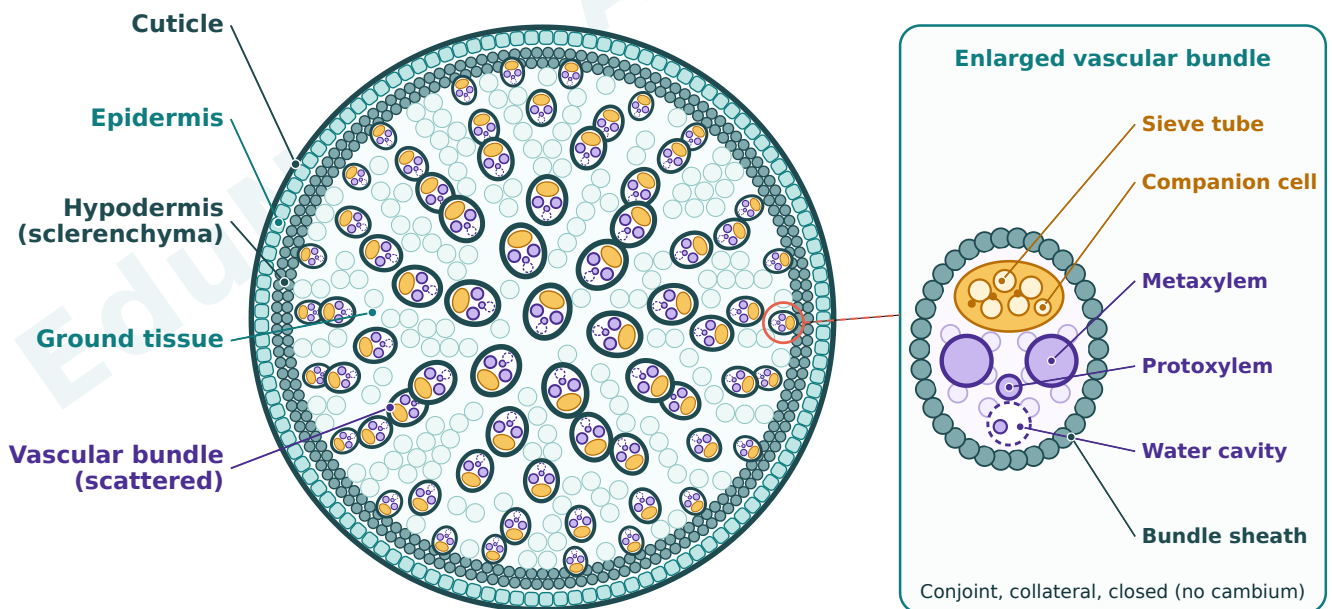


Fig. 10.4: T.S. of monocot stem (maize) with enlarged vascular bundle



Epidermis / Epiblema
 Cortex / Ground tissue
 Collenchyma
 Sclerenchyma
 Endodermis
 Pericycle
 Xylem
 Phloem
 Cambium
 Pith

Differences between Dicot Stem and Monocot Stem

Character	Dicot Stem	Monocot Stem
Examples	Sunflower (<i>Helianthus</i>), gram	Maize (<i>Zea mays</i>), wheat, sugarcane
Epidermis	Single layer with cuticle; bears multicellular hairs	Single layer with thick cuticle; hairs usually absent
Hypodermis	Collenchymatous	Sclerenchymatous
Ground tissue	Differentiated into cortex, endodermis, pericycle, medullary rays and pith	Not differentiated; one continuous ground tissue
Endodermis	Present, wavy; called starch sheath	Absent
Pericycle	Present; sclerenchyma patches (bundle caps) above bundles	Absent
Arrangement of bundles	In a single ring	Scattered in ground tissue
Number and size	Fewer, all of about the same size	Many; small and crowded near the periphery, large and fewer in the centre
Type of bundles	Conjoint, collateral and open (cambium present)	Conjoint, collateral and closed (no cambium)
Bundle sheath	Absent	Sclerenchymatous sheath around each bundle
Xylem	Endarch; vessels in radial rows	Endarch; Y- or V-shaped, with two large metaxylem vessels
Water (lysigenous) cavity	Absent	Present, formed by breakdown of protoxylem
Phloem parenchyma	Present	Absent
Medullary rays	Present between bundles	Absent
Pith	Large and well developed	Absent (not distinct)
Secondary growth	Present	Absent

• (e) T.S. of Bifacial (Dorsiventral) Leaf

Most dicot leaves are held horizontally; the upper surface receives direct light while the lower is shaded. The two surfaces therefore differ in structure — such a leaf is **bifacial** or **dorsiventral**.

Fig. 10.5: T.S. of bifacial leaf through midrib (low power)

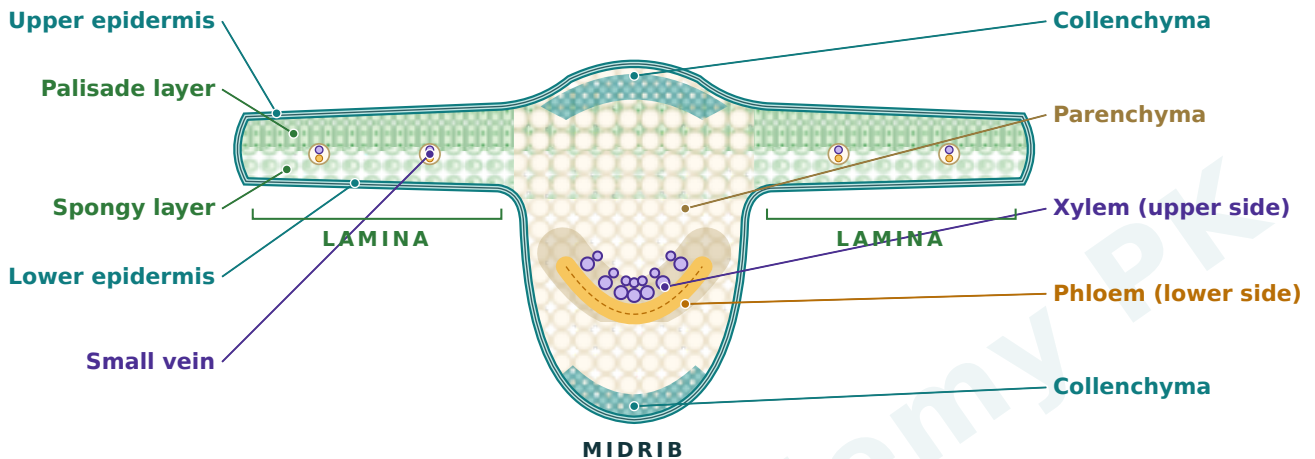
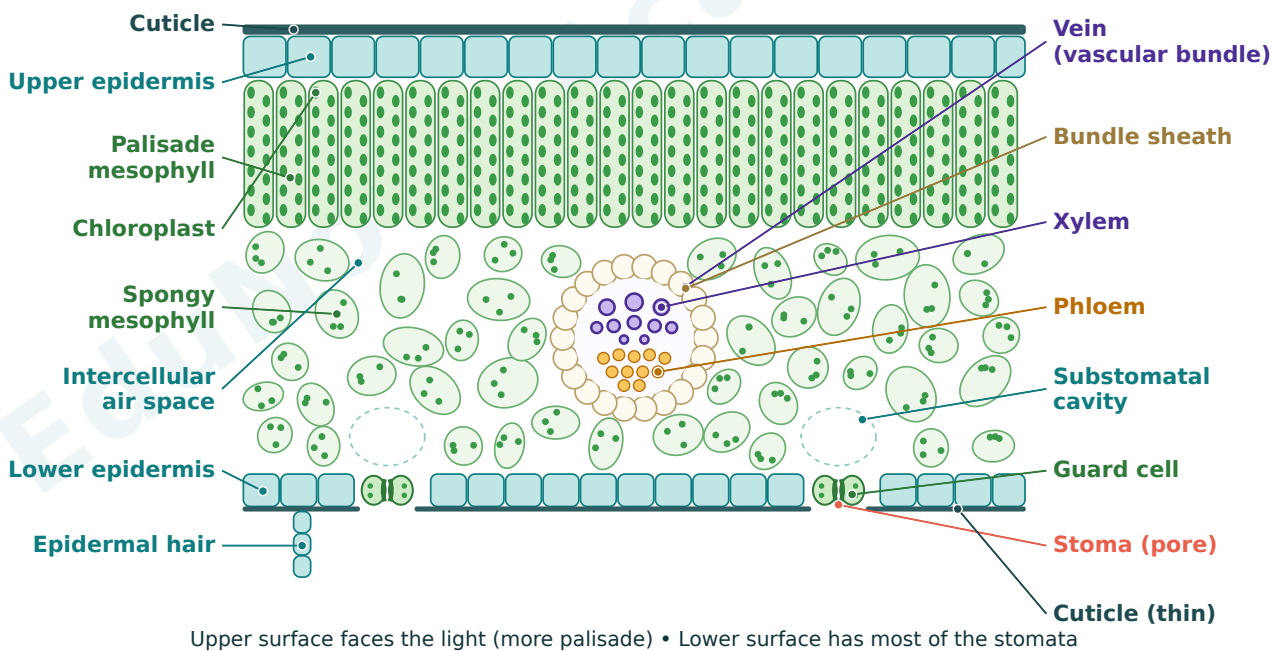


Fig. 10.6: T.S. of lamina — detailed structure (high power)



- Cuticle ■ Epidermis ■ Palisade ■ Spongy ■ Chloroplast ■ Guard cell ■ Bundle sheath / Parenchyma
- Collenchyma ■ Xylem ■ Phloem

Parts of the Leaf and their Functions

Part	Structure and Function
A. EPIDERMAL TISSUE	
Cuticle	Waxy layer of cutin covering the epidermis; thicker on the upper surface. Reduces water loss and protects the leaf.
Upper epidermis	Single layer of tightly packed, barrel-shaped cells without chloroplasts. Stomata absent or very few. Protects the leaf and lets light pass through to the mesophyll.
Lower epidermis	Single layer of cells with a thin cuticle and many stomata . May bear hairs.
Stomata and guard cells	Each stoma is a pore surrounded by two kidney-shaped guard cells, which contain chloroplasts. They open and close the pore to control gas exchange and transpiration.
B. MESOPHYLL (GROUND TISSUE)	
Palisade mesophyll	One or two layers of long, column-shaped cells, packed closely at right angles to the upper epidermis. Rich in chloroplasts — the main site of photosynthesis .
Spongy mesophyll	Irregular, loosely arranged cells with large air spaces between them and fewer chloroplasts. Allows gases to spread through the leaf; also carries out some photosynthesis.
Substomatal cavity	A large air space just above each stoma, joined to the air spaces of the spongy tissue. Gases are exchanged here with the outside air.
C. VASCULAR TISSUE (VEINS)	
Vascular bundle (vein)	Conjoint, collateral and closed. Xylem faces the upper surface and phloem faces the lower surface . Xylem brings water and minerals; phloem carries away the food made in the leaf.
Bundle sheath	A layer of parenchyma cells around each vein. Supports the vein and helps pass materials between the vein and the mesophyll.
Midrib	The largest vein, projecting on the lower side. Has collenchyma under both epidermises for support and parenchyma as ground tissue around the vascular bundle.

Bifacial Leaf vs Isobilateral Leaf

Character	Bifacial (Dicot) Leaf	Isobilateral (Monocot) Leaf
Examples	Sunflower, mango, pea (dicots)	Maize, wheat, grasses (monocots)
Position on plant	Usually horizontal	Usually vertical (erect)
Colour of surfaces	Upper surface darker green than lower	Both surfaces equally green
Mesophyll	Divided into palisade (upper) and spongy (lower)	Not divided; cells are similar throughout
Stomata	More on the lower surface	About equal on both surfaces
Shape of guard cells	Kidney (bean) shaped	Dumb-bell shaped (in grasses)

Character	Bifacial (Dicot) Leaf	Isobilateral (Monocot) Leaf
Bulliform (motor) cells	Absent	Present in upper epidermis of grasses
Venation	Reticulate (net-like)	Parallel

● Precautions

- Sections should be thin, uniform and complete (leaf sections must include the midrib).
- Keep the razor wet and handle it carefully.
- Do not over-stain; avoid air bubbles; wipe off extra glycerine.
- Always focus under low power before high power.

● Answers to Short Questions

Key Terms

Q1. What is the difference between radial and conjoint vascular bundles?

Ans. In a **radial** bundle, xylem and phloem lie on different radii and alternate with each other (roots). In a **conjoint** bundle, xylem and phloem lie together on the same radius (stems).

Q2. What do the terms exarch and endarch mean? Where is each found?

Ans. Exarch: protoxylem lies towards the outside and metaxylem towards the centre (roots).
Endarch: protoxylem lies towards the centre and metaxylem towards the outside (stems).

Q3. What are open and closed vascular bundles?

Ans. An **open** bundle has cambium between xylem and phloem, so it can form secondary tissues (dicot stem). A **closed** bundle has no cambium (monocot stem).

Q4. What is a collateral vascular bundle?

Ans. A bundle in which phloem lies on the outer side and xylem on the inner side, on the same radius.

Root

Q5. What is epiblema? Why is it also called the piliferous layer?

Ans. Epiblema is the outermost layer of the root. It bears root hairs, so it is called the piliferous (hair-bearing) layer.

Q6. Why is there no cuticle on the epiblema of a root?

Ans. Because the main job of the epiblema is to absorb water and minerals from the soil; a cuticle would block absorption.

Q7. What is the function of the cortex in a root?

Ans. It stores food (starch) and passes water from the root hairs inwards to the vascular tissue.

Q8. What are Casparian strips? What is their role?

Ans. Bands of suberin and lignin on the radial and transverse walls of endodermal cells. They stop water from passing between the cells, so water and minerals must pass through the living cells, which control what enters the xylem.

Q9. What are passage cells, and where are they found?

Ans. Thin-walled endodermal cells without thickening, present opposite the protoxylem. They let water pass quickly from the cortex to the xylem.

Q10. Why is the pericycle important in roots?

Ans. Lateral roots arise from it. In dicot roots it also forms part of the vascular cambium and the cork cambium during secondary growth.

Q11. How can you tell a dicot root from a monocot root by counting xylem groups?

Ans. A dicot root has 2–6 xylem groups (usually 4, tetrarch). A monocot root has many, more than 6 (polyarch).

Q12. Why is pith absent or very small in a dicot root?

Ans. Because the metaxylem vessels grow inwards and meet at the centre, leaving little or no room for pith.

Q13. What is conjunctive tissue?

Ans. The parenchyma (or sclerenchyma) cells present between the xylem and phloem groups in a root.

Q14. Why is there no secondary growth in a monocot root?

Ans. Because there is no cambium; the conjunctive tissue does not become meristematic.

Stem**Q15. What is the hypodermis of a sunflower stem made of, and why is it useful?**

Ans. Collenchyma. It gives mechanical strength and also flexibility to the young stem.

Q16. What is the hypodermis of a maize stem made of?

Ans. Sclerenchyma, which gives strong mechanical support to the stem.

Q17. Why is the endodermis of a dicot stem called the starch sheath?

Ans. Because its cells are rich in starch grains.

Q18. What is a bundle cap (hard bast)?

Ans. A patch of sclerenchyma of the pericycle lying on the outer side of each vascular bundle in a dicot stem. It protects and supports the phloem.

Q19. What are medullary rays? Give their function.

Ans. Strips of parenchyma between the vascular bundles of a dicot stem, joining the pith with the cortex. They carry food and water sideways (radially) and store food.

Q20. What is the importance of cambium in a sunflower stem?

Ans. Cambium divides to form secondary xylem and secondary phloem, so the stem grows in thickness (secondary growth).

Q21. Describe the arrangement of vascular bundles in a maize stem.

Ans. They are scattered throughout the ground tissue. Near the periphery they are small and closely packed; towards the centre they are larger and fewer.

Q22. What is a bundle sheath?

Ans. A layer of sclerenchyma surrounding each vascular bundle in a monocot stem, giving support and protection.

Q23. What is the water cavity (lysigenous cavity)? How is it formed?

Ans. A space in the xylem of a maize bundle, below the protoxylem. It is formed when the first protoxylem elements break down and it stores water.

Q24. Why does a vascular bundle of maize look like a "skull" or "face"?

Ans. The two large metaxylem vessels look like eyes, the protoxylem like a nose and the water cavity like a mouth, with phloem above like a cap.

Q25. Why is the ground tissue of a monocot stem called undifferentiated?

Ans. Because it is not divided into cortex, endodermis, pericycle and pith; it is one continuous tissue of parenchyma.

Q26. What is the function of pith in a dicot stem?

Ans. It stores food and water.

Identification**Q27. Give two quick features to identify a T.S. of a monocot stem under the microscope.**

Ans. Vascular bundles are scattered, and each bundle has a sclerenchymatous sheath and a water cavity (skull-like look).

Q28. Give two features to tell a root from a stem in a T.S.

Ans. Roots have radial bundles with exarch xylem and a hairy epiblema without cuticle. Stems have conjoint bundles with endarch xylem and an epidermis with cuticle.

Q29. Which has more xylem groups, maize root or gram root?

Ans. Maize root (polyarch); gram root usually has only four (tetrarch).

Leaf: Key Terms**Q30. Why is the leaf of sunflower or mango called bifacial or dorsiventral?**

Ans. Because its upper and lower surfaces are different in structure. The upper side has palisade tissue and few stomata, while the lower side has spongy tissue and many stomata.

Q31. What is the main difference between a bifacial and an isobilateral leaf?

Ans. In a bifacial leaf the mesophyll is divided into palisade and spongy tissue and stomata are mostly on the lower surface. In an isobilateral leaf the mesophyll is not divided and stomata are present on both surfaces about equally.

Q32. What is mesophyll? Into which parts is it divided in a bifacial leaf?

Ans. Mesophyll is the ground tissue of the leaf lying between the upper and lower epidermis. In a bifacial leaf it is divided into palisade mesophyll and spongy mesophyll.

Epidermis and Cuticle**Q33. What is cuticle? Why is it thicker on the upper surface?**

Ans. Cuticle is a waxy layer of cutin on the epidermis. It is thicker on the upper surface because this side faces the sun directly, where more water could be lost.

Q34. Why do epidermal cells (except guard cells) not have chloroplasts?

Ans. So that they stay transparent and let sunlight pass through to the mesophyll cells below.

Q35. Why are the cells of the epidermis closely packed without air spaces?

Ans. To protect the inner tissues and to reduce loss of water.

Stomata

Q36. Why are more stomata found on the lower surface of a bifacial leaf?

Ans. The lower surface gets less direct sunlight and heat, so less water is lost through the stomata by transpiration.

Q37. How are guard cells different from other epidermal cells?

Ans. Guard cells are kidney-shaped, have chloroplasts and have a thicker inner wall facing the pore. They can change shape to open and close the stoma.

Q38. What is a substomatal cavity?

Ans. A large air space just above each stoma in the spongy mesophyll, through which gases pass in and out.

Q39. Give two functions of stomata.

Ans. (i) Exchange of gases — CO_2 in and O_2 out during photosynthesis. (ii) Transpiration — loss of water vapour.

Palisade Mesophyll

Q40. Why are palisade cells long and arranged at right angles to the leaf surface?

Ans. So that many cells can be packed side by side under the upper surface, and light can travel down each cell past many chloroplasts. This gives maximum photosynthesis.

Q41. Why is the palisade layer found just below the upper epidermis?

Ans. Because the upper surface receives the most sunlight.

Q42. Why is the upper surface of a bifacial leaf darker green?

Ans. Because the closely packed palisade cells, full of chloroplasts, lie just below it.

Q43. Which layer of the leaf has the most chloroplasts?

Ans. The palisade mesophyll.

Spongy Mesophyll

Q44. Why are spongy cells loosely arranged with large air spaces?

Ans. The air spaces let CO_2 , O_2 and water vapour spread quickly through the leaf and reach every cell.

Q45. Is photosynthesis carried out in spongy mesophyll too?

Ans. Yes, but less than in palisade, because spongy cells have fewer chloroplasts.

Vascular Tissue

Q46. In a leaf vein, which surface does the xylem face and which does the phloem face?

Ans. Xylem faces the upper surface and phloem faces the lower surface.

Q47. What type of vascular bundle is present in a leaf?

Ans. Conjoint, collateral and closed (no cambium).

Q48. What is the function of the bundle sheath?

Ans. It surrounds the vein, supports it, and helps pass water and food between the vein and the mesophyll.

Q49. Why does the midrib bulge out, and why does it contain collenchyma?

Ans. It contains the largest vascular bundle. Collenchyma under the epidermis gives strength and flexibility to support the lamina.

Q50. Apart from conduction, what is another role of the veins?

Ans. They form a framework (skeleton) that supports the thin lamina and keeps it spread out.

Leaf: Identification**Q51. Give two features by which you can identify a T.S. of a bifacial leaf.**

Ans. (i) Mesophyll divided into palisade (upper) and spongy (lower). (ii) More stomata on the lower epidermis than on the upper.

Q52. In your section, how will you decide which side is upper and which is lower?

Ans. The upper side has the palisade layer and a thicker cuticle. The lower side has spongy tissue and many stomata, and the midrib bulges more on the lower side.

Section Cutting**Q53. Why should sections be cut very thin?**

Ans. So that light can pass through them and the cells can be seen clearly without overlapping.

Q54. Why is safranin used to stain sections?

Ans. Safranin stains lignified walls red, so xylem and sclerenchyma become easy to see.

Q55. Why do we hold the leaf in a piece of potato or carrot while cutting?

Ans. Because the leaf is thin and soft; the potato holds it firm so that thin, even sections can be cut.

Q56. Which stain is used, and what colour does xylem take?

Ans. Safranin; the lignified xylem walls become red.

PRACTICAL

11

Section B • Minor Practical

To Find and Draw Particular Tissues in Animal Specimens Preserved in Permanent Slides

Related Theory from Textbook

Biology Grade 11 > Chapter 11: Reproduction

- 11.1.1 Male reproductive system: testes, seminiferous tubules, spermatogenesis, Sertoli and Leydig cells (Fig. 11.5)
- 11.1.3 Female reproductive system: ovary, ovarian follicles, oogenesis
- 11.2 Female reproductive cycle and its hormonal regulation

Biology Grade 12 > Chapters 2, 1 and 6

- Ch 2: 2.7 Blood vessels — arteries, veins and capillaries
- Ch 1: 1.11 Structure and function of pancreas
- Ch 6: 6.2.4 Pancreas as an endocrine gland (islets of Langerhans)

A **tissue** is a group of similar cells performing a common function. Permanent slides of animal organs show how tissues are arranged to perform a function. Four important examples are: the **testis** (spermatogenesis), the **ovary** (oogenesis and follicle development), **blood vessels** (circulation) and the **pancreas** (a mixed gland with exocrine acini and endocrine islets).

• Object

To observe permanent slides of (a) T.S. of seminiferous tubules of human testis, (b) T.S. of Graafian follicle in human ovary, (c) T.S. of artery, vein and capillary, (d) T.S. of pancreas showing islets of Langerhans; and to draw labelled diagrams.

• Apparatus

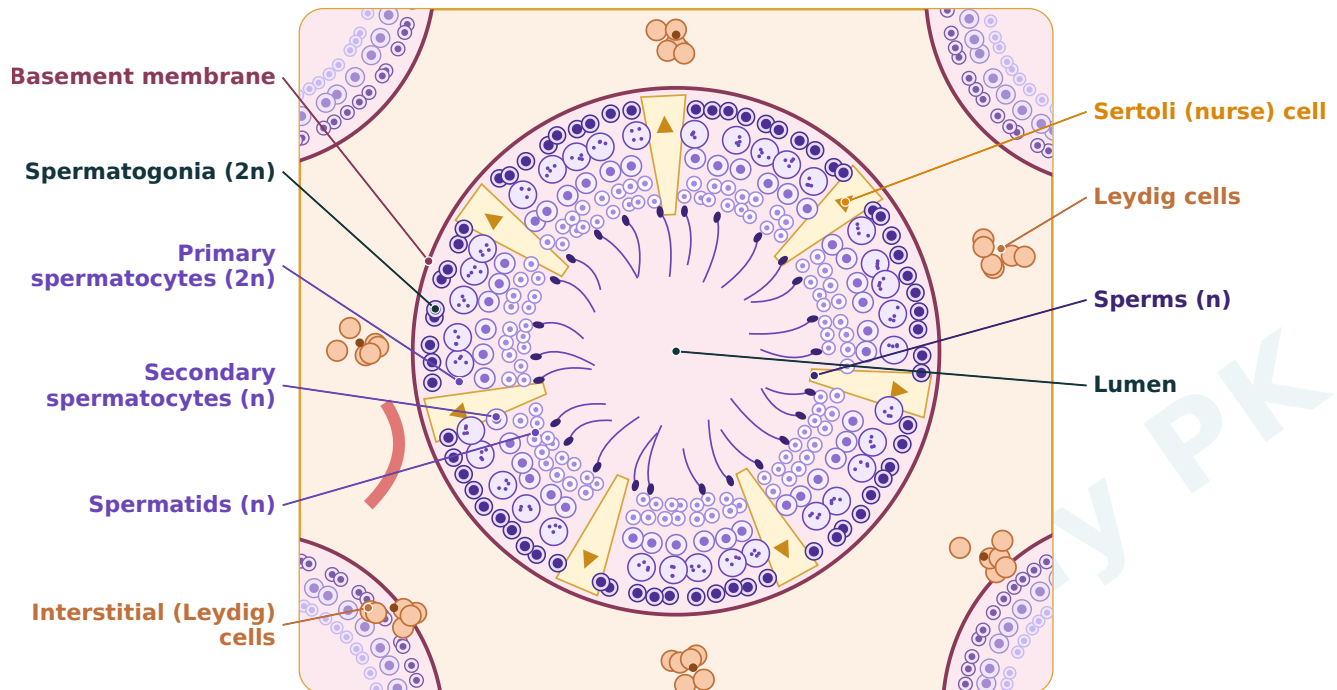
Compound microscope, permanent slides of the above specimens, lens paper, drawing sheet, pencil.

• General Procedure

1. Place the slide on the stage and focus first under low power to find the required region.
2. Move the slide so that a clear, typical area is in the centre; change to high power and focus with the fine knob.
3. Identify the tissues using the diagnostic features given below.
4. Draw a neat, large, labelled line diagram with a sharp pencil; write the title and magnification.

• (a) T.S. of Seminiferous Tubules of Human Testis

Fig. 11.1: T.S. of seminiferous tubule (human testis)

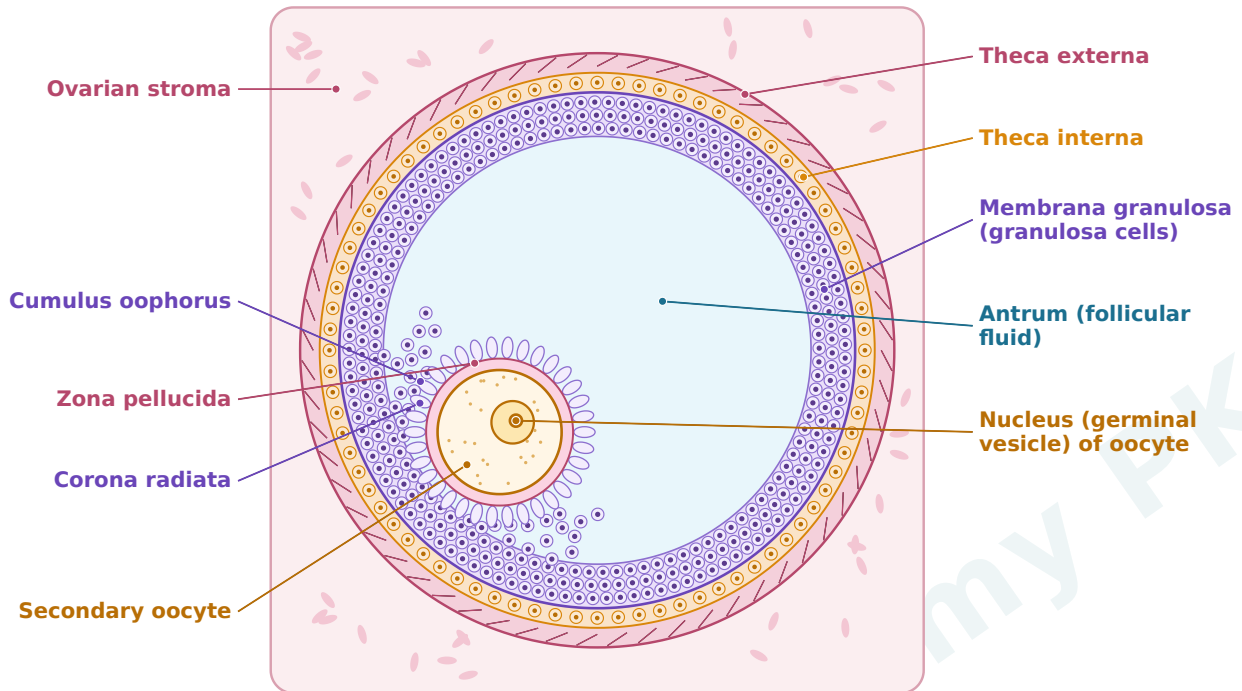


Identification Features

- Many rounded tubules cut across, each bounded by a **basement membrane**.
- Germinal epithelium with cells in stages of **spermatogenesis** from outside inwards: spermatogonia (2n) → primary spermatocytes (2n, largest) → secondary spermatocytes (n) → spermatids (n) → sperms with tails in the lumen.
- Tall **Sertoli cells** extend from basement membrane to lumen; they nourish developing sperms (stimulated by FSH) and secrete inhibin.
- **Interstitial (Leydig) cells** lie between tubules and secrete **testosterone** under the influence of LH.

• (b) T.S. of Graafian Follicle in Human Ovary

Fig. 11.2: Mature (Graafian) follicle in the ovary

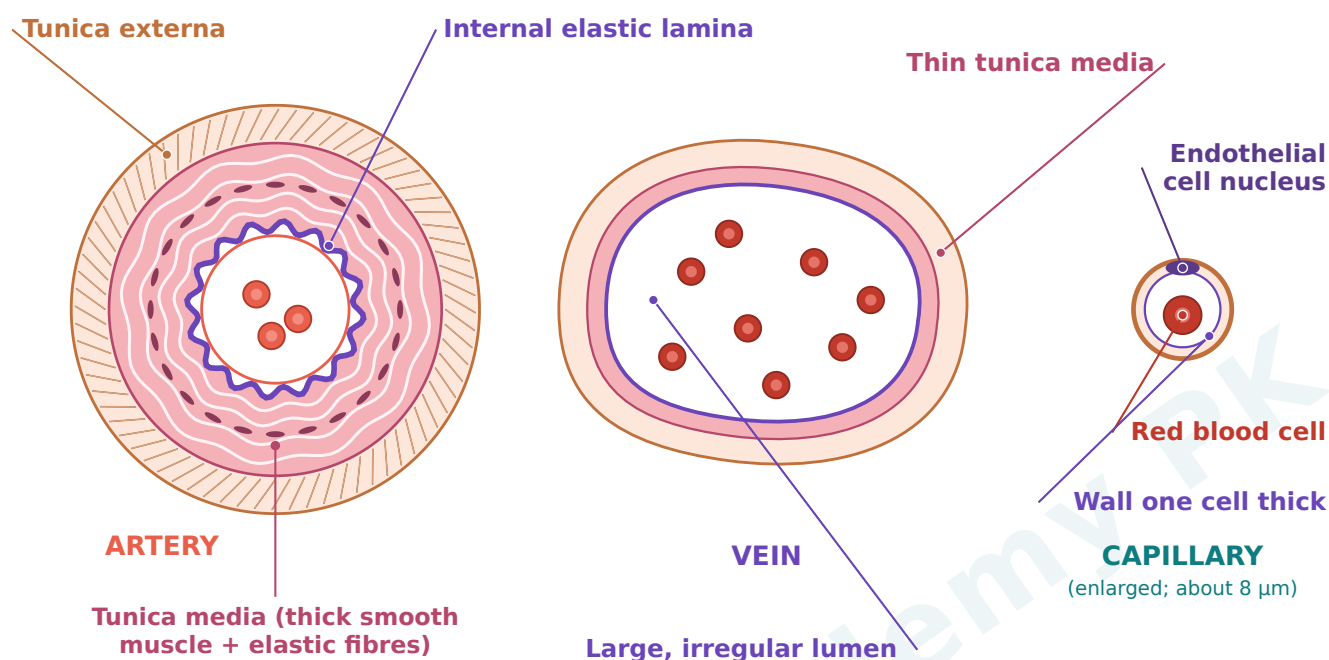


Identification Features

- A large fluid-filled cavity, the **antrum**, containing follicular fluid.
- The **secondary oocyte** lies on a mound of granulosa cells, the **cumulus oophorus**, and is surrounded by the **zona pellucida** and **corona radiata**.
- The follicle wall has **membrana granulosa** inside, and outer **theca interna** (secretes oestrogen) and **theca externa** (fibrous).
- At ovulation (under LH surge) the follicle ruptures and releases the oocyte; the remaining follicle becomes the **corpus luteum**.

• (c) T.S. of Artery, Vein and Capillary

Fig. 11.3: T.S. of artery, vein and capillary (not to the same scale)

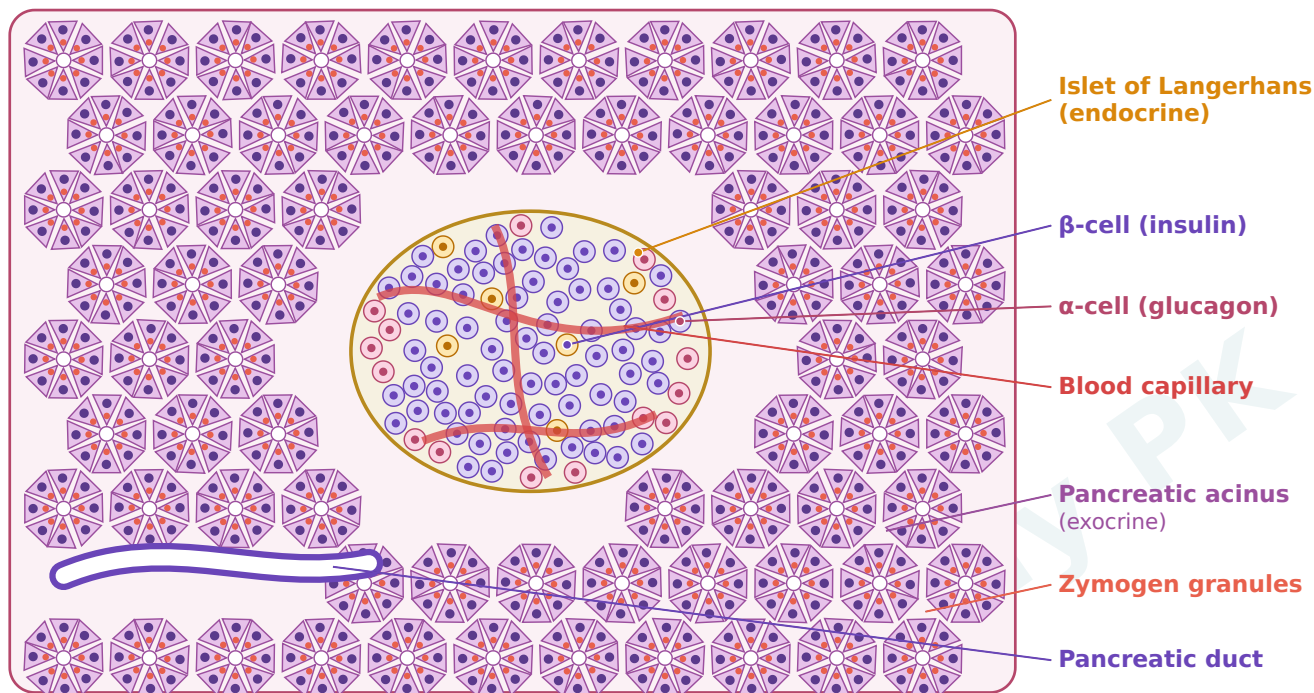


Feature	Artery	Vein
Wall	Thick, muscular and elastic	Thin, less muscle and elastic tissue
Tunica media	Very thick (smooth muscle + elastic fibres)	Thin
Lumen	Small, round	Large, often irregular / flattened
Valves	Absent (except at the base of aorta and pulmonary artery)	Present to prevent backflow
Blood pressure	High; blood flows in spurts	Low; flows smoothly
Blood carried	Away from the heart (oxygenated, except pulmonary artery)	Towards the heart (deoxygenated, except pulmonary vein)

Capillaries are the smallest vessels (about 8–10 μm); their wall is only **one cell thick (endothelium)** with no muscle or elastic layer, allowing exchange of gases, nutrients and wastes between blood and tissue fluid. Red blood cells pass through them in single file.

• (d) T.S. of Pancreas showing Islets of Langerhans

Fig. 11.4: T.S. of pancreas — acini and an islet of Langerhans



Identification Features

- Most of the pancreas consists of **acini** — rounded clusters of pyramidal cells around a small lumen, with dark **zymogen granules** at their tips. They form the **exocrine** part and secrete pancreatic juice (trypsinogen, amylase, lipase) into ducts.
- Scattered among the acini are pale, rounded patches — the **islets of Langerhans** — the **endocrine** part, richly supplied with capillaries and with no ducts.
- α -cells secrete **glucagon** (raises blood glucose); β -cells (most numerous) secrete **insulin** (lowers blood glucose); δ -cells secrete somatostatin.

• Precautions

- Always locate the region under low power first.
- Do not let the objective touch the slide; use only the fine knob under high power.
- Draw only what you see; the drawing should be large, clear, in pencil and fully labelled.
- Handle permanent slides carefully and return them to the slide box.

● Answers to Short Questions

Testis

Q1. What are seminiferous tubules?

Ans. Long, highly coiled tubules inside the testis where sperms are produced (spermatogenesis).

Q2. Write the sequence of cells in the germinal epithelium from outside to inside.

Ans. Spermatogonia → primary spermatocytes → secondary spermatocytes → spermatids → spermatozoa (sperms) in the lumen.

Q3. Which cells are haploid in the seminiferous tubule?

Ans. Secondary spermatocytes, spermatids and sperms (formed after meiosis I and II).

Q4. What is the function of Sertoli cells?

Ans. They nourish and support developing sperms, respond to FSH and secrete the hormone inhibin.

Q5. Where are Leydig cells found and what do they secrete?

Ans. In the interstitial tissue between seminiferous tubules; they secrete testosterone when stimulated by LH.

Q6. Why are the testes located in the scrotum?

Ans. Spermatogenesis needs a temperature about 2-3 °C lower than body temperature.

Ovary

Q7. What is a Graafian follicle?

Ans. A mature ovarian follicle with a large fluid-filled antrum, containing a secondary oocyte ready for ovulation.

Q8. Name the layers surrounding the oocyte in a Graafian follicle.

Ans. Zona pellucida, corona radiata, and cumulus oophorus (then membrana granulosa, theca interna and theca externa form the follicle wall).

Q9. What is the antrum?

Ans. The cavity of the follicle filled with follicular fluid.

Q10. Which hormone is secreted by the theca interna and granulosa cells?

Ans. Oestrogen.

Q11. What happens to the Graafian follicle after ovulation?

Ans. It changes into the corpus luteum, which secretes progesterone (and some oestrogen).

Blood Vessels

Q12. Name the three layers of the wall of an artery.

Ans. Tunica intima (endothelium), tunica media (smooth muscle and elastic fibres) and tunica externa (connective tissue).

Q13. Why do arteries have thick, elastic walls?

Ans. To withstand high blood pressure from the heart and to stretch and recoil, keeping blood moving smoothly.

Q14. Why do veins have valves?

Ans. Blood pressure in veins is low; valves prevent backflow and keep blood moving towards the heart.

Q15. How will you identify a vein and an artery in the same slide?

Ans. The artery has a thick muscular wall and small round lumen; the vein has a thin wall and a large, irregular lumen, often with blood cells.

Q16. Why are capillary walls only one cell thick?

Ans. To allow quick exchange of oxygen, carbon dioxide, nutrients and wastes between blood and tissues by diffusion.

Pancreas**Q17. Why is the pancreas called a mixed gland?**

Ans. It is both exocrine (acini secrete pancreatic juice into a duct) and endocrine (islets of Langerhans secrete hormones into blood).

Q18. Name the cells of islets of Langerhans and their hormones.

Ans. α -cells: glucagon; β -cells: insulin; δ -cells: somatostatin.

Q19. How can islets be distinguished from acini in a slide?

Ans. Islets are pale-staining, irregular patches of cells with many capillaries and no duct; acini are darker clusters of pyramidal cells with zymogen granules around a lumen.

Q20. What is the role of insulin?

Ans. It lowers blood glucose by increasing uptake of glucose into cells and its conversion to glycogen in liver and muscles.

Q21. What happens if β -cells fail to produce enough insulin?

Ans. Blood glucose rises and the person suffers from diabetes mellitus.

PRACTICAL

12

Section B • Minor Practical

Preparation of Temporary Slides of Animal Cells using Differential Staining and their Identification under the Light Microscope

Related Theory from Textbook

Biology Grade 11 > Chapter 1: Cells and Sub-Cellular Organelles

- 1.4 Ultrastructure of animal and plant cells; plasma membrane, nucleus, cytoplasm
- 1.3 Microscopy — observing cells under the light microscope

Biology Grade 12 > Chapter 2 / Chapter 9

- Ch 2: Blood — red blood cells, white blood cells and platelets
- Ch 9: 9.2.1 Killing cells of blood (phagocytes: neutrophils, monocytes/macrophages)
- Ch 9: 9.1 Skin and epithelia as first line of defence

Most cells are colourless and transparent, so **stains** are used to make their parts visible. In **differential staining**, a stain (or mixture of stains) colours different parts of cells differently. **Basic dyes** (methylene blue, haematoxylin) stain acidic parts such as the **nucleus (DNA)** blue/purple; **acidic dyes** (eosin) stain basic parts such as cytoplasm pink. **Leishman's** or **Giemsa** stain (a mixture of methylene blue and eosin in methanol) is used for blood smears — nuclei of white blood cells turn purple and red blood cells pink.

Temporary slide — a slide prepared for immediate study, usually in water or glycerine; not preserved permanently.

Squamous epithelium — a single layer of thin, flat, polygonal cells fitting closely like tiles, e.g. lining of mouth, skin of frog, alveoli.

Smear — a thin layer of cells (e.g. blood) spread on a slide.

Mounting — placing the specimen in a drop of liquid (water/glycerine) under a cover slip.

• Object

To prepare and study stained temporary slides of (a) squamous epithelium from the skin of frog / blood cells from a human blood smear, and (b) epithelial cells of the human oral cavity (cheek cells).

• Apparatus and Materials

Clean glass slides, cover slips, sterile toothpicks / spatula, sterile disposable lancet, cotton wool, 70% alcohol (spirit), methylene blue (1%), Leishman's (or Giemsa) stain, buffered distilled water, eosin (optional), dropper, blotting paper, forceps, needle, watch glass, compound microscope, cedarwood oil (for oil immersion), shed skin of frog (or piece from preserved frog).

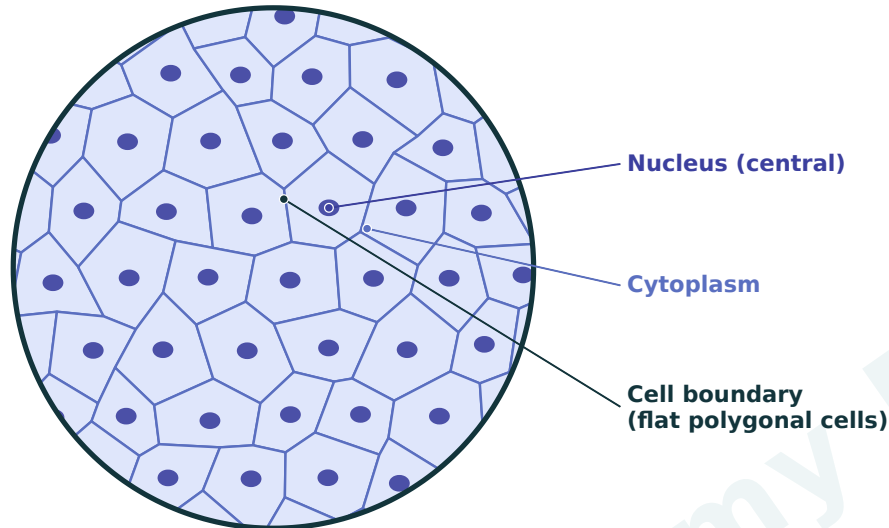
• (a-i) Squamous Epithelium from the Skin of Frog

Procedure

1. Take a small piece of the moulted (shed) skin of a frog in a watch glass of water; or scrape the skin surface gently.
2. Transfer a small, flat piece onto a clean slide and spread it with needles.
3. Add 1-2 drops of methylene blue; leave for 1-2 minutes. Wash off extra stain with water.

4. Put a drop of glycerine, lower a cover slip carefully and remove extra liquid with blotting paper.
5. Observe under low power, then high power.

Fig. 12.1: Squamous epithelium (frog skin), stained with methylene blue



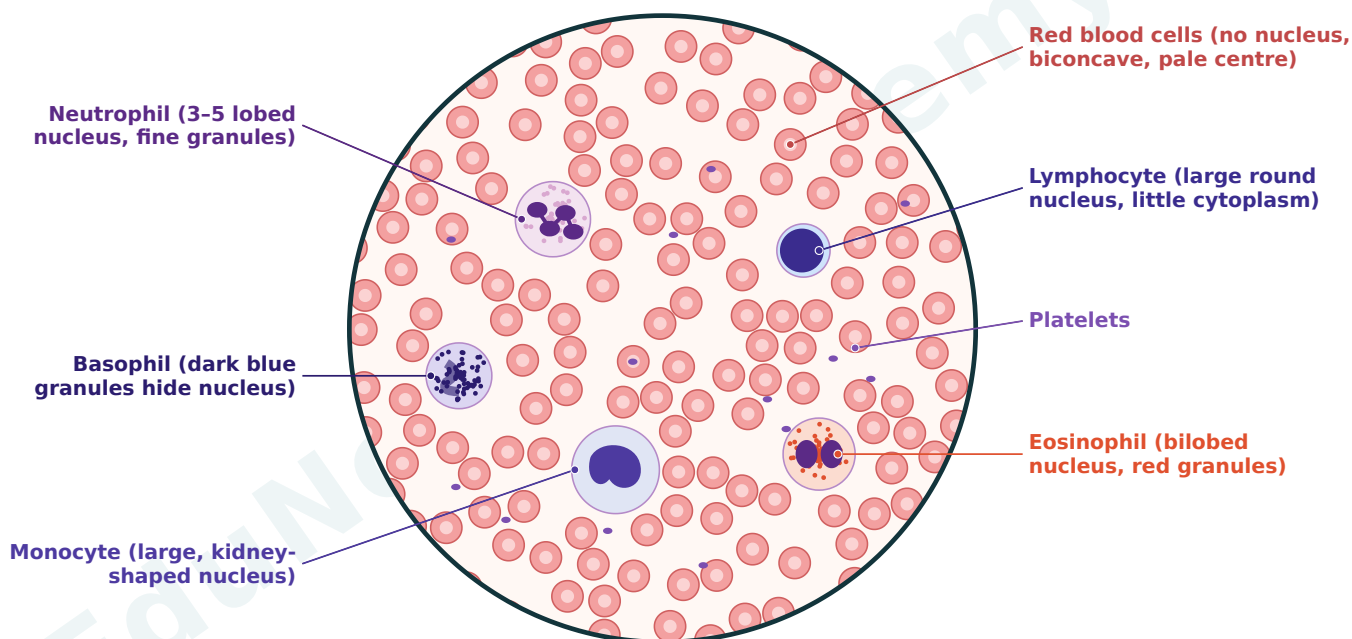
Observation: Thin, flat, many-sided (polygonal) cells fitting closely together like floor tiles with little intercellular space; each has a centrally placed, oval nucleus stained dark blue.

● (a-ii) Blood Cells from Human Blood Smear

Procedure

1. Clean the tip of the middle or ring finger with spirit and let it dry. Prick it with a sterile lancet; wipe away the first drop.
2. Place a small drop of blood near one end of a clean slide.
3. Hold a second slide (spreader) at 30–45° in front of the drop, move it back to touch the drop, and push it forward smoothly to make a thin, even smear with a feathered edge.
4. Air-dry the smear. Cover it with a few drops of Leishman's stain for 2 minutes (the methanol in the stain fixes the cells).
5. Add double the amount of buffered distilled water, mix gently and leave for 8–10 minutes.
6. Wash gently with water, let it dry, and observe under high power / oil immersion. (No cover slip is needed for a dried smear.)
7. Dispose of the lancet in a sharps container; press cotton on the finger.

Fig. 12.2: Human blood smear stained with Leishman's stain



Cell	Nucleus	Cytoplasm / features	Function
Red blood cell (erythrocyte)	Absent (mature)	Biconcave disc, pink, about 7–8 μm	Carries O_2 (haemoglobin)
Neutrophil	3–5 lobes	Fine pinkish granules; most common WBC	Phagocytosis of bacteria
Eosinophil	Two lobes	Coarse red/orange granules	Allergy, parasitic worms
Basophil	S-shaped, hidden	Large dark blue granules; rarest	Releases histamine and heparin
Lymphocyte	Large, round, fills cell	Thin rim of blue cytoplasm	Immunity (B and T cells)

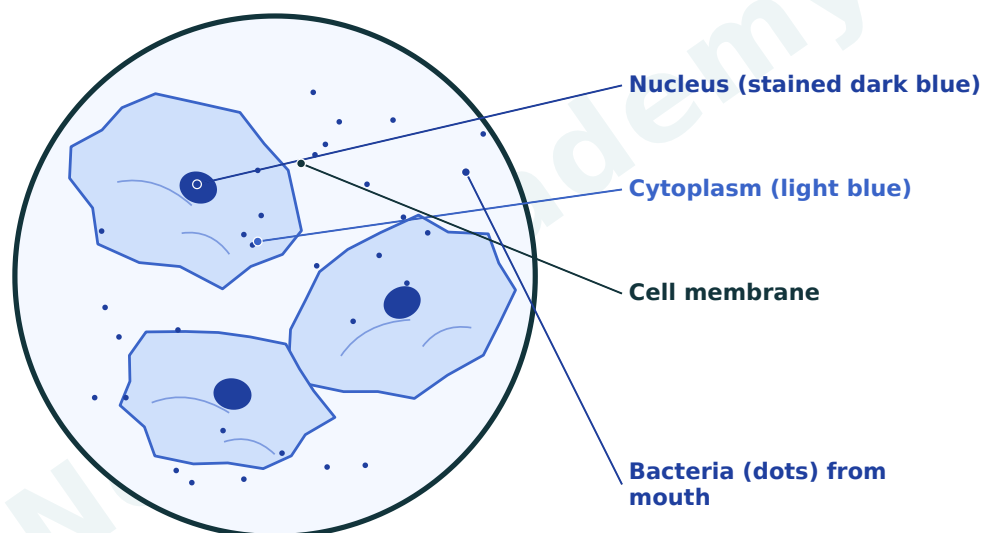
Cell	Nucleus	Cytoplasm / features	Function
Monocyte	Kidney / bean shaped	Largest WBC, grey-blue cytoplasm	Becomes macrophage; phagocytosis
Platelets	Absent	Small purple fragments	Blood clotting

● (b) Epithelial Cells of Human Oral Cavity (Cheek Cells)

Procedure

1. Rinse your mouth with water. Gently scrape the inner surface of the cheek with the blunt end of a sterile toothpick.
2. Spread the scraping evenly in a drop of water on a clean slide; let it dry slightly.
3. Add a drop of methylene blue; leave for 1 minute; wash off the extra stain gently.
4. Add a drop of glycerine, place a cover slip without air bubbles and blot extra liquid.
5. Observe under low power, then high power. Discard toothpick in disinfectant.

Fig. 12.3: Human cheek cells stained with methylene blue



Observation: Flat, irregular (roughly polygonal) cells, often folded, with no cell wall. Each has a small, dark blue, centrally placed nucleus in light blue cytoplasm, bounded by a thin cell membrane. These are **squamous epithelial cells**.

● Precautions

- Use sterile lancets and toothpicks only once; never share them. Dispose of them safely.
- Scrape the cheek gently; do not injure the mouth lining.
- Make the blood smear thin and even; a thick smear shows overlapping cells.
- Do not over-stain; wash off extra stain gently.
- Avoid air bubbles under the cover slip.
- Wash hands after the practical.

● Answers to Short Questions

Staining

Q1. What is differential staining?

Ans. Staining in which different parts of a cell (or different cell types) take up different colours, e.g. nuclei purple and cytoplasm pink with Leishman's stain.

Q2. Why is methylene blue used for cheek cells?

Ans. It is a basic dye that stains the nucleus (DNA) dark blue and the cytoplasm light blue, making the cell visible.

Q3. Why are acidic and basic dyes used together?

Ans. Basic dyes stain acidic parts (nucleus) and acidic dyes (eosin) stain basic parts (cytoplasm), so both are seen clearly in contrast.

Q4. Which stain is used for a blood smear? What does methanol in it do?

Ans. Leishman's (or Giemsa) stain; methanol fixes the cells on the slide.

Epithelial Cells

Q5. What type of epithelium lines the cheek?

Ans. Squamous (stratified squamous) epithelium; the surface cells are flat.

Q6. Give two differences between a cheek cell and an onion cell.

Ans. Cheek cell has no cell wall and no large central vacuole, and is irregular in shape; onion cell has a cellulose cell wall, large vacuole and is rectangular.

Q7. Why do cheek cells appear folded?

Ans. They are very thin and flat and have no cell wall, so they fold and wrinkle on the slide.

Q8. Why does frog skin show squamous cells?

Ans. The outer layer of the epidermis is made of flat, tightly packed squamous cells which are shed during moulting.

Blood Cells

Q9. Why is the first drop of blood wiped away?

Ans. It may contain tissue fluid and alcohol, which would affect the smear.

Q10. Why are mature human red blood cells without a nucleus?

Ans. Loss of the nucleus leaves more space for haemoglobin, and the biconcave shape increases surface area for oxygen exchange.

Q11. How will you identify a neutrophil and a lymphocyte?

Ans. Neutrophil: nucleus with 3–5 lobes and fine granules. Lymphocyte: a large round nucleus that fills almost the whole cell, with a thin rim of blue cytoplasm.

Q12. Which is the largest white blood cell?

Ans. Monocyte (with a kidney-shaped nucleus).

Q13. Which white blood cells are phagocytic?

Ans. Neutrophils and monocytes (macrophages).

Q14. Why is the spreader slide held at 30-45°?

Ans. To spread the blood into a thin, even layer (monolayer) so cells do not overlap.

PRACTICAL
13

Section B • Minor Practical

Preparation of Temporary Slides of Plant Cells and their Identification under the Light Microscope**Related Theory from Textbook****Biology Grade 11 > Chapter 1: Cells and Sub-Cellular Organelles**

- 1.4 Ultrastructure of plant cell; 1.5.1 cell wall; 1.5.2 plasma membrane
- Nucleus, vacuole and plastids (chloroplasts)

Biology Grade 11 > Chapter 9: Diversity in Plant Functions

- 9.2.2 Relationship of stomata and transpiration with gaseous exchange
- 9.3.5 Opening and closing of stomata

A plant cell has a rigid **cell wall** of cellulose outside the cell membrane, a large central **vacuole** filled with cell sap, and a **nucleus** and cytoplasm pushed to the side. Green cells contain **chloroplasts**. The **epidermis** of a leaf is a single layer of closely fitting cells without chloroplasts, interrupted by **stomata**. Each stoma is a pore surrounded by two **kidney-shaped guard cells** that contain chloroplasts and control opening and closing of the pore for gaseous exchange and transpiration.

Epidermal peel — a thin, transparent layer of epidermis peeled off a leaf or onion scale for study.

Iodine solution — stains nucleus and starch; gives a yellow-brown colour to onion cells (starch turns blue-black).

Safranin — stains cell walls and nuclei red/pink.

Stomatal index — percentage of epidermal cells that are stomata = $S \div (S + E) \times 100$.

• Object

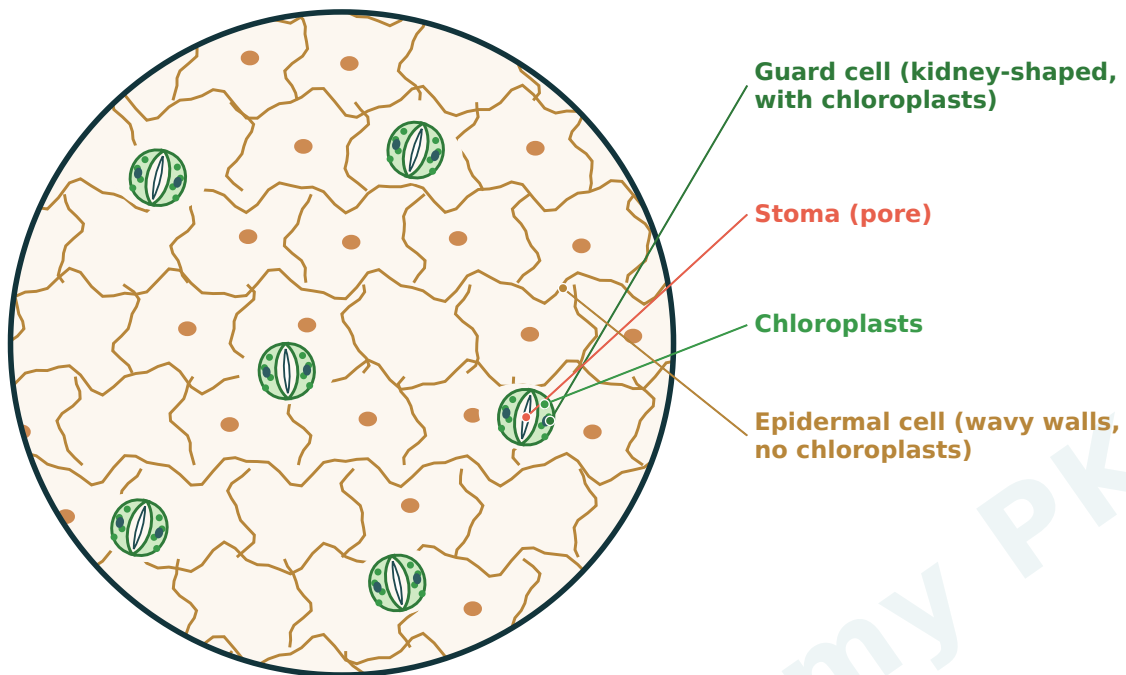
To prepare temporary slides of (a) leaf epidermis showing stomata, guard cells and epidermal cells, and (b) onion epidermal cells, and to identify their parts.

• Apparatus and Materials

Fresh leaf (e.g. *Tradescantia/Rhoeo*, bean, *Bryophyllum* or any soft dicot leaf), fleshy scale leaf of onion, forceps, needles, blade, watch glass, water, iodine solution, safranin (or methylene blue), glycerine, slides, cover slips, blotting paper, brush, compound microscope.

• (a) Leaf Epidermis: Stomata, Guard Cells and Epidermal Cells**Procedure**

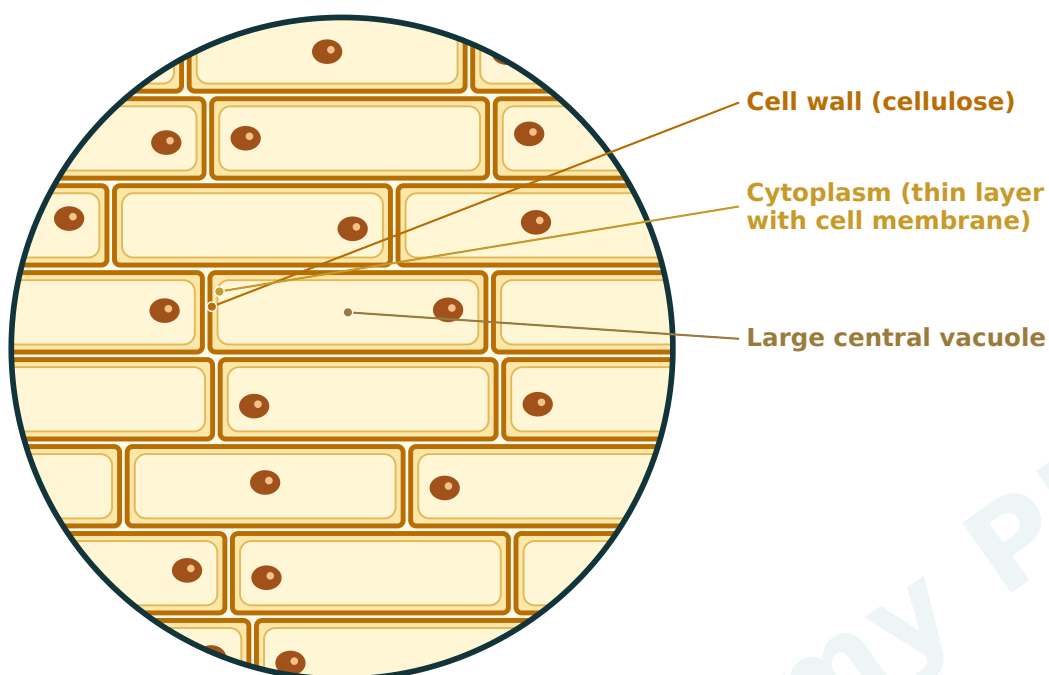
1. Fold a fresh leaf and tear it obliquely; a thin, colourless strip of the **lower epidermis** is left at the torn edge. (Or peel it with forceps.)
2. Cut a small piece of this peel and place it in water in a watch glass; the peel must not dry.
3. Stain with a drop of dilute safranin for 1 minute (optional); wash in water.
4. Place the peel flat on a slide in a drop of glycerine, with the outer surface upwards; cover with a cover slip avoiding air bubbles.
5. Observe under low power, then high power; count stomata in the field of view.

Fig. 13.1: Lower epidermis of a leaf showing stomata**Observations**

- Epidermal cells are irregular with **wavy walls**, fitting closely without intercellular spaces; they have **no chloroplasts**.
- Scattered among them are **stomata**, each with two **kidney (bean)-shaped guard cells** containing chloroplasts and a nucleus.
- The inner walls of guard cells (facing the pore) are thicker than the outer walls.
- The lower epidermis has more stomata than the upper epidermis (in dicot leaves).

• (b) Onion Epidermal Cells**Procedure**

1. Take a fleshy scale leaf from an onion bulb. Break it and peel off the thin, transparent membrane from its inner (concave) surface with forceps.
2. Put a small piece of the peel in a watch glass of water so that it does not fold or dry.
3. Place it on a slide and add a drop of iodine solution (or safranin) for 1–2 minutes; drain off the extra stain.
4. Add a drop of glycerine and lower a cover slip gently with a needle at 45° to avoid air bubbles.
5. Observe under low power and then high power.

Fig. 13.2: Onion epidermal cells stained with iodine**Observations**

- Cells are **rectangular / brick-shaped**, elongated and arranged side by side in rows without intercellular spaces.
- Each cell has a distinct **cell wall**, a thin layer of **cytoplasm** lining the wall, a large **central vacuole**, and a round **nucleus** with a nucleolus, usually near the wall.
- No chloroplasts are present (onion scale leaves grow underground and are not green).

Feature	Onion Epidermal Cell	Cheek Cell
Cell wall	Present (cellulose)	Absent
Shape	Rectangular, regular	Irregular, flat
Vacuole	Large, central	Small or absent
Position of nucleus	Near the wall (peripheral)	Central
Stain used	Iodine / safranin	Methylene blue

• Precautions

- The peel should be thin, one cell thick, and should not be allowed to dry.
- Keep the peel flat; avoid folding.
- Do not over-stain; remove extra stain and glycerine with blotting paper.
- Lower the cover slip slowly at an angle to avoid air bubbles.
- Take the lower epidermis of the leaf, where stomata are more numerous.

● Answers to Short Questions

Leaf Epidermis and Stomata

Q1. What are stomata?

Ans. Tiny pores in the epidermis of leaves (and young stems), each surrounded by two guard cells, through which gases are exchanged and water vapour is lost.

Q2. How are guard cells different from other epidermal cells?

Ans. Guard cells are kidney-shaped, contain chloroplasts, have thick inner walls and can change their turgor to open and close the pore; ordinary epidermal cells have no chloroplasts and wavy walls.

Q3. Why is the lower epidermis used for studying stomata?

Ans. In dicot leaves most stomata are on the lower surface.

Q4. Explain briefly how stomata open.

Ans. When guard cells take in K^+ ions and water, they become turgid; because their inner walls are thick and inelastic, they bend outwards and the pore opens. Loss of water makes them flaccid and the pore closes.

Q5. Why do epidermal cells lack chloroplasts?

Ans. So that they remain transparent and let light pass to the mesophyll for photosynthesis.

Q6. Calculate the stomatal index if a field shows 12 stomata and 48 epidermal cells.

Ans. Stomatal index = $12 \div (12 + 48) \times 100 = 20\%$.

Onion Cells

Q7. Why does an onion cell show no chloroplasts?

Ans. The fleshy scale leaves grow underground in the bulb, away from light, so chloroplasts do not develop; their function is storage.

Q8. Which part of the onion cell stains darker with iodine?

Ans. The nucleus, which appears dark yellow-brown.

Q9. Why is the nucleus of an onion cell pushed towards the wall?

Ans. The large central vacuole occupies most of the cell and pushes the cytoplasm and nucleus to the side.

Q10. What is the function of the cell wall?

Ans. It gives shape, support and protection to the cell and prevents it from bursting when it takes in water.

Q11. Why is glycerine used for mounting?

Ans. It does not evaporate quickly, keeps the specimen moist and makes it clearer.

General

Q12. Why is a cover slip lowered at an angle?

Ans. To push air out slowly so that air bubbles are not trapped under the cover slip.

Q13. Name two structures found in plant cells but not in animal cells.

Ans. Cell wall and large central vacuole (also chloroplasts in green cells).

Q14. Why should the peel be one cell thick?

Ans. So that light passes through and cells do not overlap, giving a clear view.

Section B • Minor Practical

PRACTICAL

14

Identification of ABO and Rh Blood Groups using Antisera; Determination of a Child's Blood Group from Parental Blood Groups and vice versa

Related Theory from Textbook

Biology Grade 11 > Chapter 12: Inheritance

- 12.2.2 Co-dominance (blood group AB)
- 12.3 Blood group systems: 12.3.1 ABO blood group system; 12.3.2 Transfusion principle
- 12.3.3 Rh blood group system; 12.3.4 Erythroblastosis foetalis

Biology Grade 12 > Chapter 9: Immunity

- Antigens and antibodies; antigen-antibody reaction (agglutination)

Blood groups depend on **antigens** (glycoproteins) on the surface of red blood cells. In the **ABO system** a single gene *I* has **three alleles** (multiple alleles): I^A , I^B and i . I^A and I^B are **co-dominant** (both are expressed together in group AB), while both are dominant over i . Plasma contains natural **antibodies** against the antigens that are absent. In the **Rh system**, people with the D antigen are **Rh positive** (DD or Dd); dd are Rh negative. When blood is mixed with an antiserum containing antibodies against an antigen present on its RBCs, the cells **agglutinate** (clump).

Blood group	Genotype(s)	Antigen on RBCs	Antibody in plasma	Can donate to	Can receive from
A	$I^A I^A$, $I^A i$	A	anti-B	A, AB	A, O
B	$I^B I^B$, $I^B i$	B	anti-A	B, AB	B, O
AB	$I^A I^B$	A and B	none	AB	all (universal recipient)
O	ii	none	anti-A and anti-B	all (universal donor)	O

● Object

(i) To identify ABO and Rh blood groups using anti-A, anti-B and anti-D antisera. (ii) To determine the possible blood groups of children from the phenotypes or genotypes of parents, and vice versa.

● Apparatus and Materials

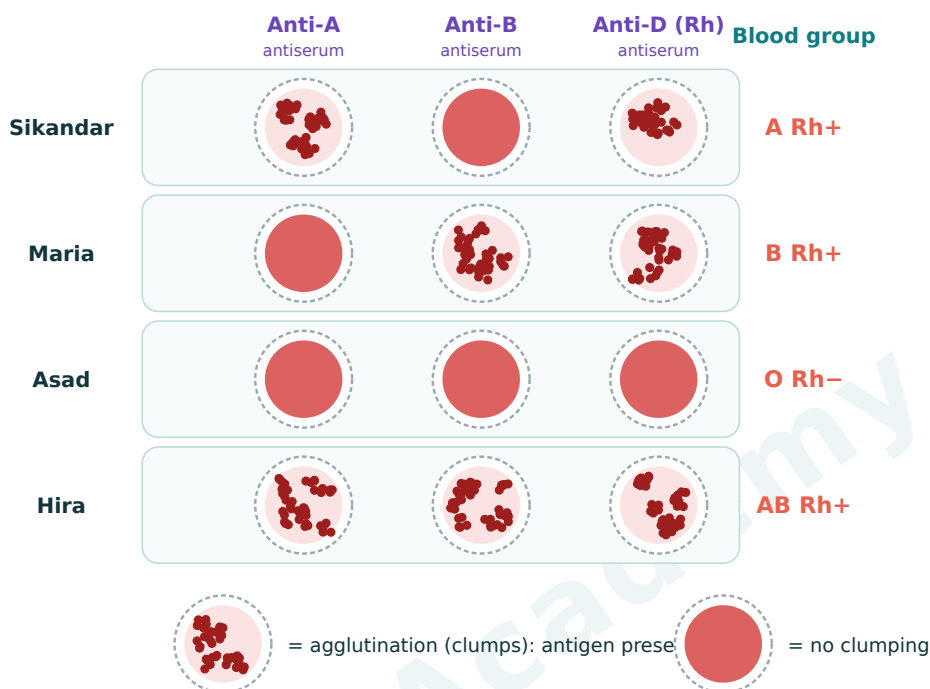
Anti-A, anti-B and anti-D (Rh) antisera, clean glass slide or white tile, sterile lancet, 70% alcohol, cotton wool, separate toothpicks / mixing sticks, glass marker, gloves.

● Procedure

1. Label a clean slide with three circles: A, B and D.
2. Put one drop of anti-A in circle A, anti-B in circle B and anti-D in circle D.

3. Clean a fingertip with spirit, prick with a sterile lancet and place one small drop of blood in each circle.
4. Mix each drop with a **separate** clean toothpick; rock the slide gently for about 1–2 minutes.
5. Look for **agglutination** (visible clumps). Record the result and find the blood group.
6. Dispose of the lancet and toothpicks safely; apply cotton to the finger.

Fig. 14.1: Blood grouping results of Sikandar's family



Anti-A	Anti-B	Anti-D	Blood group
+	–	+	A Rh+
–	+	+	B Rh+
+	+	+	AB Rh+
–	–	+	O Rh+
any	any	–	Rh– (e.g. O Rh–)

+ = agglutination; – = no agglutination.

● Genetics of Blood Groups: Worked Example

In Fig. 14.1, Sikandar is **A Rh+** and his wife Maria is **B Rh+**. Their son Asad is **O Rh–** (*ii dd*), so each parent must carry *i* and *d*. Hence Sikandar is $I^A i Dd$ and Maria is $I^B i Dd$.

ABO cross	I^B	<i>i</i>
I^A	$I^A I^B$ (AB)	$I^A i$ (A)
<i>i</i>	$I^B i$ (B)	<i>ii</i> (O)

Rh cross	<i>D</i>	<i>d</i>
<i>D</i>	<i>DD</i> (Rh+)	<i>Dd</i> (Rh+)
<i>d</i>	<i>Dd</i> (Rh+)	<i>dd</i> (Rh–)

Result of the cross

ABO: AB : A : B : O = **1 : 1 : 1 : 1** (each 25%). Rh: Rh+ : Rh– = **3 : 1**.

Combined probability, e.g. O Rh– child = $\frac{1}{4} \times \frac{1}{4} = \mathbf{1/16}$; AB Rh+ child (like Hira) = $\frac{1}{4} \times \frac{3}{4} = \mathbf{3/16}$.

More examples

Parents	Possible children	Not possible
O × O (<i>ii</i> × <i>ii</i>)	O only	A, B, AB
AB × O (<i>I^AI^B</i> × <i>ii</i>)	A, B (1 : 1)	AB, O
A × B (both heterozygous)	AB, A, B, O	—
AB × AB	A, AB, B (1 : 2 : 1)	O
Rh– × Rh– (<i>dd</i> × <i>dd</i>)	Rh– only	Rh+

Erythroblastosis foetalis

If an **Rh– mother** carries an **Rh+ foetus**, some foetal RBCs may enter her blood at birth; she makes anti-D antibodies. In a later Rh+ pregnancy these antibodies cross the placenta and destroy the foetus's RBCs (haemolytic disease of the newborn). It is prevented by giving the mother **anti-D (Rh immunoglobulin)** injection within 72 hours of delivery.

● Precautions

- Use a new sterile lancet; wear gloves; do not share lancets.
- Use a separate toothpick for each antiserum to avoid mixing.
- Do not add too much blood; one small drop is enough.
- Observe within 2 minutes; drying at the edges may look like clumping.
- Keep antisera in a refrigerator; check expiry date.

● Answers to Short Questions

ABO and Rh Systems

Q1. What is meant by multiple alleles? Give an example.

Ans. More than two alleles of a gene present in a population (a person carries only two), e.g. I^A , I^B and i of the ABO gene.

Q2. Explain co-dominance with the example of blood group AB.

Ans. In $I^A I^B$ individuals both alleles are fully expressed, so both A and B antigens appear on RBCs; neither allele masks the other.

Q3. Why is a person of blood group O called a universal donor?

Ans. O RBCs have no A or B antigens, so they are not agglutinated by antibodies of the recipient (O Rh– is the true universal donor).

Q4. Why is AB called a universal recipient?

Ans. The plasma of an AB person contains neither anti-A nor anti-B antibodies, so it does not attack donor RBCs.

Q5. What is agglutination?

Ans. Clumping of RBCs when antibodies bind to the matching antigens on their surface.

Q6. Which antigen decides the Rh blood group?

Ans. The D antigen; people with it are Rh+ and those without it are Rh–.

Test Results

Q7. Blood clumps with anti-A and anti-D but not anti-B. What is the blood group?

Ans. A Rh+.

Q8. No clumping occurs with any antiserum. What is the blood group?

Ans. O Rh–.

Q9. Why must a separate toothpick be used for each drop?

Ans. To avoid carrying antiserum from one drop to another, which would give false results.

Q10. What is the transfusion principle?

Ans. The donor's RBC antigens must not match the antibodies in the recipient's plasma; otherwise agglutination and haemolysis occur.

Genetic Problems

Q11. A man of blood group A ($I^A i$) marries a woman of group B ($I^B i$). Give the genotypes and phenotypes of children.

Ans. $I^A I^B$ (AB), $I^A i$ (A), $I^B i$ (B), ii (O) in the ratio 1 : 1 : 1 : 1.

Q12. Can parents of blood groups AB and O have a child of group O? Explain.

Ans. No. The AB parent gives either I^A or I^B , so every child receives one of these; children can only be A ($I^A i$) or B ($I^B i$).

Q13. A child is O Rh–. Both parents are A Rh+. Give the parents' genotypes.

Ans. Both must be $I^A i Dd$.

Q14. Two Rh+ parents have an Rh– child. Is this possible?

Ans. Yes, if both parents are heterozygous (Dd); the chance of a dd child is $1/4$.

Q15. What is erythroblastosis foetalis and how is it prevented?

Ans. Destruction of foetal RBCs by the anti-D antibodies of an Rh– mother carrying an Rh+ foetus (usually in a second pregnancy). It is prevented by giving anti-D immunoglobulin to the mother soon after each delivery.

PRACTICAL
15

Section B • Minor Practical

To Identify and Draw Different Parts of Sporophyte and Gametophyte Generations of a Fern Plant (*Adiantum*)**Related Theory from Textbook****Biology Grade 11 > Chapter 8: Kingdom Plantae**

- 8.3 Tracheophyta; 8.4 Pteridophyta (seedless vascular plants)
- 8.4.4 Pteropsida — Filicinae (ferns)
- Life cycle of fern (*Adiantum*): sporophyte and gametophyte generations; Fig. 8.10

Ferns (class **Filicinae**, group Pteropsida) are **seedless vascular plants**. *Adiantum* (maidenhair fern) grows near moist walls and watercourses. Its life cycle shows **heteromorphic alternation of generations**: a large, independent, diploid **sporophyte** and a small, independent, haploid **gametophyte** (prothallus). Ferns are **homosporous**, and their antherozoids need water to swim to the egg.

Circinate vernation — young leaves (fiddleheads) are coiled and unroll as they grow.

Sorus (pl. sori) — a cluster of sporangia on the underside of a leaflet.

False indusium — the reflexed (bent) margin of the leaflet that covers the sori in *Adiantum*.

Ramenta — brown scales covering the rhizome.

• Object

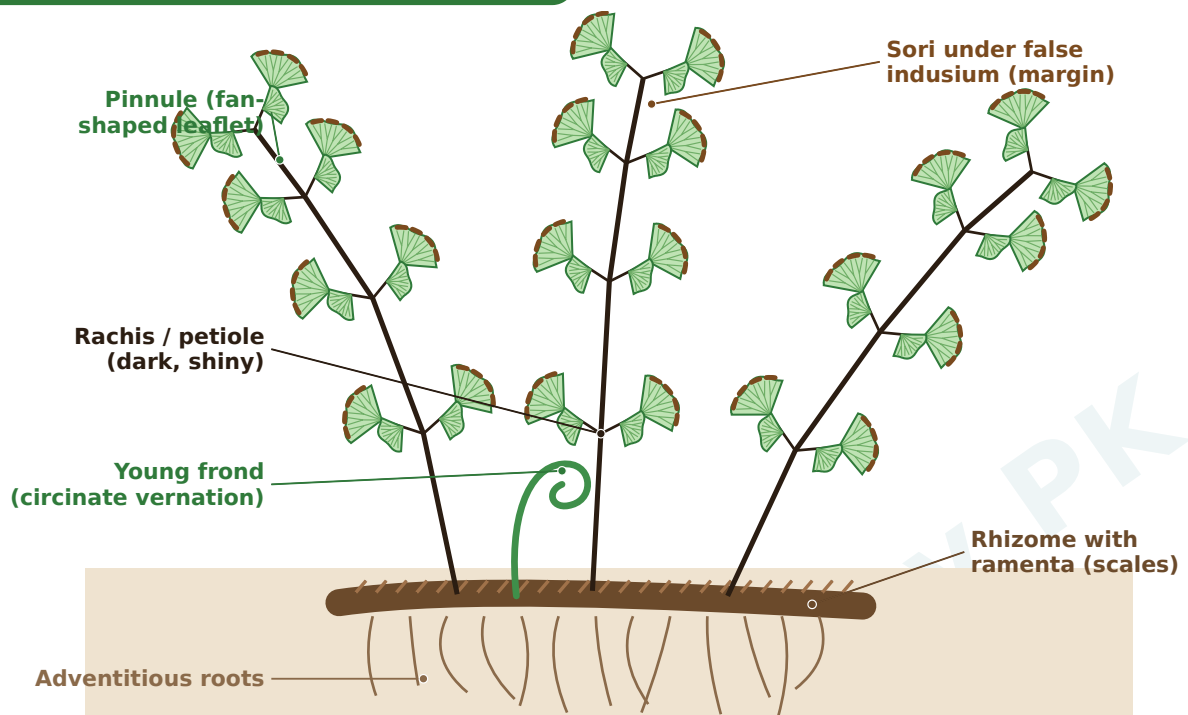
To study a specimen of *Adiantum* and prepared slides of its sporangium and prothallus; to identify and draw the parts of the sporophyte and the gametophyte.

• Material and Apparatus

Fresh or preserved *Adiantum* plant, prepared slides of sorus / sporangium and prothallus (gametophyte), hand lens, needles, slides, glycerine, compound microscope.

• A. Sporophyte Generation (2n)

Fig. 15.1: *Adiantum* — the sporophyte plant



- The plant body is the diploid **sporophyte**, differentiated into **rhizome**, **adventitious roots** and **fronds** (leaves).
- **Rhizome**: short, stout, horizontal, underground stem covered with brown scales called **ramenta** and persistent leaf bases.
- **Roots**: fibrous adventitious roots from the lower side of the rhizome.
- **Fronds**: large, pinnately compound; the rachis is dark, smooth and shiny (“maidenhair fern”). Young fronds show **circinate vernation**.
- **Pinnules** are fan-shaped with **dichotomous venation**. **Sori** lie on the underside along the margins, covered by the **false indusium**.

Fig. 15.2: Sori on a pinnule and V.S. through the false indusium

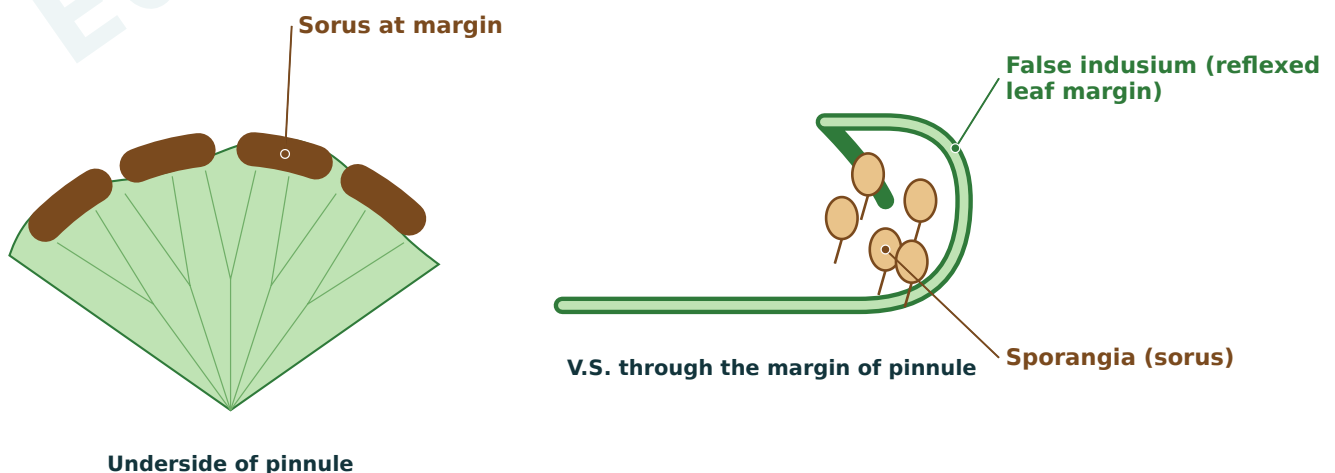
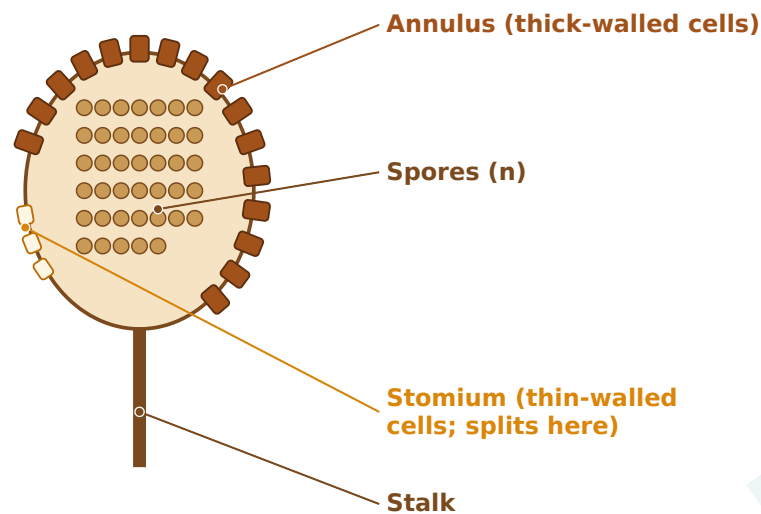
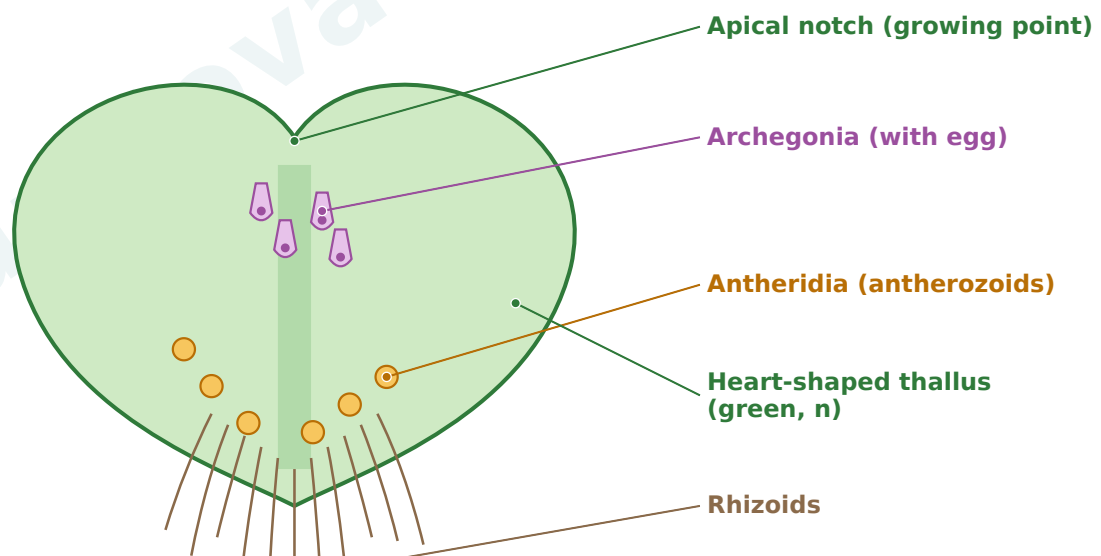


Fig. 15.3: A sporangium of *Adiantum*

Sporangium: a stalk and a biconvex **capsule** with a single-layered wall. A row of thick-walled cells, the **annulus**, arches over the capsule; thin-walled cells called **stomium** form the weak region where the capsule splits. Spore mother cells divide by **meiosis** to form haploid **spores** (with exine and intine). When the capsule dries, the annulus contracts and the sporangium bursts at the stomium, dispersing spores.

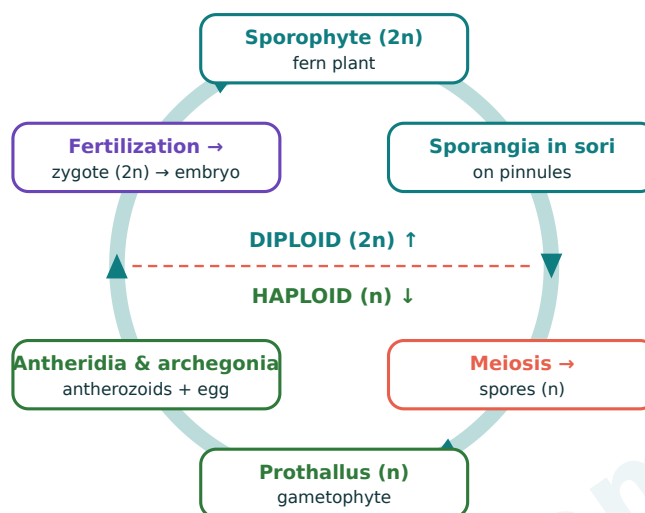
• B. Gametophyte Generation (n)

Fig. 15.4: Prothallus (gametophyte) of *Adiantum*, ventral view

- A spore germinates into a small, green, **heart-shaped prothallus** with a central **notch** (growing point); it is several cells thick in the middle and one cell thick at the margins.
- **Rhizoids** on the lower surface anchor it and absorb water and minerals; it makes its own food and is independent.
- **Antheridia** (globular) develop near the rhizoids and produce many spirally coiled, multiciliate **antherozoids**.

- **Archegonia** (flask-shaped, with venter containing an **egg** and a neck) develop near the notch.
- In the presence of water, antherozoids swim to the archegonia (chemotaxis) and fertilize the egg; the **zygote** develops into a new sporophyte.

Fig. 15.5: Life cycle of *Adiantum* (alternation of generations)



Feature	Sporophyte	Gametophyte
Ploidy	Diploid (2n)	Haploid (n)
Size and form	Large plant with rhizome, roots and fronds	Small, flat, heart-shaped thallus
Nutrition	Independent, photosynthetic	Independent, photosynthetic
Reproductive structures	Sporangia in sori produce spores by meiosis	Antheridia and archegonia produce gametes by mitosis
Life span	Long-lived, perennial	Short-lived

• Precautions

- Observe the sori on the underside of the pinnules with a hand lens.
- Handle the specimen gently; do not damage the pinnules.
- Focus the prothallus slide under low power before high power.
- Draw neat, labelled diagrams.

● Answers to Short Questions

Sporophyte

Q1. Why is *Adiantum* called the maidenhair fern?

Ans. Because its rachis is dark, smooth and shiny like a hair.

Q2. What is circinate vernation?

Ans. The coiling of young leaves (fiddleheads) which unroll as they grow; a characteristic of ferns.

Q3. What areramenta?

Ans. Brown, dry scales covering the rhizome and leaf bases of ferns.

Q4. Where are sori present in *Adiantum*?

Ans. On the underside of the pinnules along the margins, covered by the reflexed leaf margin.

Q5. What is a false indusium?

Ans. The bent (reflexed) margin of the leaflet that protects the sori; it is not a true outgrowth like a true indusium.

Q6. What type of venation is found in *Adiantum* pinnules?

Ans. Dichotomous (forked) venation.

Sporangium

Q7. Name the parts of a fern sporangium.

Ans. Stalk and capsule; the capsule wall has an annulus (thick-walled cells) and stomium (thin-walled cells); spores are inside.

Q8. How are spores formed in the sporangium?

Ans. By meiosis of diploid spore mother cells; so spores are haploid.

Q9. What is the role of the annulus in spore dispersal?

Ans. On drying, the thick-walled annulus cells contract and pull on the capsule, which splits at the weak stomium and throws out the spores.

Q10. Why are ferns called homosporous?

Ans. They produce only one kind of spore (all spores are alike).

Gametophyte and Life Cycle

Q11. Describe the prothallus of *Adiantum*.

Ans. A small, green, heart-shaped, independent gametophyte with an apical notch, rhizoids, antheridia near the rhizoids and archegonia near the notch.

Q12. Why is water necessary for fertilization in ferns?

Ans. The multiciliate antherozoids must swim through water to reach the archegonium.

Q13. What is chemotaxis?

Ans. Movement in response to a chemical; antherozoids swim towards chemicals released by the archegonium.

Q14. What is meant by heteromorphic alternation of generations?

Ans. A life cycle in which the sporophyte and gametophyte generations alternate and are different in form.

Q15. Which generation is dominant in ferns?

Ans. The sporophyte ($2n$) — it is large, long-lived and independent.

Q16. Give two economic uses of ferns.

Ans. Ornamental plants and bouquets; some are edible (e.g. *Marsilea*); male fern gives a drug against intestinal worms; ancient ferns formed coal.

PRACTICAL

16

Section B · Minor Practical

To Study the Structure of Male and Female Cones of *Pinus*

Related Theory from Textbook

Biology Grade 11 > Chapter 8: Kingdom Plantae

- 8.5 Spermatophyta: adaptations of seed plants (heterospory, ovule, pollen tube)
- 8.5.1 Gymnosperms — general characteristics
- Life cycle of *Pinus*: male and female cones, pollination, male and female gametophytes, fertilization and seed (Fig. 8.13, 8.14)

Gymnosperms (“naked seeds”) are seed-producing vascular plants whose ovules lie exposed on the surface of **megasporophylls**; they have no fruits. *Pinus* (pine) is an evergreen conifer. The plant is a diploid **sporophyte** with a tall woody trunk, needle-like leaves and taproot. It is **heterosporous** and bears two kinds of cones (**strobili**) on the same tree (monoecious).

Male cone (staminate strobilus) — small (less than an inch), in clusters on upper branches; spirally arranged microsporophylls, each with two microsporangia (pollen sacs).

Female cone (ovulate strobilus) — large (6–12 inches), woody, on lower branches; spirally arranged megasporophylls (ovuliferous scales), each with two ovules.

Pollination — transfer of winged pollen grains (microspores) by wind to the ovules of female cones.

Seed — fertilized ovule; its integument becomes the seed coat. Pine seeds (chilghoza) are eaten as dry fruit.

● Object

To study the external features and longitudinal sections of male and female cones of *Pinus*, and to draw their labelled diagrams.

● Material and Apparatus

Branches of *Pinus* with male cones, mature female cones, prepared slides of L.S. of male and female cones and of pollen grains, hand lens, needle, compound microscope.

• A. Male Cone

Fig. 16.1: Cluster of male cones

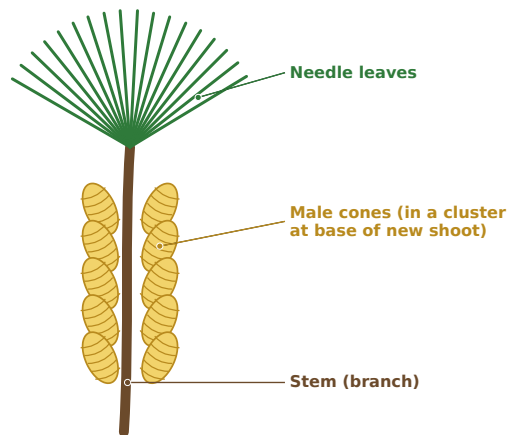


Fig. 16.2: L.S. of male cone

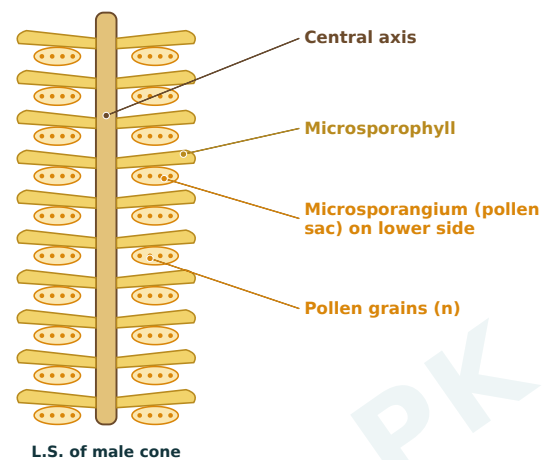
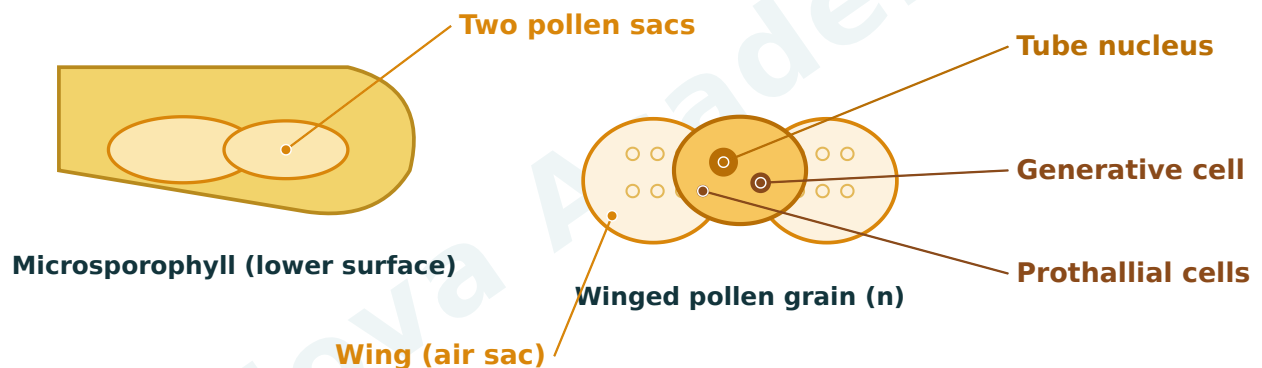


Fig. 16.3: Microsporophyll and winged pollen grain



- Male cones are small, soft, yellowish and oval, borne in **clusters** at the base of new shoots on upper branches.
- Each cone has a central **axis** bearing many spirally arranged, scale-like **microsporophylls**.
- Each microsporophyll bears **two microsporangia (pollen sacs)** on its lower surface.
- Microspore mother cells divide by meiosis to form haploid **microspores** which develop into winged **pollen grains** (male gametophytes: prothallial cells, tube nucleus and generative cell). The two **wings** help in wind pollination.

• B. Female Cone

Fig. 16.4: Mature female cone

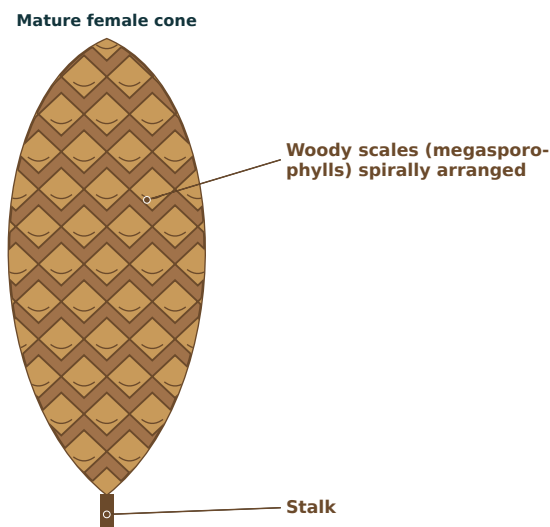


Fig. 16.5: L.S. of female cone

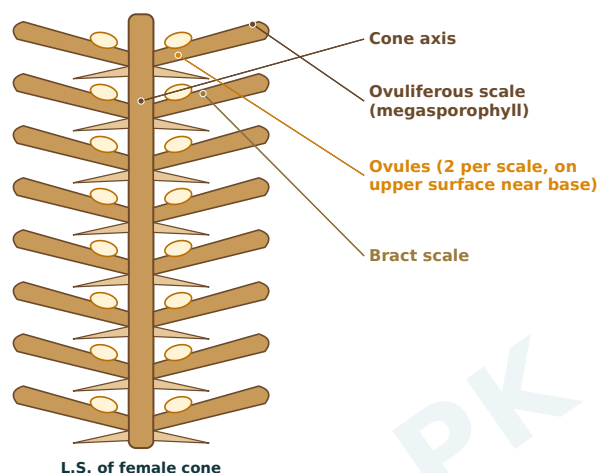
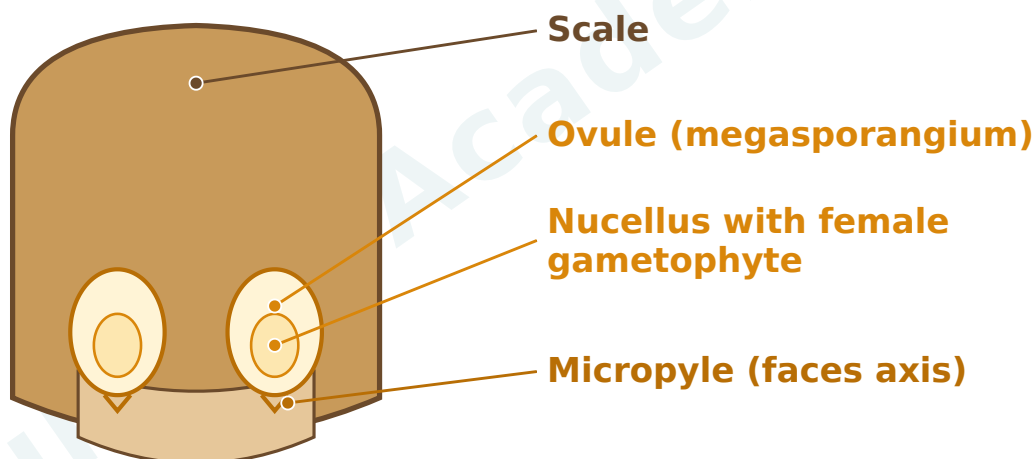


Fig. 16.6: Ovuliferous scale with two ovules



Ovuliferous scale, upper surface

- Female cones are large, woody and brown when mature; they take about **two to three years** to mature and are borne on lower branches.
- A woody central axis bears many spirally arranged **ovuliferous scales (megaspore-phylls)**, each with a small **bract scale** below it.
- Each ovuliferous scale bears **two ovules** on its upper surface near the base, with the **micropyle** facing the axis.
- In each ovule a megaspore mother cell forms four megaspores by meiosis; only one is functional. It forms the **female gametophyte** with archegonia, each containing an egg.

Feature	Male Cone	Female Cone
Size	Small (less than an inch)	Large (6-12 inches)

Feature	Male Cone	Female Cone
Position	In clusters on upper branches	Singly or in small groups on lower branches
Texture	Soft, yellowish; short-lived	Hard, woody; takes 2–3 years to mature
Sporophylls	Microsporophylls	Ovuliferous scales (megasporephylls) + bract scales
Sporangia per sporophyll	Two pollen sacs on the lower surface	Two ovules on the upper surface
Spores	Many microspores (winged pollen)	One functional megaspore per ovule

● Precautions

- Use a hand lens to see pollen sacs and ovules.
- Handle mature female cones carefully; scales are hard and sharp.
- Focus slides under low power first.
- Draw neat labelled diagrams with titles.

● Answers to Short Questions

Gymnosperms

Q1. Why are gymnosperms called naked-seeded plants?

Ans. Their ovules, and later seeds, lie exposed on the surface of megasporophylls and are not enclosed in an ovary or fruit.

Q2. What does heterosporous mean?

Ans. Producing two kinds of spores — small microspores (male) and large megaspores (female).

Q3. Why is *Pinus* called a conifer?

Ans. Because its spore-producing structures are cones (strobili).

Q4. Give two xerophytic features of *Pinus* leaves.

Ans. Needle-like leaves with thick cuticle and sunken stomata (also wax on surface).

Male Cone

Q5. Where are male cones found on a pine tree?

Ans. In clusters on the upper branches, at the base of new shoots.

Q6. How many pollen sacs are present on each microsporophyll, and where?

Ans. Two, on the lower (abaxial) surface.

Q7. What is the function of the wings of pollen grains?

Ans. They make the pollen light and help its dispersal by wind over long distances.

Q8. Name the cells of a mature pollen grain.

Ans. Prothallial cells, tube nucleus (cell) and generative cell.

Female Cone

Q9. What are ovuliferous scales?

Ans. Woody megasporophylls of the female cone, each bearing two ovules on its upper surface.

Q10. What is a bract scale?

Ans. A small scale present below each ovuliferous scale in the female cone.

Q11. How many functional megaspores are formed in each ovule?

Ans. One; of the four megaspores formed by meiosis, three degenerate.

Q12. What is the micropyle?

Ans. A small opening at the tip of the ovule through which the pollen tube enters.

Q13. How long does a female cone of *Pinus* take to mature?

Ans. About two to three years; fertilization occurs about a year after pollination.

Q14. Differentiate between male and female cones of *Pinus* (any two points).

Ans. Male cones are small, soft and in clusters on upper branches with microsporophylls; female cones are large, woody, on lower branches with ovuliferous scales bearing ovules.

Q15. Give two economic uses of gymnosperms.

Ans. Softwood for construction, paper and plywood; resins, turpentine and oils; edible chilghoza seeds; ephedrine from *Ephedra*.

PRACTICAL
17

Section B • Minor Practical

To Observe and Identify the Characteristics of Representative Vertebrate Animals (Amphibians, Reptiles, Birds and Mammals)**Related Theory from Textbook****Biology Grade 11 > Chapter 10: Animalia**

- 10.2 Diversity in animals: phylum Chordata, sub-phylum Vertebrata
- General characteristics of Class Amphibia, Class Reptilia, Class Aves and Class Mammalia
- Transition from aquatic to land habitat; the amniote egg
- Subclasses of mammals: Prototheria, Metatheria, Eutheria

Vertebrates (sub-phylum Vertebrata of phylum Chordata) have a backbone. The super-class **Tetrapoda** (four-limbed) includes the classes **Amphibia**, **Reptilia**, **Aves** and **Mammalia**. The move from water to land is seen in this sequence: amphibians still depend on water, while reptiles, birds and mammals are **amniotes** — their embryo develops in a fluid-filled sac (amnion), which freed them from water for reproduction.

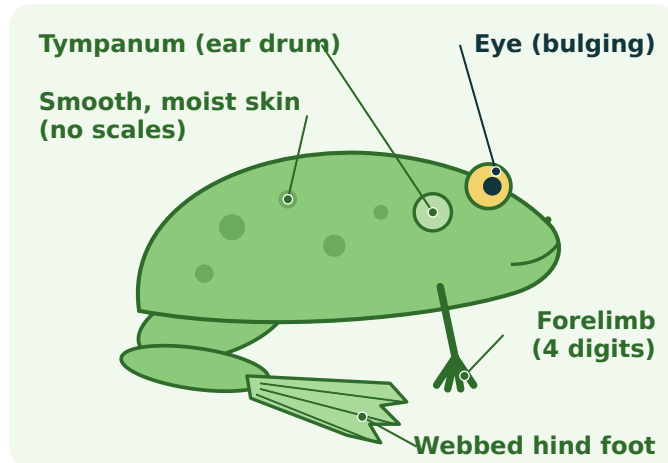
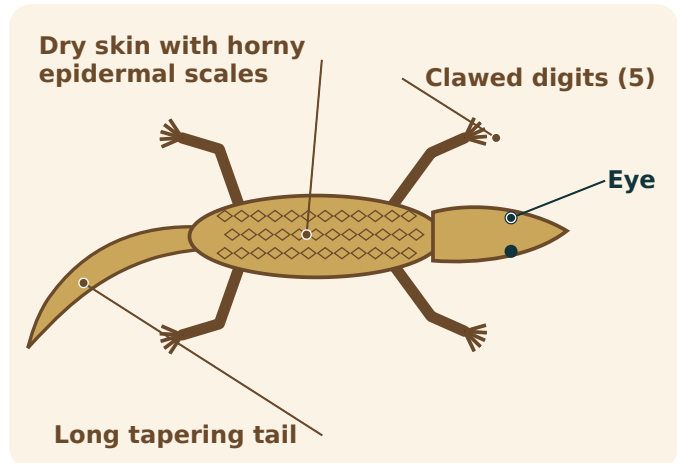
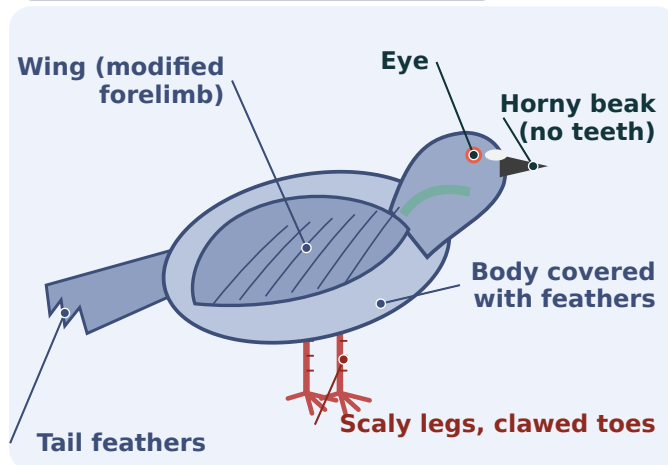
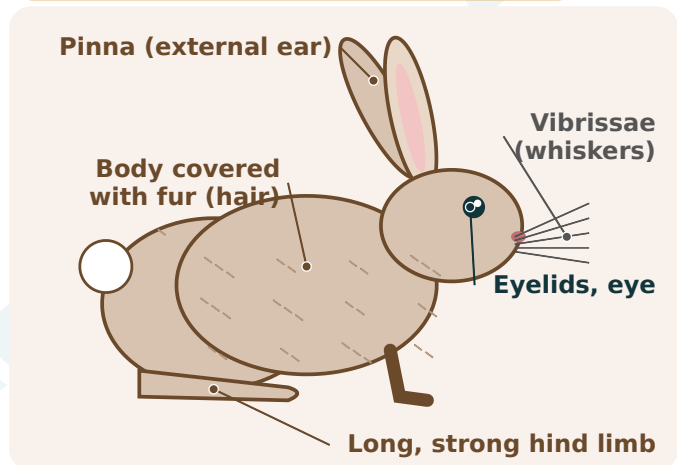
Feature	Amphibia	Reptilia	Aves	Mammalia
Skin	Smooth, moist, glandular; no scales	Dry, rough with horny scales	Feathers; scales on legs	Glandular; hair (fur)
Heart	3-chambered (2 atria, 1 ventricle)	Incompletely 4-chambered (crocodile 4)	4-chambered; right aortic arch	4-chambered; left aortic arch
Respiration	Gills (larva); lungs and skin (adult)	Lungs	Lungs with air sacs	Lungs; diaphragm present
Body temperature	Cold-blooded (poikilothermic)	Cold-blooded	Warm-blooded (endothermic)	Warm-blooded
Reproduction	External fertilization (mostly); eggs in water; metamorphosis	Internal fertilization; amniotic eggs with leathery/limy shell	Internal fertilization; large yolky eggs with shell	Internal fertilization; mostly viviparous; young fed on milk
Examples	Frog, toad, salamander	Lizard, snake, tortoise, crocodile	Pigeon, sparrow, ostrich, penguin	Rabbit, man, bat, whale

● Object

To observe preserved specimens (or diagrams) of a frog, a lizard, a pigeon and a rabbit, and to identify the characteristics of their classes.

● Material

Preserved specimens / models / charts of frog (*Rana*), lizard, pigeon (*Columba*), rabbit (*Oryctolagus*); hand lens; dissecting tray; gloves.

Fig. 17.1: Frog (Class Amphibia)**Fig. 17.2: Lizard (Class Reptilia)****Fig. 17.3: Pigeon (Class Aves)****Fig. 17.4: Rabbit (Class Mammalia)**

● Identification Features

1. Frog — Class Amphibia

- Body divided into head and trunk; no neck and no tail in adult.
- Skin smooth, moist and slimy, without scales; used for respiration.
- Two pairs of pentadactyl limbs: forelimbs short with 4 digits; hind limbs long, with 5 **webbed** toes for swimming and jumping.
- Bulging eyes with eyelids; **tympanum** behind each eye.
- Three-chambered heart; cold-blooded; lays eggs in water; development through tadpole larva (**metamorphosis**).

2. Lizard — Class Reptilia

- Body divisible into head, neck, trunk and a long tail.
- Skin dry and rough, covered with **horny epidermal scales** — prevents water loss.
- Two pairs of pentadactyl limbs, each digit ending in a **claw**.
- Breathes by lungs only; heart incompletely four-chambered; cold-blooded.
- Internal fertilization; lays **amniotic eggs** with leathery shell on land.

3. Pigeon — Class Aves

- Streamlined, boat-shaped body divisible into head, neck, trunk and tail.
- Body covered with **feathers**; legs with **scales** and clawed toes.
- Forelimbs modified into **wings**; jaws form a horny **beak** without teeth.
- Light skeleton with air spaces; lungs with air sacs; four-chambered heart; warm-blooded.
- Lays large, yolky eggs with calcareous shell; only one ovary functional.

4. Rabbit — Class Mammalia

- Body divisible into head, neck, trunk and a short tail.
- Skin covered with **hair (fur)** and has sweat, sebaceous and **mammary glands**.
- External ears (**pinnae**) present; whiskers (vibrissae) on snout.
- Diaphragm separates thorax and abdomen; four-chambered heart; RBCs without nucleus; warm-blooded.
- Gives birth to young ones (viviparous, placental) and feeds them on milk.

● Precautions

- Wear gloves while handling preserved specimens; do not inhale formalin fumes.
- Observe features with a hand lens; do not damage specimens.
- Wash hands after the practical.

● Answers to Short Questions

Amphibia

Q1. Why are amphibians called “double life” animals?

Ans. They live partly in water (larval stage, breeding) and partly on land (adult).

Q2. Why is the skin of a frog kept moist?

Ans. It is used for gaseous exchange; gases dissolve in moisture and diffuse through the thin, vascular skin.

Q3. What is the tympanum?

Ans. The eardrum, a circular membrane behind the eye of a frog, which receives sound vibrations.

Q4. Why are amphibians not a very successful group on land?

Ans. They depend on water for reproduction, development and moist skin; they lack amniotic eggs and waterproof skin.

Reptilia

Q5. How are reptiles adapted to life on land?

Ans. Dry, scaly, waterproof skin; lungs for breathing; internal fertilization; amniotic eggs with shell.

Q6. What is an amniote egg?

Ans. An egg with extra-embryonic membranes (amnion, chorion, allantois) and a shell, in which the embryo develops in its own “private pond” of fluid.

Q7. Which reptile has a completely four-chambered heart?

Ans. The crocodile.

Aves

Q8. Give three adaptations of birds for flight.

Ans. Streamlined body with feathers; forelimbs modified into wings; light, hollow bones with air spaces (also air sacs, no teeth, one ovary).

Q9. What is the syrinx?

Ans. The voice box of birds, at the junction of trachea and bronchi.

Q10. Name two flightless (running) birds.

Ans. Ostrich and kiwi (also penguin).

Q11. Why are birds said to be warm-blooded?

Ans. They maintain a constant body temperature regardless of surroundings (endothermic).

Mammalia

Q12. Give two features found only in mammals.

Ans. Hair on the body and mammary glands (also diaphragm, external pinnae, three ear ossicles, non-nucleated RBCs).

Q13. What is the diaphragm?

Ans. A muscular partition that divides the body cavity into thoracic and abdominal cavities; helps in breathing.

Q14. Name the three subclasses of mammals with an example of each.

Ans. Prototheria — egg-laying (duck-billed platypus); Metatheria — pouched (kangaroo); Eutheria — placental (rabbit, man).

Q15. Why is the duck-billed platypus called a connecting link?

Ans. It lays eggs and has a cloaca like reptiles, but has hair and mammary glands like mammals.

Comparison**Q16. Compare the heart of the four classes.**

Ans. Amphibia: 3-chambered; Reptilia: incompletely 4-chambered; Aves and Mammalia: completely 4-chambered.

Q17. Which of these classes are cold-blooded and which warm-blooded?

Ans. Amphibians and reptiles are cold-blooded (poikilothermic); birds and mammals are warm-blooded (endothermic).

PRACTICAL
18

Section B · Minor Practical

To Observe and Identify the Characteristics of Representative Examples of Kingdom Protista (Protozoa, Algae, Myxomycota and Oomycota)**Related Theory from Textbook****Biology Grade 11 > Chapter 7: Protists and Fungi**

- 7.1 Protists — the evolutionary relationship
- 7.2 Major groups of protists: 7.2.1 Protozoa; 7.2.2 Algae; 7.2.3 Green algae
- 7.2.4 Fungus-like protists: Myxomycota; 7.2.5 Oomycota
- 7.2.6 Importance of protists to humans

Kingdom **Protista** contains mostly unicellular or simple multicellular **eukaryotes** that are not plants, animals or fungi. They live in water, moist soil or inside other organisms. Protists are grouped into four major groups: **Protozoa** (animal-like), **Algae** (plant-like), and the fungus-like **Myxomycota** (slime moulds) and **Oomycota** (water moulds).

Group	Salient features	Examples
Protozoa (animal-like)	Unicellular, heterotrophic; move by pseudopodia, cilia or flagella (parasites may lack locomotory organs); food and contractile vacuoles; form cysts	<i>Amoeba</i> , <i>Paramecium</i> , <i>Giardia</i> , <i>Plasmodium</i> , foraminifera
Algae (plant-like)	Photosynthetic (chlorophyll a + other pigments); unicellular, filamentous or thalloid; no roots, stems, leaves or vascular tissue; unicellular sex organs	<i>Euglena</i> , diatoms, dinoflagellates, kelps (brown), red algae, <i>Chlamydomonas</i> , <i>Spirogyra</i> , <i>Volvox</i> , <i>Ulva</i>
Myxomycota (plasmodial slime moulds)	Diploid, multinucleate plasmodium wrapped in slime; in dry conditions forms stalked sporangia producing spores by meiosis	<i>Physarum</i>
Oomycota (water moulds)	Coenocytic (aseptate) hyphae with cellulose walls; asexual zoospores from sporangia; sexual oospores	<i>Phytophthora infestans</i> (late blight of potato), <i>Saprolegnia</i>

● Object

To observe prepared slides, cultures or preserved specimens of representative protists and to identify their characteristic features.

● Material and Apparatus

Prepared slides of *Amoeba*, *Paramecium*, *Euglena*, *Chlamydomonas*, *Spirogyra*; specimen/slide of slime mould (*Physarum*) and of *Phytophthora*-infected potato leaf; pond water culture; slides, cover slips, dropper, compound microscope.

● Procedure

1. Place a drop of pond water / culture on a slide (add a few cotton fibres to slow down fast-moving *Paramecium*); cover with a cover slip.
2. Observe under low power, then high power; or study the prepared slides.
3. Identify the organisms using the features below and draw labelled diagrams.

● A. Protozoa (Animal-like Protists)

Fig. 18.1: Amoeba

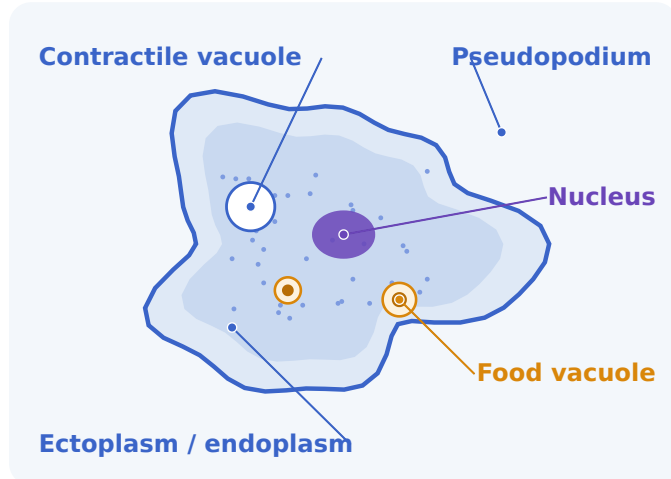
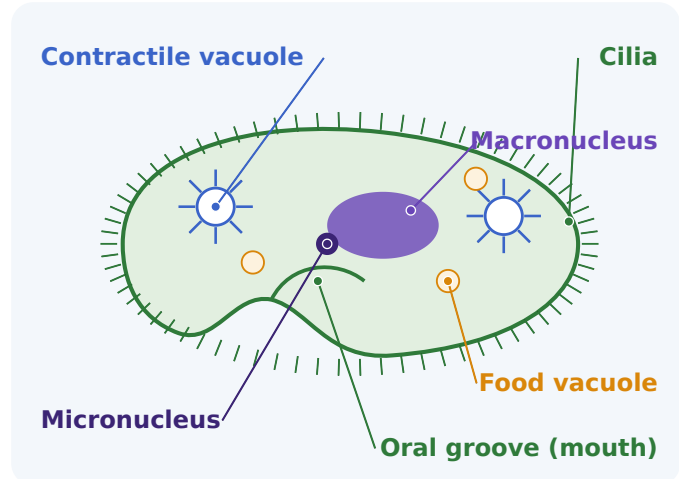


Fig. 18.2: Paramecium



- **Amoeba**: irregular, constantly changing shape; moves and feeds by **pseudopodia**; cytoplasm has clear ectoplasm and granular endoplasm, one nucleus, a **contractile vacuole** (osmoregulation) and food vacuoles.
- **Paramecium** (ciliate): slipper-shaped, covered with **cilia** for movement and feeding; **oral groove** leads to mouth; a large **macronucleus** and small **micronucleus**; two star-shaped contractile vacuoles.

● B. Algae (Plant-like Protists)

Fig. 18.3: Euglena

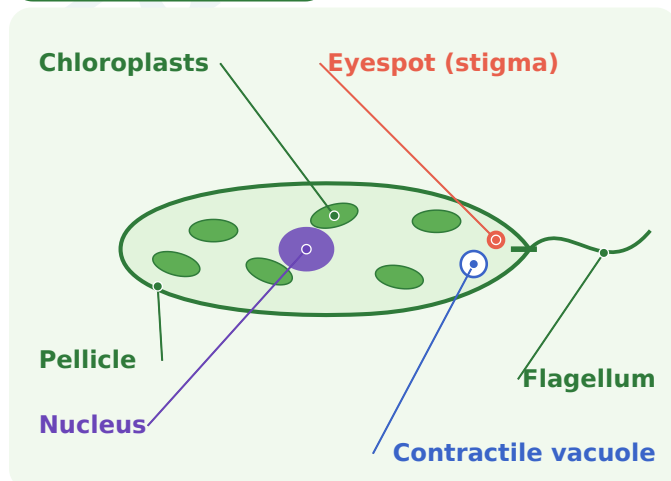


Fig. 18.4: Chlamydomonas

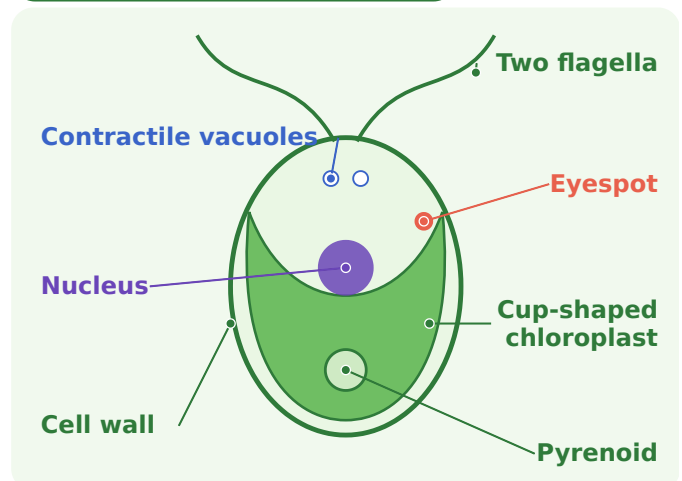
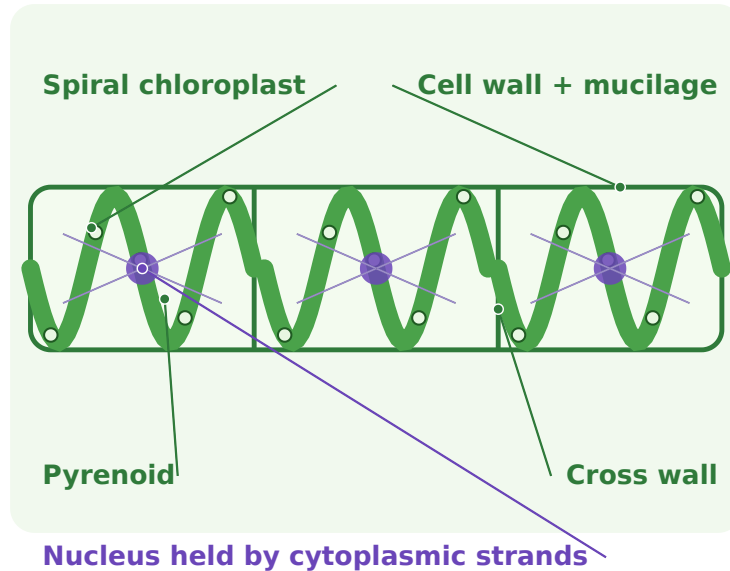
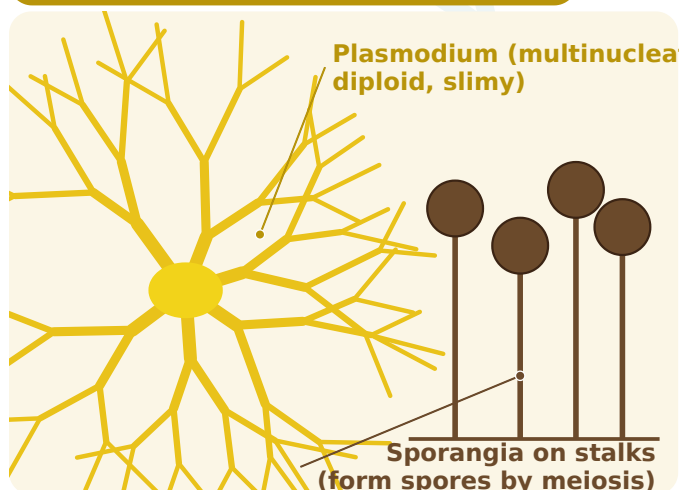
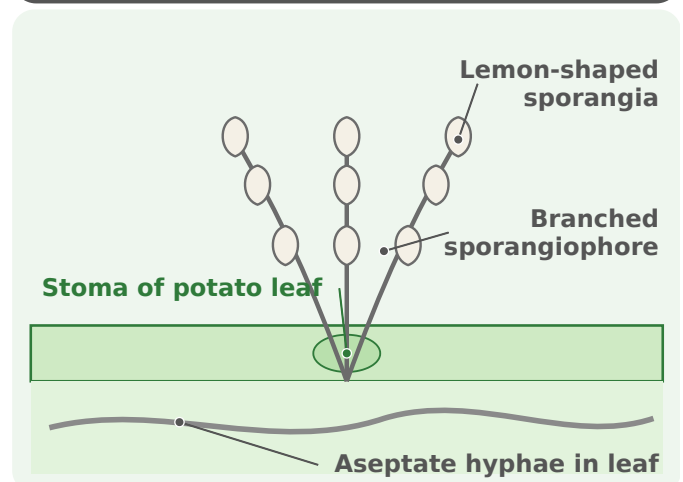


Fig. 18.5: *Spirogyra* filament (three cells)

- ***Euglena***: spindle-shaped, flexible **pellicle** (no cell wall), one long **flagellum**, red **eyespot**, many chloroplasts; can photosynthesize or absorb food (mixotrophic).
- ***Chlamydomonas*** (green alga): unicellular, oval, cellulose cell wall, **two equal flagella**, **cup-shaped chloroplast** with a **pyrenoid**, red eyespot, two contractile vacuoles.
- ***Spirogyra*** (green alga): unbranched filament of cylindrical cells; each cell has one or more **spiral, ribbon-shaped chloroplasts** with pyrenoids, and a nucleus suspended in the central vacuole by cytoplasmic strands; slimy (mucilage) to touch.

• C. Myxomycota and Oomycota (Fungus-like Protists)

Fig. 18.6: Slime mould (*Physarum*)**Fig. 18.7: *Phytophthora infestans* on potato leaf**

- **Plasmodial slime mould (*Physarum*)**: a bright yellow, diploid, multinucleate mass of cytoplasm (**plasmodium**) spreading as a network over decaying logs and leaves, engulfing bacteria. In dry conditions it forms stalked **sporangia**, which produce haploid spores by meiosis.

- **Water mould (*Phytophthora infestans*):** aseptate (coenocytic) hyphae with **cellulose** walls grow inside potato leaves; branched sporangiophores come out through stomata bearing **lemon-shaped sporangia** that release motile zoospores. It causes **late blight of potato** (Irish potato famine, 1845–47).

● Precautions

- Use a thin layer of culture and a cover slip to prevent drying.
- Use low light (partly closed diaphragm) to see transparent protozoa clearly.
- Handle pond water with care; wash hands afterwards.
- Draw labelled diagrams of each specimen with its name and group.

● Answers to Short Questions

Protists in General

Q1. Why are protists placed in a separate kingdom?

Ans. They are eukaryotes that do not fit into plants, animals or fungi; most are unicellular with very diverse forms, nutrition and life cycles.

Q2. Name the four major groups of protists.

Ans. Protozoa, algae, Myxomycota (slime moulds) and Oomycota (water moulds).

Q3. Name the locomotory organs of *Amoeba*, *Paramecium* and *Euglena*.

Ans. Pseudopodia, cilia and a flagellum respectively.

Protozoa

Q4. What is the function of the contractile vacuole?

Ans. It pumps out excess water from the cell (osmoregulation) in freshwater protozoa.

Q5. How does *Amoeba* obtain food?

Ans. By phagocytosis — pseudopodia surround the food particle and enclose it in a food vacuole, where it is digested by enzymes.

Q6. Why does *Paramecium* have two types of nuclei?

Ans. The macronucleus controls daily metabolic activities; the micronucleus is involved in reproduction (conjugation).

Q7. Name two parasitic protozoa and the diseases they cause.

Ans. *Plasmodium* — malaria; *Entamoeba histolytica* — amoebic dysentery (also *Giardia* — giardiasis; *Leishmania* — leishmaniasis).

Algae

Q8. Why are algae called plant-like protists?

Ans. They contain chlorophyll and make their own food by photosynthesis, like plants.

Q9. How do algae differ from plants?

Ans. Algae have no roots, stems, leaves or vascular tissue, have unicellular sex organs, and their zygotes are not protected by the parent body.

Q10. What is a pyrenoid?

Ans. A protein body in the chloroplast of algae, associated with starch formation and storage.

Q11. Give two features of *Spirogyra*.

Ans. Unbranched filament; spiral ribbon-shaped chloroplasts with pyrenoids; nucleus suspended by cytoplasmic strands; slimy mucilage.

Q12. Why is *Euglena* sometimes considered both plant-like and animal-like?

Ans. It photosynthesizes with chloroplasts but has no cell wall, moves by a flagellum and can absorb food in darkness.

Q13. Give the importance of algae.

Ans. They carry out about 50–60% of the photosynthesis on Earth, produce oxygen and form the base of aquatic food chains; diatoms and kelps are also of economic use.

Fungus-like Protists**Q14. What is a plasmodium in slime moulds?**

Ans. A diploid, multinucleate mass of cytoplasm without cell walls, wrapped in slime, which moves and feeds like a giant amoeba.

Q15. Why are slime moulds and water moulds not placed with true fungi?

Ans. Slime moulds have amoeboid stages without cell walls; water moulds have cellulose (not chitin) walls and flagellated zoospores.

Q16. Which disease is caused by *Phytophthora infestans*?

Ans. Late blight of potato, which caused the Irish potato famine.

PRACTICAL
19

Section B • Minor Practical

To Observe and Identify the Characteristics of Representative Examples from Different Divisions of Kingdom Fungi**Related Theory from Textbook****Biology Grade 11 > Chapter 7: Protists and Fungi**

- 7.3 General characteristics of fungi (hyphae, mycelium, nutrition, reproduction)
- 7.4 Diversity among fungi: Zygomycota, Ascomycota, Basidiomycota, Deuteromycota (Fig. 7.15–7.18)
- 7.5 Importance of fungi; importance of yeast

Fungi are eukaryotic, heterotrophic (saprotrophic, parasitic or mutualistic) organisms that absorb food. Their body (**mycelium**) is made of thread-like **hyphae** with cell walls of **chitin**; hyphae may be **aseptate (coenocytic)** as in *Rhizopus* or **septate** as in *Penicillium*. They store food as glycogen and oil, are non-motile, and reproduce by spores formed asexually or sexually. Fungi are classified mainly on the basis of their **sexual spores**.

Division	Diagnostic features	Examples
Zygomycota (conjugating fungi)	Aseptate hyphae; asexual spores in sporangia; sexual reproduction by conjugation forming a thick-walled zygospore	<i>Rhizopus nigricans</i> (black bread mould)
Ascomycota (sac fungi)	Septate hyphae; asexual conidia on conidiophores (or budding in yeast); sexual ascospores (usually 8) in a sac-like ascus	Yeast, <i>Neurospora</i> , morels, truffles
Basidiomycota (club fungi)	Septate hyphae; dikaryotic mycelium; sexual basidiospores (usually 4) on club-shaped basidia , often in a fruiting body (basidiocarp)	<i>Agaricus</i> (mushroom), rusts, smuts, puffballs
Deuteromycota (imperfect fungi)	Sexual stage absent (unknown); reproduce only by conidia ; genetic recombination by parasexuality	<i>Penicillium</i> , <i>Aspergillus</i> , <i>Alternaria</i> , <i>Fusarium</i>

• Object

To observe specimens, prepared slides or diagrams of representative fungi of Zygomycota, Ascomycota, Deuteromycota and Basidiomycota, and to identify their diagnostic features.

• Material and Apparatus

Mouldy bread (*Rhizopus*), mouldy orange/bread (*Penicillium*, *Aspergillus*), yeast suspension in sugar solution, fresh mushroom (*Agaricus*), prepared slides (T.S. of mushroom gill, ascus), needles, slides, cover slips, lactophenol cotton blue stain, hand lens, compound microscope.

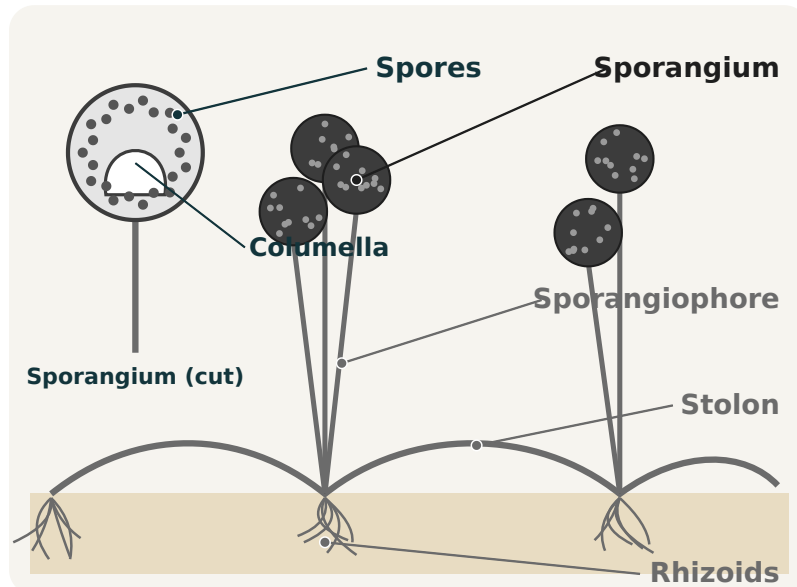
• Procedure

1. Pick a little mould with a needle and place it in a drop of lactophenol cotton blue (or water) on a slide; tease it apart gently and cover.

2. For yeast, place a drop of actively fermenting yeast suspension on a slide and cover.
3. Examine the mushroom with a hand lens; cut a thin section of the gills for the microscope, or use the prepared slide.
4. Observe under low and high power and draw labelled diagrams.

• A. Zygomycota – *Rhizopus* (Black Bread Mould)

Fig. 19.1: *Rhizopus* on bread



- Cottony white mycelium that later turns black; hyphae are **aseptate (coenocytic)**.
- Horizontal **stolons**; at intervals **rhizoids** anchor the mould and absorb food.
- Erect **sporangiophores** bear black, round **sporangia** with a dome-shaped **columella** and many spores.
- Sexual reproduction by conjugation of + and – strains forms a dark, thick-walled **zygospore**.

• B. Ascomycota – Yeast (and Asci)

Fig. 19.2: Budding yeast

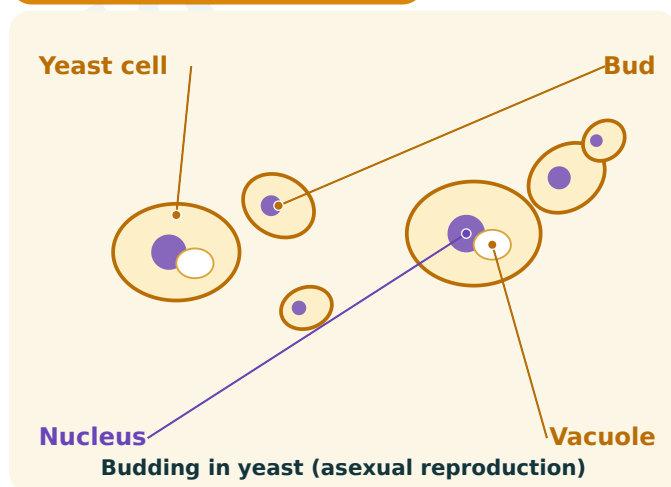
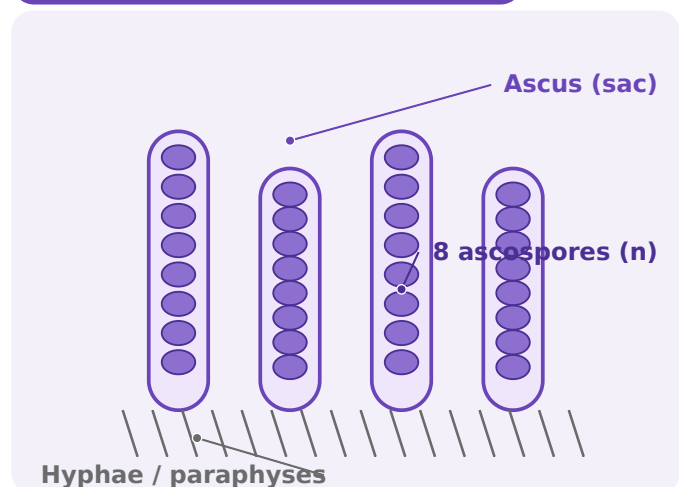


Fig. 19.3: Asci with ascospores



- Yeast (*Saccharomyces*) is **unicellular**, oval, with a nucleus and vacuole; reproduces asexually by **budding** (chains of buds may form).
- Sexual spores (**ascospores**, usually 8) are formed inside a sac called the **ascus**.
- Yeast ferments sugar into ethyl alcohol and CO_2 — used in baking and brewing.

• C. Deuteromycota — *Penicillium* and *Aspergillus*

Fig. 19.4: *Penicillium*

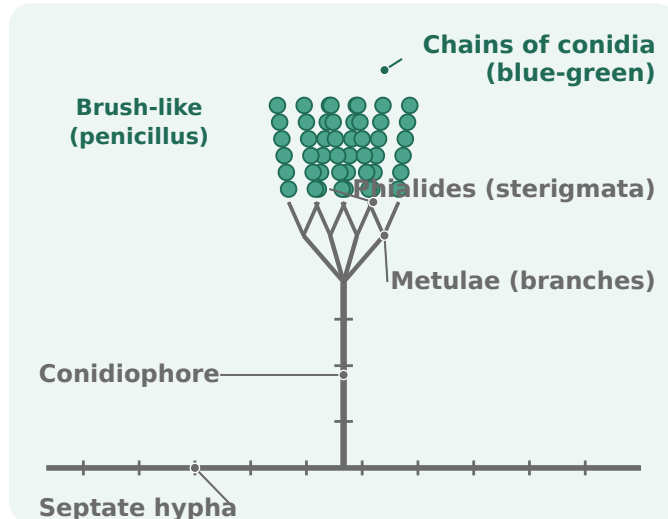
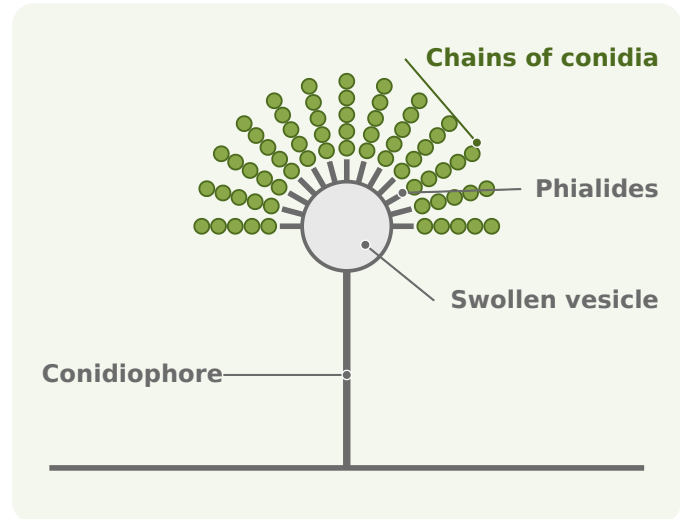


Fig. 19.5: *Aspergillus*



- ***Penicillium*** (blue-green mould): septate hyphae; conidiophores branch into a **brush-like** head (penicillus) of metulae and phialides bearing chains of **conidia**. Source of the antibiotic **penicillin** (*P. notatum*).
- ***Aspergillus***: conidiophore ends in a swollen **vesicle** covered with phialides that bear radiating chains of conidia.
- No sexual stage is known — hence “imperfect fungi”.

• D. Basidiomycota — *Agaricus* (Mushroom)

Fig. 19.6: *Agaricus* (basidiocarp)

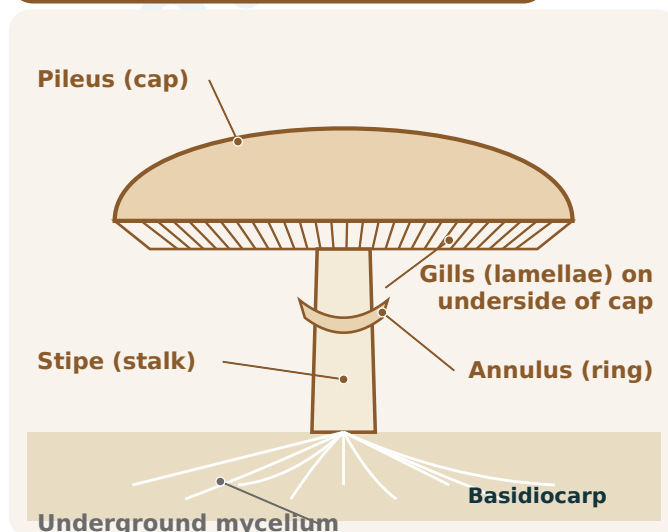
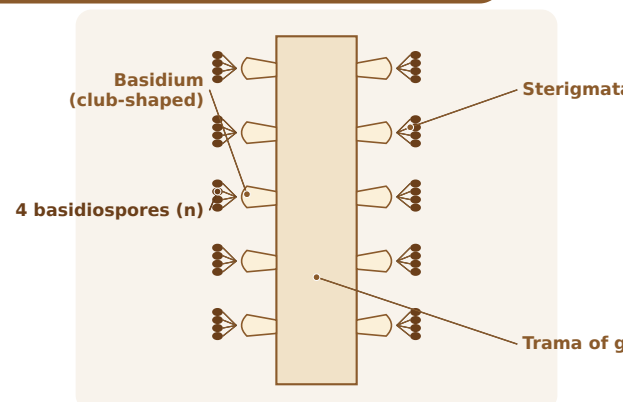


Fig. 19.7: Part of gill with basidia



- The visible mushroom is the fruiting body (**basidiocarp**) made of a **stipe** (stalk), an **annulus** (ring) and an umbrella-shaped **pileus** (cap).
- The underside of the cap has many radiating **gills**; their surface bears club-shaped **basidia**, each with **four basidiospores** on sterigmata.
- An extensive **underground mycelium** absorbs food from soil rich in organic matter.

● Precautions

- Do not inhale spores of moulds; handle mouldy material with a needle and wash hands afterwards.
- Never taste wild mushrooms; many are poisonous.
- Use a thin preparation and avoid air bubbles.
- Draw each fungus with its division and label clearly.

● Answers to Short Questions

General

Q1. Give four characteristics of fungi.

Ans. Eukaryotic; heterotrophic by absorption; body of hyphae (mycelium) with chitin cell walls; reproduce by spores; store glycogen; non-motile.

Q2. Differentiate between septate and aseptate hyphae.

Ans. Septate hyphae are divided by cross walls (septa), e.g. *Penicillium*; aseptate (coenocytic) hyphae have no cross walls and many nuclei in a continuous cytoplasm, e.g. *Rhizopus*.

Q3. On what basis are fungi classified?

Ans. Mainly on the type of sexual spores and the structures that produce them (zygospore, ascus, basidium; absent in Deuteromycota).

Zygomycota

Q4. Why is *Rhizopus* called black bread mould?

Ans. It commonly grows on bread and its mature sporangia are black.

Q5. What are stolons and rhizoids?

Ans. Stolons are horizontal hyphae running over the surface; rhizoids are root-like hyphae that anchor the mould and absorb nutrients.

Q6. What is a zygospore?

Ans. A thick-walled resistant spore formed by fusion of + and – gametangia (conjugation) in Zygomycota.

Ascomycota

Q7. Why are Ascomycota called sac fungi?

Ans. Their sexual spores (ascospores) are produced inside a sac-like structure called the ascus.

Q8. How does yeast reproduce asexually?

Ans. By budding — a small outgrowth (bud) forms on the parent cell, receives a nucleus and separates as a new cell (also by fission).

Q9. Give two uses of yeast.

Ans. Baking (CO₂ leavens dough) and brewing (alcohol); also a model organism in genetic research.

Deuteromycota

Q10. Why are Deuteromycota called imperfect fungi?

Ans. No sexual stage (perfect stage) is known in their life cycle; they reproduce only by conidia.

Q11. What is parasexuality?

Ans. A process in imperfect fungi in which portions of chromosomes are exchanged between two nuclei in the same hypha, giving genetic recombination without sexual reproduction.

Q12. How can *Penicillium* and *Aspergillus* be distinguished under the microscope?

Ans. *Penicillium* has a brush-like branched conidiophore; *Aspergillus* has a conidiophore ending in a swollen vesicle with radiating chains of conidia.

Q13. Name an antibiotic obtained from a fungus.

Ans. Penicillin, from *Penicillium notatum*.

Basidiomycota**Q14. Why are Basidiomycota called club fungi?**

Ans. Their sexual spores are produced on club-shaped basidia.

Q15. Name the parts of a mushroom.

Ans. Pileus (cap), gills (lamellae), annulus (ring), stipe (stalk) and underground mycelium.

Q16. How many basidiospores are produced on each basidium?

Ans. Four, borne on small stalks called sterigmata.

Q17. Name two Basidiomycota that cause plant diseases.

Ans. Rusts (e.g. wheat rust) and smuts.

ABOUT THIS BOOK

Learn it. Perform it. Explain it.

This book prepares HSSC students for the Practical Based Assessment (PBA) of Biology conducted by the Federal Board of Intermediate and Secondary Education, Islamabad. Every practical listed in the FBISE Assessment Framework is explained step by step — from the related theory in the NBF textbooks to the procedure, observations, calculations and the kind of short questions asked in the examination.

19

PRACTICALS

77+

LABELLED DIAGRAMS

369

QUESTIONS
ANSWERED

40

PBA MARKS

- ✓ “Related Theory” box linking each practical to the textbook chapter and topics
- ✓ Step-by-step procedures, precautions and safety notes
- ✓ Statistics made simple: mean, SD, SE, error bars and charts
- ✓ Clear, colour-coded diagrams drawn for easy reproduction in the exam
- ✓ Sample observations, worked calculations and graphs
- ✓ Answers to short questions in simple, exam-ready language

01 Enzyme activity: temperature, pH, concentration
03 Benedict’s test with colorimeter
05 Magnification from photomicrographs
07 Use and misuse of antibiotics
09 Setting up the light microscope
11 Testis, ovary, blood vessels, pancreas
13 Temporary slides of plant cells
15 Fern (*Adiantum*)
17 Amphibians, reptiles, birds, mammals
19 Kingdom Fungi

02 % and molar solutions; serial dilution
04 Eyepiece graticule & stage micrometer
06 Kirby-Bauer antibiotic sensitivity
08 Variability, statistics & experiment design
10 T.S. of root, stem and bifacial leaf
12 Temporary slides of animal cells
14 ABO and Rh blood groups
16 Male and female cones of *Pinus*
18 Kingdom Protista

“ Perform every practical. Record every observation.

Understand every result. ”